Chapter 5: Ecosystem services and human well-being

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Human induced changes in the N cycle have numerous positive and negative effects on the cultural services that are provided to society through natural and working landscapes. Key services influenced by reactive N include the aesthetic value, recreational value, cultural heritage values, and spiritual and religious values of certain landscape elements and characteristics.

Shifts between natural, agricultural and urban land uses all made possible through N fertilizers and fossil fuel, have significant impacts on the aesthetic appearance of both natural and manmade environments in California. Studies suggest that most people prefer the visual appearance of environments along the following land use gradient: natural habitat > diversified agricultural > agricultural monoculture > urban > industrial.

Loses of N to aquatic and terrestrial ecosystems through runoff and air pollution have a number of adverse effects on recreational opportunities in California. Recreational opportunities such as fishing, hunting, hiking and bird watching are diminished because N losses tend to promote ecologically harmful eutrophication and anoxia in surface water bodies, and increases in N deposition on native grassland and forest ecosystems. These changes in N availability generally reduce native biodiversity and subsequent recreational opportunities.

Agritourism, culinary travel and other rural recreational activities (e.g. vineyards, u-pick farms) are examples of some of the benefits of N fertilizer and fossil fuel use. Recent research indicates that opportunities for agritourism have been expanding in recent years with numerous ancillary benefits for job creation and economic growth in California’s rural areas.

Excess N in the environment can have detrimental impacts on native species, biodiversity, and natural and working landscapes, thus diminishing their natural heritage value to society. Many of these elements of our natural environment are prominent subjects of nature study, literature, and other aspects of our cultural heritage.

Many religious traditions consider important species, locations, or geographic features to be "sacred". To the extent that N impacts biodiversity and ecosystem change, the spiritual and religious value that people derive from these species and places may be diminished.

Shared cultural and spiritual values can also be a key source of motivation and inspiration for environmental stewardship. While this potential exists, more work is needed to determine effective ways to couple local cultural and spiritual values with sound science and public policy.

Studies in this field rarely attach monetary (or even quantitative) values to cultural services. Like much of the rest of the world, there is very little quantitative evidence for California on cultural services generally and even less on cultural services specifically linked to N flows. The authors have made an effort to include in the text all those cases where they have found quantitative evidence, which is presented along with appropriate use of controlled vocabulary regarding uncertainty. The authors believe this approach is preferable to omitting these important (yet difficult to quantify and monetize) considerations.

5.5 Cultural services

5.5.0 Introduction

The scenic beauty of California's landscape is a vital part of our natural and cultural heritage. Prominent features of California's environment, both natural and man-made, play a central role in the formation of our individual and collective values as a society. Urban, rural and wilderness settings also provide the backdrop for shared experiences with others, which over many generations have resulted in the distinctive regional culture and sub-cultures for which California is known the world over. These and other "nonmaterial benefits that people obtain from ecosystems" are defined in the Millennium Ecosystem Assessment as cultural services (MA 2003; MA 2005). While the cultural services offered by ecosystems are often difficult to characterize and quantify, there is broad agreement that they encompass 1) aesthetic value, 2) recreation, 3) cultural heritage, and 4) spiritual or religious values (MA 2005; Daniel et al. 2012). These are the deep but intangible values which John Muir described in *The Mountains of California* when he wrote "Everybody needs beauty as well as bread, places to play in and pray in, where nature may heal and give strength to body and soul." (Muir 1894).

At present very little research has been done specifically examining the effects of N on the cultural services provided by ecosystems. Given that the links between N and cultural ecosystem services are for the most part indirect, this lack of coverage in the scientific literature is understandable. While noting that "the importance of cultural services has consistently been recognized," Daniel et al. 2012 (p-.8813-4) summarize some of the major challenges in quantitatively valuing cultural and religious services.

That said, a recent review of the ecosystem services altered by increases in reactive N in the US has drawn needed attention to the dearth of information that exists regarding the cultural services potentially affected by N (Compton et al. 2011). These authors primarily highlight the adverse effects of

N pollution on fishing, hiking, and other recreational activities through declines in air quality, water quality and biodiversity (Table 5.0.1). However, they also suggest that N-related impacts on ecosystem quality and biodiversity may also have ramifications for other cultural and spiritual values as well.

In this section, we expand on this nascent effort and assess how the uses of N (and its losses to the environment) affect the cultural services that California's ecosystems provide to society. Since impacts of N on land use and biodiversity constitute two important avenues through which N indirectly affects cultural services, we begin by examining these land use and biodiversity effects first, followed by an exploration of various types of cultural services, including the aesthetic and recreational value of California's landscapes, cultural heritage, and spiritual and religious values, of which the latter two have thus far received little attention in the scientific literature. To close the chapter, we then consider some of the ways that cultural and spiritual values, when coupled with sound science, can help society to address the consequences of N pollution by motivating people from diverse belief systems to adopt sustainable practices that are aligned with their shared values of environmental stewardship, social justice and community.

5.5.1 Effects of nitrogen on land use and biodiversity

5.5.1.1. Land use and agrobiodiversity

The use of fossil fuels and N fertilizers has in large part facilitated the expansion of urban and suburban land uses and the intensification of agricultural land uses. Since the end of the Second World War the availability and low cost of N fertilizers have largely decoupled crop and livestock systems and allowed for less diverse and more intensive crop rotations (Russelle et al. 2007; Sulc and Tracy 2007). This specialization of crop and animal production systems has notable economic advantages, but has also had important effects on land use decisions and agrobiodiversity, and has posed challenges in managing fertilizers and manure so as to protect air and water quality (Russelle et al. 2007).

5.5.1.2 Aquatic biodiversity

In California's aquatic ecosystems, eutrophication (excess nutrients) and hypoxia (low levels of dissolved oxygen) are two of the most direct consequences of N losses to surface water bodies. The main causes of eutrophication are elevated levels of nitrate (NO_3^-) (and phosphorous (P)) in agricultural runoff, and high ammonium (NH_4^+) loads in effluent from wastewater treatment plants. Eutrophication can lead to population shifts within native plant and animal communities and have ramifications for the entire aquatic food web (Gilbert 2010). For example, diatoms generally prefer NO_3^- over NH_4^+, unlike many algae which preferentially use NH_4^+ (Berg et al. 2001; Glibert 2010; Brown 2010). Thus as NO_3 has become less available relative to NH_4^+ in the San Francisco Bay, the structure of phytoplankton communities have shifted from diatoms to algae (Gilbert 2010; Jassby 2008). Diatoms are considered a higher quality food source for higher order aquatic species, and thus the shift in species composition towards algae have been correlated with declines in pelagic fish populations in the San Francisco Estuary (Jassby 2008; Gilbert 2010).

Fish are also particularly sensitive to high levels of dissolved NH_4^+, which can affect the central nervous system and ultimately lead to death (Randall and Tsui 2002). Nutrient loading and harmful algal blooms have also contributed to episodic and seasonal occurrences of hypoxia in many of California's major coastal estuaries and waterways (e.g., San Francisco Bay, San Diego Bay, Monterey Bay, Los Angeles Harbor, Alamitos Bay, Anaheim Bay) (CENR 2010; Table 5.5.1). While oxygen levels have improved in some water bodies over recent decades (e.g,. South San Francisco Bay, Los Angeles Harbor, Alamitos Bay), several recent episodes of hypoxia have led to fish kills in the North San Francisco Bay

(Bricker et al. 2007; Lehman et al. 2004). Physical and biological processes occurring in the ocean, such as shoaling from oxygen minimum zones of the California Current can also be an important cause of hypoxia off the California Coast (Bograd et al. 2008; Chan et al. 2008). The relative importance of nutrient loading from local anthropogenic sources versus shifts in ocean currents as factors contributing to hypoxia off the California Coast merits further research.

[Table 5.5.1]

Oxygen depletion also affects biodiversity in inland freshwater bodies. For example, oxygen depletion in the Merced, Tuolumne, Stanislaus and San Joaquin Rivers has been found to interfere with the migration of fall run Chinook salmon and in some cases lead to fish kills among popular sport fish (e.g., salmon, steelhead) (Hallock et al. 1970; Jassby et al. 2005; Volkmar and Dahlgren 2006). In the Stockton Deepwater Ship Channel, which is a stretch of the San Joaquin River, Jassby et al. (2005) found that NH_4^+ loading from a regional wastewater treatment facility was the primary factor controlling year-to-year variability in dissolved oxygen and indicated that NH_4^+ loads have been increasing over the long term. However, at the monthly time scale they found that dissolved oxygen concentrations were also driven by patterns of reservoir release and the overall amount of river discharge, with levels of dissolved NH_4^+ and phytoplankton biomass having a somewhat smaller effect (Jassby et al. 2005). Thus, while it is generally accepted that N pollution is often a factor in the recent episodes of hypoxia (and fish kills) more work is needed to determine the relative extent to which point and non-point sources contribute to the problem.

5.5.1.3 Terrestrial biodiversity

It is well established in the scientific literature that increased N deposition caused by air pollution is among the most important factors driving long term changes in plant species diversity across many global and local ecosystems (Bobblink et al. 2010; De Vries et al. 2010; see Chapter 4 for an accounting of N deposition and flows in California). Annual deposition of N can vary widely throughout California, with the highest levels of deposition (e.g,. < 25 kg N ha^{-1} yr^{-1}) occurring downwind of major urban centers (Fenn et al. 2010; Figure 5.5.2). It is generally accepted that the increased availability of N drives competitive interactions among plant species, alters community composition and makes conditions unfavorable for many native or rare plant species (Bobbink et al. 1998; Fenn et al. 2003; Figure 5.5.3). This is particularly true in environments that are naturally N limited. In some habitats reduced forms of N (e.g., NH_3, NH_4) can be toxic to sensitive plant species, particularly when soils are acidic and weakly buffered (Kleijn et al. 2008). The process of nitrification, which converts NH_4 to NO_3^- can also lead to long term soil acidification, leaching of base cations and increased concentrations of potentially toxic metals (e.g., aluminum), all of which can degrade soil quality and limit plant growth (De Vries et al 2003). While less widespread, certain N gases and aerosols (e.g., nitric acid (HNO_3) vapor) can have direct toxic effects on plants growing near point sources of air pollution (Pearson and Stewart 1993; Fenn et al. 2003).

[Figure 5.5.2]

[Figure 5.5.3]

In California's Mediterranean climate, cool moist winters coupled with summer drought tend to generate soils that are rich in base cations. Consequently, increased competition for N from nitrophilous and invasive plant species are more important ecological issues than soil acidification and leaching of bases (Fenn et al. 2003; 2008). For example, high rates of N deposition (10-15kg N ha^{-1} yr^{-1}) near San Jose California have contributed to the invasion of exotic grasses at the expense of native forb species that are key host plants for the endangered Checkerspot Butterfly (Weiss 1999). Similarly, N deposition and invasion by annual grasses has contributed to a major decline of the native coastal sage scrub habitat in the Riverside-Side Perris Plain (Padgett et al. 1999; Padgett and Allen 1999). Nagy et al. (1998) suggest that encroachment by invasive annual grasses in the Mohave Desert also diminishes the quality and availability of forage for threatened desert tortoise species (e.g., *Gopherus agassizii*). Studies conducted in California grasslands that use fertilizer to simulate atmospheric deposition provide further experimental evidence that N addition favors colonization by invasive plants and a decline in native N-fixing species (Huennke et al. 1990; Zavaleta et al. 2003).

The effects of increased N deposition and air pollution on the biodiversity of lichen species in California's chaparral and forest ecosystems are well established in the scientific literature. At a relatively low N deposition rate of 6kg N ha^{-1} yr^{-1}, Fenn et al. (2008) observed shifts in species composition from those naturally dominated by N-sensitive lichen species (e.g., *Letharia vulpina*) to communities dominated by more N-tolerant lichen species. Similar shifts in lichen communities in response to N deposition have recently been documented in the Sacramento and San Joaquin Valleys, the Coast Range, and the Sierra Foothills (Fenn 2010; Fenn et al. 2011). These are important ecological findings because large areas of California's chaparral and forest ecosystems are exposed to N deposition rates in the 3-5 kg ha^{-1} yr^{-1} range (Fenn et al. 2008; Fenn et al. 2010; Figure 5.5.2). Overall, N and O_3 pollutants are estimated to have contributed to the disappearance of up to 50% of the lichen species that occurred in the Los Angeles Air Basin in the early 1900s (Fenn et al. 2003; Fenn 2011; Riddell et al. 2008; Figure 5.5.3). How this shift in lichen species affects the larger food web is unclear and will require further study, but many pollution-sensitive macrolichens are known to be important forages for birds, small mammals and deer (McCune and Geiser 1997).

It is generally accepted that N deposition in combination with other N-related air pollutants (e.g., ozone (O_3)) is also adversely affecting plant communities in mixed conifer forests (Takemoto et al. 2001). It should be noted that high levels of O_3, which is formed from emissions of nitrogen oxides

(NO_x) and volatile organic compounds (VOC), is widely considered to have the most severe impacts on plant growth in natural ecosystems relative to other air pollutants (Fenn et al. 2003; Campbell et al. 2007; Figure 5.5.4). Several studies in the San Bernardino Mountains have indicated that a combination of O_3 exposure and N deposition is disrupting the physiology of ponderosa pine (*Pinus ponderosa*) by reducing fine root growth and increasing above ground wood and foliage production (Takemoto et al. 2001; Fenn et al. 2003; Fenn et al. 2008). The authors suggest that this physiological change in plant biomass allocation increases the amount of litter and fuel wood on the forest floor thereby increasing the risk of severe fire damage (Fenn et al. 2003). In southern California's San Bernardino Mountains the number of understory plant species in mixed conifer forests declined by 20-40% between 1973 and 2003 in two of the most polluted sites, while invasive species became more abundant (Allen et al. 2007). However, multiple confounding factors (e.g., several air pollutants, O_3, and precipitation differences) occurring across the six study sites make it difficult to attribute the impacts specifically to N deposition (Allen et al. 2007). While studies suggest that California's chaparral plant communities are less prone to changes in species composition and invasive species, N enrichment of soils has been associated with declines in the diversity and productivity of arbuscular mycorrhizal fungi near Los Angeles (Egerton-Warburton et al. 2000; Egerton-Warburton et al. 2001; Fenn et al. 2011).

[Figure 5.5.4]

While most anthropogenic changes to the N cycle tend to decrease natural biodiversity, there are several instances where increased N availability from anthropogenic sources offers important benefits to biodiversity in California. Perhaps the most noteworthy example is the provision of food and habitat to migratory birds that overwinter in flooded rice fields following harvest (Hill et al. 2006). In this rice cropping system, the residual grain which falls to the ground during rice harvest provides high quality forage that attracts numerous bird species that migrate along the Pacific Flyway. A study of food abundance and feeding behavior among various bird species concluded most species had slightly higher feeding efficiency in semi-natural wetland than flooded rice fields, but that flooded rice fields offered reduced risks of predation (Elphick 2000). Overall, these authors concluded that flooded rice fields provide functionally equivalent foraging habitat relative to semi-natural wetlands and better foraging habitat than non-flooded fields (Elphick 2000; Elphick and Oring 1998).

These findings highlight some of the primary effects of anthropogenic N additions on the biodiversity of California's aquatic and terrestrial ecosystems, but the relatively small number of local studies limits our ability to comprehensively assess the geographic and temporal trends that may exist throughout much of the state. Moreover, to our knowledge, there have been no studies in California that have systematically examined the social or economic aspects of biodiversity decline. However, the role of biodiversity in the cultural value derived from California's aquatic and terrestrial resources is further explored in the following sections.

5.5.2 Aesthetic value

The study of aesthetics is primarily interested in the creation, perception and appreciation of beauty, particularly in response to art or nature. In the field of landscape aesthetics a key question is how people appreciate urban, rural and wilderness landscapes (Parsons and Daniel 2002; Home et al. 2010; Howley 2011). As global society becomes increasingly urban, research has also begun to examine how shifts in land use affect the aesthetic value of certain landscape qualities (Nohl 2001). Some of the aesthetic qualities that can be enhanced or diminished through shifts in land use include: the variety or diversity of landscape features (e.g., water bodies, landforms, built structures, vegetation types), the naturalness of the landscape, the rural or agrarian characteristics of a locality, the regional identity of a place, and the vista quality (Nohl 2001; Daniel 2001). While cultural factors no doubt play an important role in the appreciation of landscapes, it is also well established that people in general have a strong aesthetic preference for landscapes that would have provided ancestral humans with good habitat (Orians and Heerwagen 1992; Tress et al. 2001; Dutton 2003). As such, people across cultures tend to prefer the appearance of landscapes with vistas of savannas, open-space, water, green vegetation, wooded areas, and environments that are likely to offer plentiful food and shelter (Kaplan and Herbert 1987; Dutton 2003; Howley 2011).

What influence might human activities that alter the N cycle have on these aesthetic landscape characteristics? The use of fossil fuels and N fertilizers has in large part facilitated the expansion of urban and suburban land uses and the intensification of agricultural land uses. In terms of aesthetics, it is well-established in the social science literature that people's affinity for a landscape tends to be inversely related to the intensity of the land use (Arriaza et al. 2004; Dramstad et al. 2006; Lindemann-Matthies et al. 2010; Howley 2011). For example, studies indicate that imagery of wilderness and agrarian landscapes are consistently preferred over visual depictions of urban and industrial settings (Howley 2011). Thus, the judicious use of inorganic and organic N fertilizers may be seen by many as providing an important benefit to society by supporting aesthetically appealing and agriculturally productive "working landscapes".

However, even among agricultural landscapes psychological studies also show that people typically prefer diverse and lower intensity cropping systems as opposed to monocultures (Lindemann-Matthies et al. 2010). Likewise, aesthetic and ecological concerns have also been raised about the extent to which unique or highly valued wilderness areas are displaced by agricultural and urban land uses. Clearly any land use choice involves a complex mix of benefits and tradeoffs between aesthetic values and other important ecosystem services such as food provisioning or shelter. The forester, farmer and author Aldo Leopold (1999), put it this way; "The true problem of agriculture and all other land uses, is to achieve both utility and beauty, and thus permanence. A farmer has the same obligation to help, within reason, to preserve the biotic integrity of his community as he has, within reason, to preserve the culture which rests on it. As a member of the community, he is the ultimate beneficiary of both." In the case of N, this would imply balancing its utility as an input with its disutility as a pollutant that can also diminish the beauty of a landscape by degrading the quality of air, land and water resources or by altering the biodiversity of native ecosystems.

In Section 5.3 of this chapter we examine the adverse effects of N on air quality and human well-being in California, due mainly to emissions of NO_x and NH_3 and the formation of secondary air pollutants (PM, O_3, smog). Several recent studies have also shown that air pollution and reduced visibility have undesirable effects on the aesthetic value of the places where people reside and enjoy recreational activities (Abt Associates Inc. 2000). The National Park Service categorizes daily visibility measurements into three groups: (1) good visibility are days in the lowest 20^{th} percentile; (2) mid-range visibility days are in the middle of the 40^{th}-60^{th} percentile; and (3) poor visibility are days above 80^{th} percentile (Abt Associates Inc. 2000). Air quality improvements in the San Bernardino Mountains between 1988 and 1998 have reduced the number of poor visibility days in the San Gorgonia Wilderness Area (Figure 5.5.1; Abt Associates Inc. 2000). During the same period, no significant improvements in visibility were observed in Yosemite National Park (Figure 5.5.1; Abt Associates Inc. 2000). Overall, Abt Associates Inc. (2000) valued the economic impact of air pollution in California on residential and recreational visibility at approximately $61 million and $219 million respectively. This suggests that despite the improvements in California's air quality over recent decades, poor visibility continues to degrade the beauty and aesthetic value of residential and recreational areas. It also suggests that nitrogen's contribution to this degradation in the state's air quality comes with considerable cultural and economic cost.

[Figure 5.5.1]

5.5.3 Recreational value

In addition to diminishing the aesthetic value of a landscape, losses of N to the environment can also affect recreational activities (e.g., fishing, hiking, hunting, etc.) by changing the biodiversity, species composition, and ecological function of aquatic and terrestrial ecosystems (Compton et al. 2010; Smart et al. 2011). The N-induced impacts of hypoxia and eutrophication on aquatic biodiversity, as noted in section 5.5.1.2, especially affect the recreational value of aquatic ecosystems in California when they reduce populations of sport fish, such as salmon and steelhead. The economic value of California's recreational salmon fishery alone has been estimated at $205 million (Business Forecasting Center, 2010).

Recreational swimming is also affected by eutrophic conditions and high bacterial counts commonly found at many of California's coastal and inland swimming areas, particularly following heavy storm events that carry runoff from urban and rural land uses (Collias 1985; Noble et al. 2003). A survey of water quality at 254 shoreline sites between Santa Barbara (CA) and Ensenada (MX) found that 60% of all sites (and > 90% near urban areas) failed to meet state water quality standards for three bacterial indicators (enterococci, fecal coliforms and total coliforms) during storm flow events, while only 6% of these sites were above the threshold during dry weather (Noble et al. 2003). However, a recent study at Mission Bay California found that these traditional bacterial indicators were poor predictors of adverse health outcomes (e.g., diarrhea and skin rash) among swimmers exposed to polluted water at beach sites, but identified a novel viral indicator (coliphage) that was significantly associated with increased health risks among male swimmers (Colford et al. 2007). Blue-green algal blooms are also associated with health risks to swimmers and others who come into contact with affected water bodies, with health effects ranging from rashes, skin and eye irritation, allergic reactions, and gastrointestinal upset, to liver toxicity and neurotoxicity (CDC 2012). According to a 2013 report by the California Department of Public Health, recent blue-green algal blooms had recently been reported in rivers and lakes in 8 different counties throughout California plus the San Francisco Bay Delta (CDPH 2013). These studies show the uncertainty associated with attributing detrimental impacts to specific pollutants (be they N-related or otherwise) and highlights the complex effects that infrastructure for water storage, sewage treatment and surface runoff have on ecosystem health and downstream recreational activities.

The long-term changes in plant species diversity and ecosystem function caused by increased availability of N in terrestrial ecosystems, as documented in section 5.5.1.3, can affect the recreational value of these ecosystems as well. Several studies have highlighted the value of recreation in biodiverse landscapes as a means of promoting people's psychological and physical well-being (Daniel et al. 2012). Fuller et al. (2007) found that psychological well-being, assessed using surveys gauging park visitors' reflection and attraction to certain landscape features, was positively correlated with habitat diversity and species richness. Biodiversity may also enhance recreational experiences by increasing the likelihood of memorable wildlife encounters (Harrod 2000; Naidoo et al. 2005). For example, the level of satisfaction experienced during many recreational activities (e.g., hunting, fishing, bird watching) is often highly dependent on the abundance of particular species of interest as well as the overall species richness of a landscape (Stallman et al. 2011).

On the other hand, as noted in section 5.5.1.3, the widespread presence of winter-flooded rice fields in northern California, made possible in part by the availability of cheap N fertilizers, raises the recreational value of landscapes that might otherwise be lost to other uses not supportive of wildlife habitat.

The economic value of recreational hunting and bird watching on rice land or other agricultural lands has not been quantified, but a 2002 survey of 179 rice producers enrolled in a rice enhancement project documented that 75% allowed hunting on their land, with annual hunting fees ranging from $1,000 to $3,000 per hunter (Garr 2002, cited in Eadie et al. 2008).

Inorganic and organic N fertilizers also facilitate the cultivation of a diverse range of perennial and annual crops (>300 crops) that have made California a national and international destination for agritourism and culinary travel. Prime examples are the state's many vineyards and wineries, "U-pick" farms with fruit and berries that visitors can harvest themselves, and livestock operations that offer visitors the opportunity to learn how food is produced by participating in seasonal management activities (e.g., calving, shearing, cheese making) (Rilla et al. 2011). Recent surveys suggest that each year more than 2.4 million people participate in agritourism activities on California farms and ranches and generate approximately $35 million in revenue (Rilla et al. 2011; USDA 2009). Moreover, the agritourism sector is expected to be a significant source of economic growth and jobs for California's rural communities in the coming years (Rilla et al. 2011).

The role of N in shaping the recreational value of the state's natural and agricultural ecosystems is complex. Additional work will be needed to address the gaps in our knowledge of how N pollution impacts recreational usage of California's natural ecosystems and to develop management strategies that enhance recreational experiences.

5.5.4 Cultural heritage values

Cultural heritage is often defined as "the legacy of biophysical features, physical artifacts, and intangible attributes of a group or society" that help to define the identity of the individual or group and provide experience shared across generations (Daniel et al. 2012). California's natural and managed landscapes and ecosystems have great value to society as locations where a variety of expressions of cultural heritage take form, including knowledge acquisition and transfer, traditional livelihood practices, and artistic expression. Human interactions with these landscapes and ecosystems over time define and reinforce important cultural constructs and identities. For example, culturally valuable species and places include the iconic bald eagles and condors that soar above the Sierra Nevada, symbolizing freedom and independence, and the magnificent groves of redwoods standing tall along California's North Coast, reminders of endurance and the slow evolution of nature. Cultural values and identities are also associated with managed landscapes, as exemplified by the idyllic vineyards that are synonymous with the Napa and Sonoma Valleys, and the oak savannas and rangelands of the Coast Range that support "happy cows". Given that these landscapes provide numerous cultural heritage services to society, the degree to which human-induced changes to the N cycle either support or diminish these ecosystems (and their resulting services) merits closer examination.

Knowledge, generated through scientific as well as other means, is one important aspect of cultural heritage. Natural and working landscapes provide a place where observation, measurement, and critical assessment can help society accumulate knowledge about species, ecosystems and N cycling that has both practical and scientific value. Barbour et al. (1993) estimate that roughly 30% of California's native plant species are found nowhere else in the world. As discussed above, biodiversity in many California ecosystems is often adversely affected by N pollution and the loss of native habitat. These reductions in biodiversity are likely to limit opportunities for nature study, hinder scientific discovery and in some cases limit the practical application of new knowledge (Compton et al. 2010; Smart et al. 2011). For instance, the Northern California black walnut (*Juglans hindsii*) is traditionally used as a root stock for commercial English walnut varieties that are cultivated on approximately 280,000 acres in California (in some cases a hybrid of the California black and English walnuts called

"Paradox" is also used as rootstock) (Ramos 1997; NASS 2011). In California *J. hindsii* typically grows in riparian woodlands and despite its use in the walnut industry, it is classified as a threatened species since only a few native stands remain (IUCN 2012). Given the practical benefits of this and other native plant and animal species, one can reasonably say that the loss of native species due to N pollution (or land use change enabled by fuel and fertilizer) can diminish the genetic resources available to future generations of scientists, plant and animal breeders, and other industry innovators.

Biodiversity changes such as those mentioned above also hold potentially large implications for the maintenance of unique livelihoods and cultural identities of California's indigenous peoples. Extensive research (e.g. Anderson 2005) has documented the reliance of California's Indian tribes on hundreds of species of plants and animals for food, cordage, firewood, basketry, and construction. In almost every contemporary California Indian tribe, one can find individuals of all ages who fish and hunt for food and gather native plants for food, medicinal, handicraft, and ceremonial uses. The economies of some northern California tribes are built substantially or entirely around fishing and hunting. Salmon, in particular, often play a significant role in these economies (Anderson 2005). However, the viability of salmon fishing is threatened by hypoxia, as discussed above.

An upsurge in interest in some traditional practices in recent decades is evidenced by the founding of the California Indian Basket Weavers Association in 1992 (www.ciba.org), which works with land management agencies to promote access to traditional gathering lands and use of management practices that promote populations of native plant species used in basket making. Some of the many species used include native perennial bunchgrasses, such as deergrass, which, as noted above, have been supplanted in many areas by non-native annual grasses and are more difficult to find. The causes of these species shifts are varied and include prominent factors such as cessation of controlled burning, a practice traditionally used by many California tribes (Anderson 2005), and therefore the role specifically of N deposition in these shifts is suggested but unproven. However, in so far as any of the N-related biodiversity losses noted above affect species directly used by California's indigenous people, it poses a threat to the lifestyles, economies, and cultures of these groups, as well as to their physical health, which is often predicated on access to wholesome traditional foods (Lynn et al. 2013).

The cultural values imbued in California landscapes are also evident in the abundance of artistic expression that has arisen over the last one and a half centuries of Euro-American settlement of the West Coast. For example, values of nature as an "antidote" to civilization arise in the prose writings of the famous California naturalist and essayist John Muir, who wrote "It is a good thing, therefore, to make short excursions now and then to the bottom of the sea among the dulse and coral, or up among the clouds on mountain-tops, or in balloons, or even to creep like worms into dark holes and caverns underground, not only to learn something of what is going on in those out-of-the-way places, but to see better what the sun sees on our return to common everyday beauty." (Muir 1894). Muir's emphasis on the need for immersion in and preservation of California's pristine wild places encapsulates the spirit of a growing interest in preserving natural areas, which would later come to be called "wilderness," from overexploitation of economically useful resources. For example, at one point he wrote that "thousands of tired, nerve-shaken, over-civilized people are beginning to find out that going to the mountains is going home; that wildness is a necessity; and that mountain parks and reservations are useful not only as fountains of timber and irrigating rivers, but as fountains of life" (Muir 1997). This sentiment regarding the value of California's unique landscapes and species played a central role in the early advocacy for the United Sates national park system led by John Muir, Theodore Roosevelt and others (Roosevelt 1913). Eventually, Muir's work culminated in his founding of the Sierra Club in San Francisco in 1892, a group that has been involved in public legislative efforts to preserve wilderness areas and conserve land, air, and water resources ever since. With a current membership of more than 100,000 people, the Sierra Club remains one of the largest and most influential environmental organizations in the United States.

While a thorough survey of the arts and humanities is beyond the scope of this assessment, several other prominent themes that emerged in mid-20th century American nature writing exemplify a growing national movement valuing nature as something to be loved and stewarded instead of feared as dangerous or viewed only as a resource for economic exploitation. For example, in *A Sand County Almanac*, Aldo Leopold extends the definition of human community to include the natural world and the land itself, a definition that entails certain ethical obligations to the land (Leopold 1949). From his perspective as both forest ecologist and farmer, Leopold writes that “All ethics so far evolved rest upon a single premise: that the individual is a member of a community of interdependent parts. His instincts prompt him to compete for his place in that community, but his ethics prompt him also to co-operate; perhaps in order that there may be a place to compete for. The land ethic simply enlarges the boundaries of the community to include soils, waters, plants, and animals, or collectively: the land” (Leopold 1949). Moreover, Leopold’s “land ethic” attempts to balance the practical and intrinsic values of the land. For instance, he writes that “A land ethic of course cannot prevent the alteration, management, and use of these 'resources,' but it does affirm their right to continued existence, and, at least in spots, their continued existence in a natural state” (Leopold 1949).

If Leopold was the father of the land ethic, Rachel Carson (a marine biologist) was most certainly the mother of the sea ethic. While Carson does not use the term sea ethic, a recent critique of Carson’s *Under the Sea-Wind* by Bratton (2004) suggests that there are several parallel concepts that are shared between the two authors. In particular, is Leopold and Carson’s joint recognition that 1) humans need to understand the complexity of aquatic and terrestrial ecosystems; 2) their observation that humans activities can disrupt ecosystem process through over-extraction, degradation and pollution; and 3) their belief that human imagination and scientific inquiry can help us more fully value life, nature and its key ecological processes (Carson 1941; Leopold 1949; Bratton 2004). Toward the end of her career Carson also became concerned with the use of pesticides and their growing impact on terrestrial ecosystems, and on birds in particular. This concern is the basis of her final book *Silent Spring*, where she laments that "Over increasingly large areas of the United States, spring now comes unheralded by the return of the birds, and the early mornings are strangely silent where once they were filled with the beauty of bird song" (Carson 1962). Through their literature Carson and Leopold link science-based ecological knowledge with the aesthetic beauty of nature, and in so doing became voices of the modern land stewardship movement, whose proponents place a high value on both natural and working landscapes that preserve the integrity of their respective ecosystems. In so far as N pollution threatens the health of these ecosystems, it threatens the material basis of these social values. Conversely, in so far as prudent use of N enhances agricultural landscapes, it can support these stewardship values. .

Another key theme in contemporary American literature is people's experience of the human and natural world through one's "sense of place" (Snyder 1993; Lopez 1996). This branch of nature writing is dependent on the existence of distinct cultural landscapes and regional subcultures, and its popularity illustrates the continued value of these entities to many people within contemporary society. David Masumoto, a Fresno-based peach farmer of Japanese-American decent, is one contemporary author whose writing reflects a strong sense of place and land stewardship from an agrarian viewpoint. In his book *Epitaph for a Peach,* Masumoto (1995) chronicles his efforts to rescue the Sun Crest peach, "one of the last remaining truly juicy peaches", from commercial obsolescence due to the industry's preference for a uniform and less perishable product rather than overall flavor and quality. But perhaps more importantly, he also illustrates the curiosity, artistry and traditional wisdom that are part of his agrarian cultural values. One way that he does this is through his description of why he uses legume cover crops and their role in the nitrogen cycle. “Some farmers question the value of cover crops. How much nitrogen do they produce? Do they consume huge volumes of water? What plants attract which beneficial insects? All valid questions that need research, these issues will take years to determine and may never be clear. But the benefits of my fall planting go beyond making interesting plant mixtures and achieving proper nitrogen levels. Every fall I plant seeds of change for the next year. I am an explorer and adventurer, a wild man in the woods. No one can know the exact benefits of my cover crops; they are a blend of artistry and the wisdom of experience, a creation and reaffirmation of tradition” (Masumoto 1995).

In a similar vein, Wendell Berry, icon of the land stewardship movement at the national level, argues that the rural exodus and urbanization of America, and our subsequent loss of connection to the land, has diminished our cultural and spiritual identity (Berry 1977). In his case, he uses the example of waste recycling as the agrarian basis of fertility to critique modern urban culture. “Ninety-five percent (at least) of our people are also free of any involvement or interest in the maintenance phase of the cycle. As their bodies take in and use the nutrients of the soil, those nutrients are transformed into what we are pleased to regard as “wastes” – and are duly wasted. This waste also has its cause in the old “religious” division between body and soul, by which the body and its products are judged offensive” (Berry 1977).

One implication of this class of literature is that some farming practices are especially imbued with cultural values relating to land stewardship. In addition, this literature suggests that certain types of agricultural landscapes, including those occupied by locally-oriented, regionally diversified family farms such as Masumoto’s, can best embody the cultural significance of a sense of place. By extension, then, any trends that threaten the viability of these farming practices or these agrarian landscapes can potentially threaten the preservation of these cultural values. However, the relationship between these trends and the use of N is complex. On the one hand, the rapid increase in availability of cheap inorganic N fertilizers (see Chapter 3) may have reduced the use of certain traditionally important farming practices. On the other hand, the role of easily available N in supporting the continued existence of widespread agricultural landscapes that are key to cultural identity in California also merits consideration.

[Box 5.5.1]

5.5.5 Spiritual and religious values

Since many religious traditions were established during pre-scientific times, it is perhaps not surprising that direct references to N and its role in the environment are rare among the world's sacred texts and scriptures. Similar to the cultural heritage values discussed above, the complex relationship that exists between N, the environment, and people's spiritual values has not been rigorously examined. That said the broader ecosystem services literature has recently begun to examine some interesting lines of inquiry on spiritual and environmental values that are beginning to fill the gap (Taylor 2004; Bhattacharya et al. 2005; Daniel et al. 2012). These studies note that spiritual values regarding our relationship to (and appropriate use of) nature have existed since prehistoric times and remain an important part of the contemporary spiritual values of virtually all global cultures. Here we specifically examine spiritual values in the context of N-related impacts on the environment.

As discussed by Daniel et al. (2012) one of the primary ways that spiritual values are linked to the environment is through the practice of giving "sacred" status to important species, locations, or geographic features (Daniel et al. 2012). This practice of granting sacred status to species and places is common to many religious traditions practiced in California, though the degree of reverence attached to these rituals can vary widely among religions, subcultures and time periods. How something becomes viewed as sacred also varies widely, but common ways include significant references to particular species or sites in creation narratives, oral traditions, scriptures, and religious rituals. For example, California's Miwok tribes have a creation narrative, preserved through oral tradition, which depicts humans first emerging from feathers planted into the soil by supernatural personages with both animal and human characteristics (e.g., coyote, fox) (Kroeber 1907; Taylor 2005). Likewise, several indigenous tribes hold the belief that certain animals (e.g., buffalo, salmon, whales) offer themselves up as food for humans and thus are given a place of reverence within the spiritual tradition (Harrod 2000; Daniel et al. 2012). Consequently, Native American hunting rituals often include moral requirements for how to treat the bodies of animals after they are killed. There are also spiritual dimensions to the indigenous practices used to tend and harvest important plant species including the careful use of fire to maintain meadows and the gathering of tubers, acorns and buckeyes (Kroeber 1907; Anderson 2005). Some believe that failure to observe these rituals and practices will cause animals to withdraw from humans and thus lead to suffering and starvation (Harrod 2000). Hence, many rituals are specifically intended to renew both the animals and the landscape in anticipation of future hunting seasons (Harrod 2000).

Sites where these mythical events or religious rituals take place also have deep spiritual attachments among contemporary indigenous groups and are often considered sacred ground. For example, the Miwok roundhouses erected at sacred sites located on reservations, and in Point Reyes and Yosemite National Parks, are still used for important rituals and dances (Taylor 2005). Likewise, in some indigenous oral traditions the Great Spirit is said to have lived on Mount Shasta and thus the mountain is revered as the center of creation by the Shasta, Modoc, Ajumawi, Atsuwegi, and Wintu tribes. These beliefs regarding sacred species and sites are also part of a broader world view that does not draw a conceptual distinction between the natural and spiritual worlds, but rather sees the land itself as a sacred being (Bradey 1999). These beliefs and sacred sites remain a vital part of the contemporary world view held by many Native Americans in California. As a result, the impacts of N-related air and water pollution on the sacred sites (and to lesser extent the species) of tribal communities are now being addressed through the environmental justice components of the US Clean Air Act and the California Environmental Protection Act (USEPA 1999; NEJAC 2002; AB 52).

While prominent in the Native American world view, attributing some measure of sacred value to the natural environment is common in many other spiritual traditions as well; be they rooted in traditional religious beliefs or other forms of contemporary spirituality (Fick 2008; Ball 2013; Hitzhusen et al. 2013; Taylor 2004; Taylor 2010). These values from other cultural and spiritual traditions also merit consideration when assessing the broader impacts of N use and pollution on society. That said, much more research is needed to determine which of these diverse spiritual values are most relevant and how they might be influenced by the complex interactions between N and the natural environment.

5.5.6 Cultural and spiritual values as motivators for addressing N issues

In this section, we have focused mainly on how nitrogen can affect various landscapes, natural resources, ecosystems, and species which have important cultural and spiritual value to society. Given how closely entwined cultural and spiritual values are with nature it is perhaps not surprising that they can often play a central role in shaping the environmental ethics of our communities (Leopold 1949; Taylor 2005). Likewise, such values can also be a key source of motivation and inspiration for environmental stewardship (Posey 1999; Taylor 2004; Hitzhusen et al. 2013). Indeed, there is growing evidence from the social sciences that people’s perception of the scientific facts related to nutrient cycling, air and water pollution, and climate change are strongly mediated by their cultural and spiritual perspectives, which therefore have large implications for their individual and collective responses (Bickerstaff 2004; Schweizer et al. 2013). Thus a better understanding of the values that motivate, or possibly deter, environmental stewardship is likely to be a useful complement to the scientific knowledge, technologies and policies that are assembled to address environmental problems (Hitzhusen et al. 2013).

Table 5.5.2 illustrates the wide range of cultural and spiritual values that have played a key role in motivating society in California (and beyond) to respond to environmental issues related to land stewardship and pollution, and to N in particular. Most of these examples are drawn from the literature discussed in the sections above. Here we suggest that these values in many instances have helped to shape the specific goals of large social movements that bring people together at the local, national and international scales and raised awareness of pressing social and environmental issues. And while conflicts on priorities and policies can often arise among people who emphasize different values, common ground can often be cultivated by considering our shared values and our collective link to the local landscape and ecology (Snyder 1993).

[Table 5.5.2]

Of particular relevance to our discussion of N management and agriculture, sets of shared cultural and religious values led to a joint environmental stewardship "covenant" that was made between Christian watermen and farmers in the Chesapeake Bay watershed (Emmerich 2009; Hitzhusen et al. 2013). In this example the watermen promised that they would abide by various crab harvesting regulations, while the farmers upstream promised to adopt improved nutrient management practices to reduce eutrophication and water pollution. Hitzhusen et al. (2013) argue further that while such anecdotes are instructive on their own, the key to developing transformative models of environmental stewardship is to identify ways to synergistically couple cultural and spiritual values with sound science and effective public policy. One instance of positive synergism between cultural values and science education is a nationwide conservation program known as "Soil Stewardship Sundays" (Hitzhusen et al.

2013). The movement was initiated in the 1920's and 1930's during the Dust Bowl by the National Catholic Rural Life Conference, but it is now supported by a wide range of faith communities as well as scientists at the National Association of Conservation Districts who provide technical training to farmers on soil stewardship and nutrient management (Woods 2009; http://www.nacdnet.org/stewardship). Specific initiatives within California similarly combine religious or spiritual practice with land stewardship. For example, the Green Gulch Farm in Marin County, part of the San Francisco Zen Center, conducts Buddhist training and public teachings, while also encouraging volunteers to work on the organic farm and in maintenance of the larger watershed that the farm occupies, as part of their Zen practice. Examples of more secular efforts to instill stewardship values in California include the Center for Land-Based Learning (CLBL), which engages high school students in hands-on farming and conservation projects, with the explicit goal of addressing "the need to instill conservation and stewardship values in high school students", in order to meet the "needs for healthier land and more wildlife habitat." (from the CLBL website http://landbasedlearning.org/slews.php).

In addition to shared values, a shared sense of place and a keen awareness of the local culture and ecology can also form the basis for individual and collective responses to environmental challenges. Notably, empirical evidence from social psychology studies has found that sense of place or "place attachment" can be a significant determinant of sustainable behavior for several N-related issues including water quality (Stedman 2002; Lubell et al. 2002), climate change (Schweizer et al. 2013), and other aspects of biodiversity and ecosystem management (Cantrill 1998). In particular, regional watershed partnerships and other cooperative institutions based on the inherent ecological boundaries of natural resources are viewed by some as an effective complement, or alternative, to the role played by federal or state regulatory agencies (Lubell et al. 2002; Snyder 1993). Cultivating a shared sense of place can also foster a closer connection between local farmers and consumers, spur economic enterprise associated with “civic agriculture” (e.g., farmer’s markets, CSA’s etc.), and ultimately encourage wider adoption of sustainable farming practices (DeLind 2002; Rilla et al. 2011; Thayer 2003). These lines of research highlight the merits of rigorously examining the role of cultural values in the context of sustainable natural resource management, and indicate that additional work is needed to effectively address the coupled social-ecological challenges associated with N pollution.

Of course the language of science often fails to fully capture and convey the deep cultural values which tie us to the land and motivate our collective decisions regarding our use of natural resources. This deficiency of science underscores our intrinsic need for poetry, stories and songs that are rooted in the local landscape. Our local beat poet Gary Snyder no doubt had California’s diverse cultural and ecological landscape in mind when he wrote “If the ground can be our common ground, we can begin to talk to each other (human and non-human) once again” (Snyder 1993). He also believed that “This sort of future culture is available to whoever makes the choice, regardless of background. It need not require that a person drop his or her Buddhist, Voudun, Jewish, or Lutheran beliefs, but simply add to his or her faith or philosophy a sincere nod in the direction of the deep value of the natural world” (Snyder 1993).

California is gold-tan grasses, silver grey tule fog,
olive –green redwood, blue-grey chaparral,
silver-hue serpentine hills.
Blinding white granite,
blue-black rock sea cliffs,
- blue summer sky, chestnut brown slough water,
steep purple city streets – hot cream towns.
Many colors of the land, many colors of the skin

- Gary Snyder (1993)

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Box 5.5.1 Poem depicting the use of legume cover crops entitled *Enriching the Earth* by Wendell Berry (1985) [Return to text]

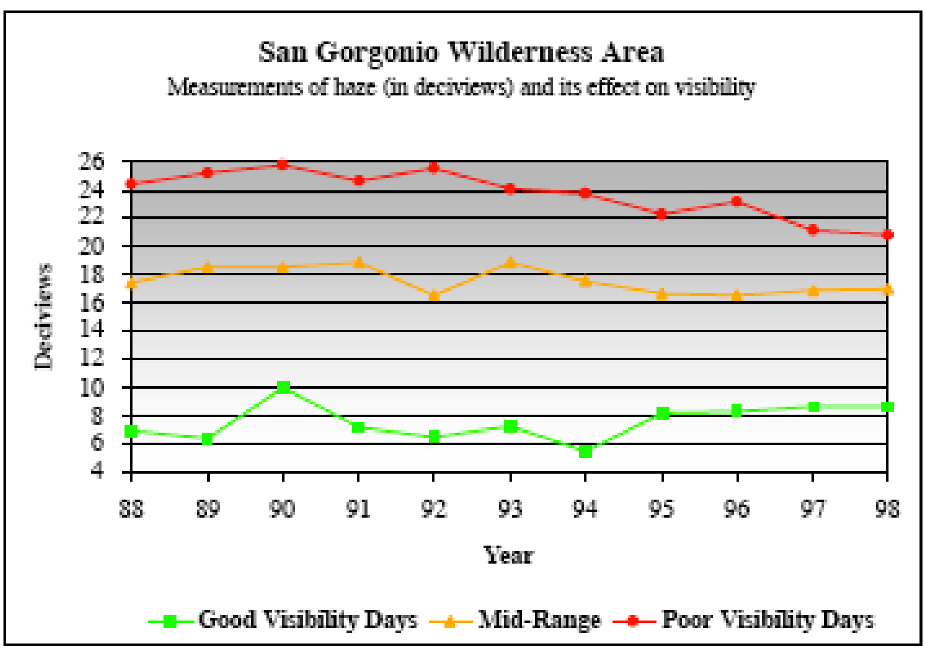
Enriching the Earth

To enrich the earth I have sowed clover and grass
to grow and die. I have plowed in the seeds
of winter grains and various legumes,
their growth to be plowed in to enrich the earth.
I have stirred into the ground the offal
and the decay of the growth of past seasons
and so mended the earth and made its yield increase.
All this serves the dark. Against the shadow
of veiled possibility my workdays stand
in a most asking light. I am slowly falling
into the fund of things. And yet to serve the earth,

not knowing what I serve, gives a wideness
and a delight to the air, and my days
do not wholly pass. It is the mind's service,
for when the will fails so do the hands
and one lives at the expense of life.
After death, willing or not, the body serves,
entering the earth. And so what was heaviest
and most mute is at last raised up into song.

Figure 5.5.1 Visibility trends at San Gorgonia Wilderness Area and Yosemite National Park from 1988 to 1998. Measurements of good (green), mid-range (yellow) and poor visibility days (red) are expressed in deciviews illustrated by the grayscale. Deciviews are units used in a logarithmically scaled haze index based on the light extinction coefficient (Pitchford and Malm 1994). Source: Abt Associates Inc. 2000.

[Return to text]



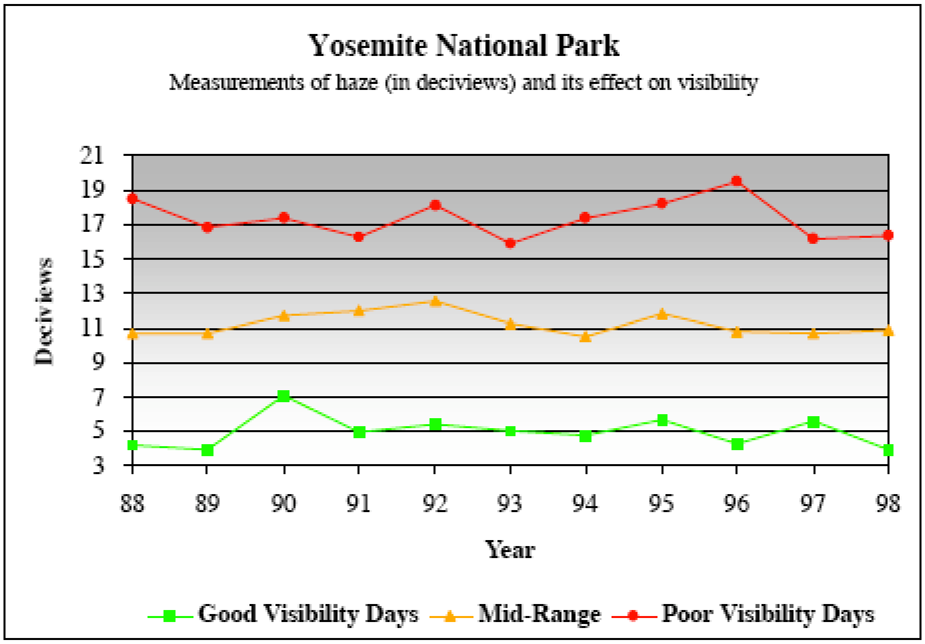


Figure 5.5.2 Map of total annual N deposition in California based on simulations from the US EPA Community Multiscale Air Quality (CMAQ) model. Simulated N deposition in forested areas has been adjusted based on the linear relationship with empirical throughfall data. Source: Fenn et al. 2010.

[Return to text]

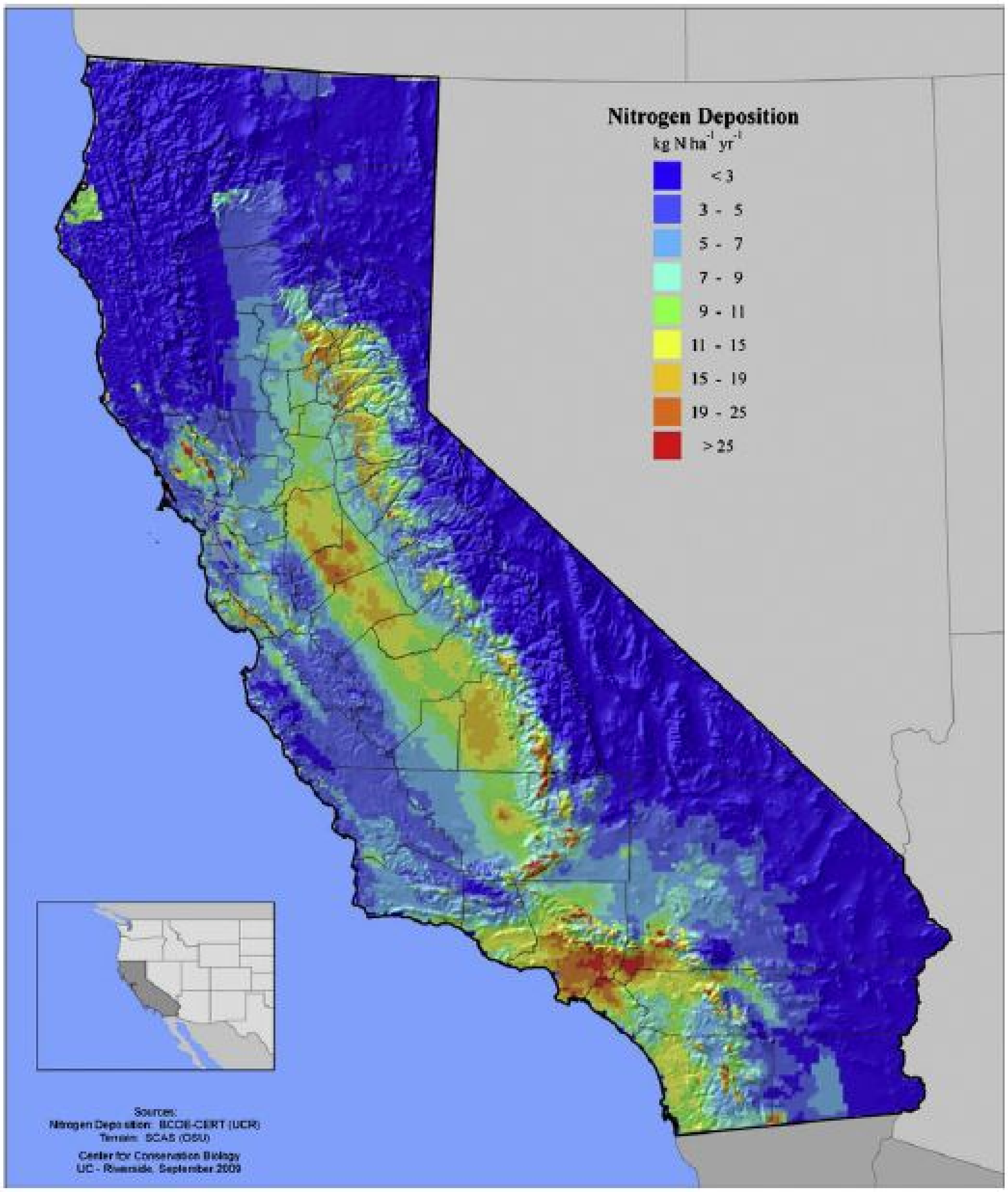


Figure 5.5.3 Map of the western United States showing the primary geographic areas where nitrogen (N) deposition effects have been reported. Areas where effects of air pollution on lichen communities have been reported in California and in Colorado are represented by pink triangles. The areas shown in red in Oregon and Washington (lichen communities affected by N deposition) are kriged data. Only lakes

at an elevation greater than 1000 meters and with a nitrate (NO_3^-) concentration of more than 5 microequivalents per liter (measured in fall surveys or on an annual volume-weighted basis) are shown in this figure. Other high-elevation lakes in the West also had elevated NO_3^- concentrations but were excluded, because N sources other than N deposition may have contributed to the elevated concentrations of NO_3^-. Source: Fenn et al. 2003. Also see Data Table 23. [Return to text]

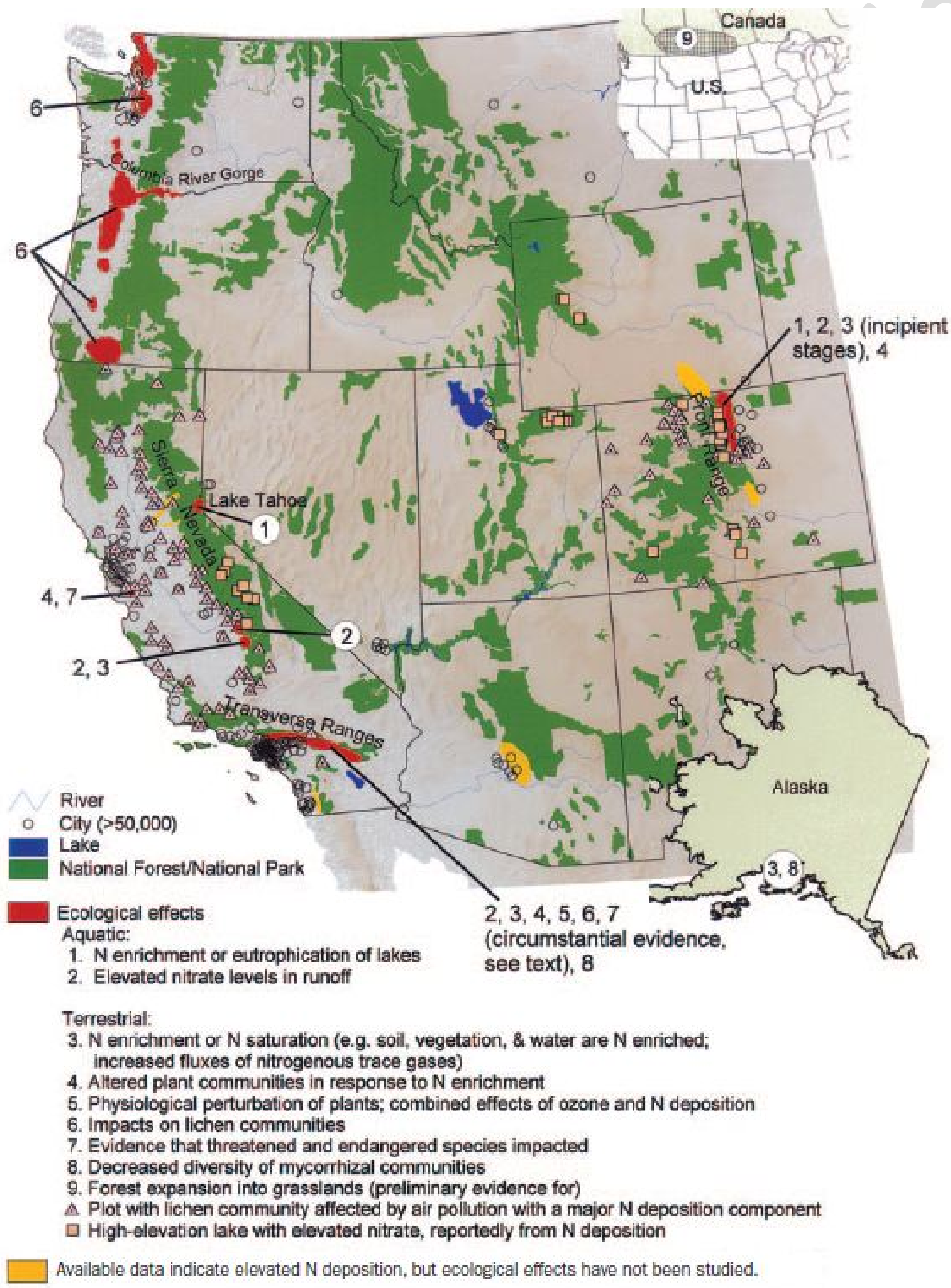


Figure 5.5.4 Biosite index estimates and risk to forest of injury from O_3 exposure, 2000-2005 average.

For more details on the biosite index methods, see Data Table 23 in the present N Assessment and Appendices 1, 2 and 3 of the primary literature source. Source: Campbell et al. 2007. [Return to text]

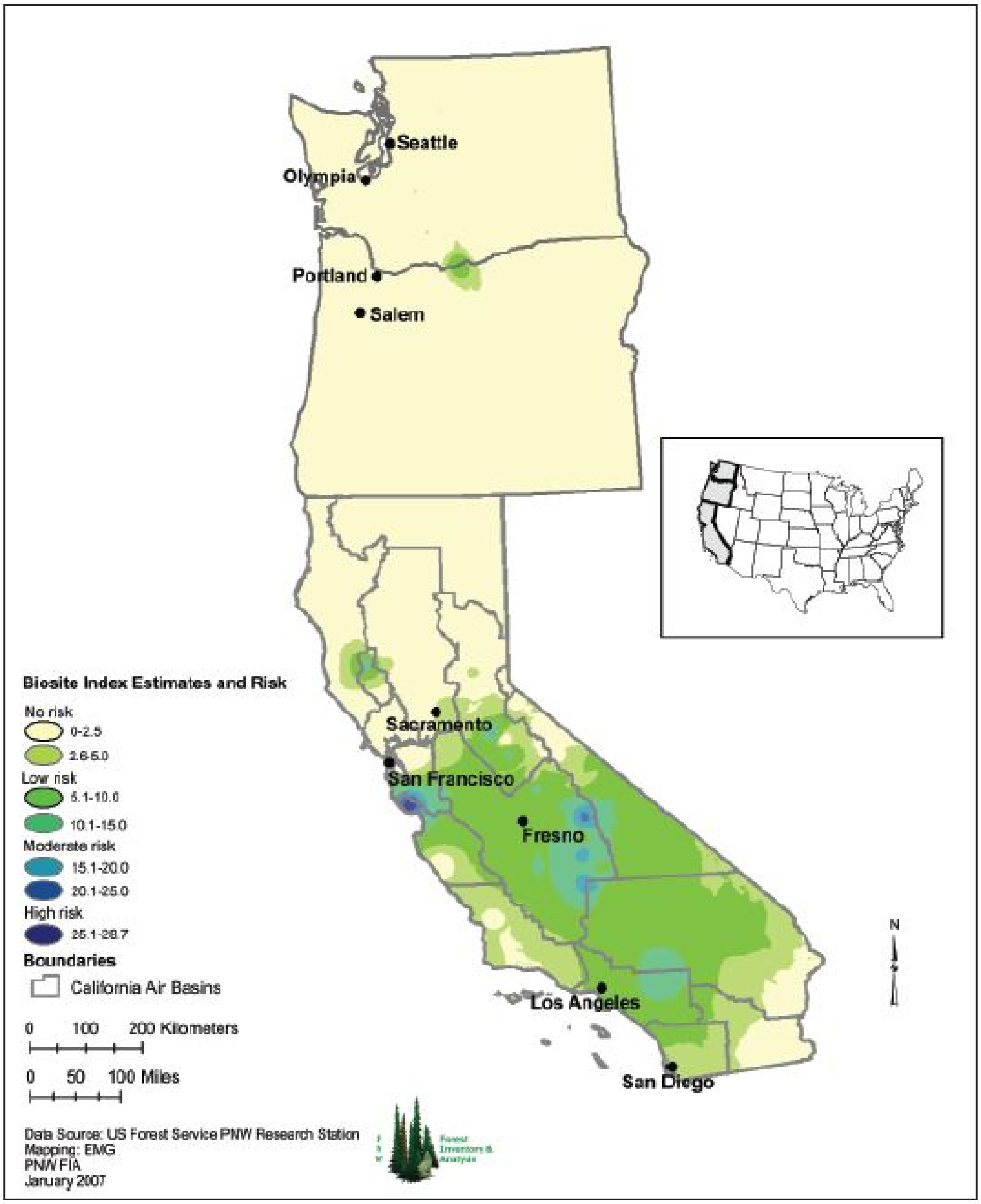

Seattle
Olympia
Portland
Salem
Sacramento
San Francisco
Fresno
Los Angeles
San Diego
Biosite Index Estimates and Risk
No risk
0-2.5
2.6-5.0
Low risk
5.1-10.0
10.1-15.0
Moderate risk
15.1-20.0
20.1-25.0
High risk
25.1-28.7
Boundaries
California Air Basins
0 100 200 Kilometers
0 50 100 Miles
N
Data Source: US Forest Service PNW Research Station
Mapping: EMG
PNW FIA
January 2007

Table 5.5.1 Location, date, hypoxic and eutrophic status, and cause of nitrogen related biological impacts to surface water bodies in California. Source: Adapted from CENR 2010. [Return to text]

Location	Decade	Status of Water Body	Cause	Biological Impacts	References
Los Angeles Harbor	1950	*Hypoxic (improved)* - seasonal hypoxia observed since 1950s. Recent improvements due to nutrient management in the watershed.	Not reported	Hypoxic events have caused mass mortality at the sea bottom (benthic zone), requiring multi-year recovery.	Reish, 1955; Collias, 1985; Reish, 2000
Long Beach Harbor	1960	*Hypoxic (improved)* - water quality has improved recently as a result of increased runoff controls in the drainage area.	Not reported	Not reported	Collias, 1985; Whitledge, 1985
South San Francisco Bay	1960	*Hypoxic (improved)* - Seasonal hypoxia, observed since the 1960s, has been nearly eliminated with the construction of modernized sewage treatment plants	Sewage discharge	Not reported	Nichols et al. 1986; Bricker et al. 2007
Coyote Creek	1970	*Hypoxia (episodic)*	Partly caused by sewage spills.	Fishermen report absence of fish and pelagic invertebrates, with fish returning when hypoxia ends.	Cloern & Oremland, 1983
San Joaquin River	1970	*Hypoxic (episodic)*	In part by sewage discharge from the Stockton Regional Wastewater Control Facility and agricultural runoff from further upstream.	Low oxygen conditions (<6 mg/L) interfere with spawning and migration of fish, in particular the Chinook Salmon. In 2003, fish kills of steelhead and salmon reported as the result of a hypoxic event.	Jassby et al. 2005; Lehman et al. 2004; Bricker et al. 2007
Tomales Bay/Bodega Harbor	1980	*Eutrophic* - eutrophication has been a concern in the bay since the 1980s.	Sources include runoff from animal waste (dairies and rangelands), failing septic systems, streambank and road erosion, storm drains, and boating activities.	Poor water quality causes seasonal closure of shellfish beds, high bacterial counts in swimming areas along tributaries to the bay.	Collias, 1985

North San Francisco Bay Estuary	1980s - 2000s	*Hypoxic (episodic)*- seasonal hypoxia first observed in 1980s.	Nutrient sources include discharge from sewage treatment plants and urban and agricultural runoff.	Recently, seasonal hypoxia has resulted in fish kills.	Lehman et al. 2004
Alamitos Bay	1990	*Hypoxic (episodic)* - oxygen levels improved from 1990s-2000s, but an estimated 2 km^2 still affected by episodic hypoxia since 2000.	High population density, leading to high levels of nutrient runoff.	Not reported	Rabalais, 1998
Elkhorn Slough	1990	*Hypoxic (improved)*	Located within a highly productive agricultural landscape and receives high nutrient inputs from agricultural runoff.	Eutrophication has led to high phytoplankton populations, persistent macroalgal mats, and hypoxia.	Collias, 1985; Bricker et al. 1999; Bricker et al. 2007; Sanger et al. 2002
Newport Bay	1990	*Hypoxic (improved)* - Dissolved oxygen levels improved from 1990s-2000s; less than 1km^2 has been affected by periodic hypoxia since 1990s.	Urban runoff is the primary source of nutrient loads. Nutrient levels expected to decrease in the future due to diversion and treatment of stormwater.	Large macroalgae blooms occur, especially after heavy rainfall.	Collias. 1985; Rabalais, 1998
San Diego Bay	1990	*Hypoxic (periodic)* - estimated 4.5 km^2 affected by periodic hypoxia since 1990s.	High population density, leading to high levels of nutrients.		Collias, 1985; Rabalais, 1998
Santa Monica Bay	1990	*Hypoxic (unknown)* - wastewater treatment plants began improvements in the 1960s, and by 2002 both plants had fully upgraded to secondary treatment.	Receives direct sewage discharges from two wastewater treatment plants.	Shift in the community of benthic organisms living in the sediments to only the most pollution tolerant species. Improvements in benthic diversity observed since 1995.	NEPCCR 2007
Tijuana Estuary	1990	*Hypoxic (improved)* - estimated 0.13 km^2 affected by periodic hypoxia in last decade; oxygen levels improving since 1990.	Untreated sewage from Tijuana, Mexico.	Area is an essential breeding, feeding and nesting ground for over 370 species of migratory and native birds, including six endangered species.	Sanger et al. 2002; Bricker et al. 2007
Anaheim Bay	2000	*Eutrophic* - moderate eutrophic areas.	Urban runoff and agriculture in the watershed.		Bricker et al. 2007
Monterey Bay	2000	*Hypoxic (seasonal)*	Natural and anthropogenic factors.	Not reported	Okey, 2003

Central San Francisco/San Pablo/Suisun Bays	2000	*Eutrophic*	Agriculture, urban runoff, and insufficient wastewater treatment in the region.	Moderate eutrophication and algal blooms.	Bricker et al. 2007

Table 5.5.2 Examples of cultural values that have played a role in motivating society to respond to environmental issues related to nitrogen, land stewardship and pollution. [Return to text]

Cultural Values	Region	Issues or Movement	Response	References
Spiritual Value	Global	Nature and Religion, Environmental Ethics	Religious leaders from Buddhism, Christianity, Hinduism, Islam and Judaism gathered in 1986 to issue joint Assisi Declarations on humanity's spiritual relationship to nature.	ARC (1986)
Spiritual Value	Global & U.S.	Environmental Ethics Climate Change	Faith-based organizations from many religions are active participants in global efforts to address the causes and consequences of climate change through religious education, community action projects, interfaith partnerships, and United Nations initiatives.	Faith-350 (2013) Posas (2007)
Cultural Heritage Recreational Value	Global & U.S.	Organic, Local and Slow Food Movements	California-based writers M. Pollan and E. Schlosser are prominent figures in these contemporary movements which critique how food and culture intersect on our plate.	Pollan (2008) Schlosser (2001)
Cultural Heritage Aesthetic Value	U.S.	Land Ethics, Conservation, Pesticides, Pollution	Nature writing of A. Leopold and R. Carson helped raise awareness of environmental issues (pesticides, degradation of aquatic and terrestrial ecosystems), and the resulting movement led to the federal Clean Air and Water Acts of the 1970's.	Leopold (1949) Carson (1951) Carson (1962)
Cultural Heritage Spiritual Value	U.S.	Soil Conservation	Soil Stewardship Sundays initiated in the 1920's by the National Catholic Rural Life Conference to address declines in rural culture and soil quality. The movement expanded and is currently supported by various faith communities in U.S, and the secular National Association of Conservation Districts.	Woods (2009) Hitzhusen et al. (2013)
Cultural Heritage Recreational Value Spiritual Value	U.S. & California	Nature Conservation, Transcendental Philosophy	The nature writing and activism of R.W. Emerson, H.D. Thoreau, and J. Muir emphasized the transcendental unity of man and nature, and helped to establish the U.S. National Park system as a place for recreation and reflection.	Emerson (1849) Muir (1894, 1901) Rettie (1996)
Cultural Value Spiritual Value	U.S. & California	Environmental Justice, Air and Water Quality	Policy engagement by Native American communities has helped incorporate their cultural concerns and spiritual values into the policy frameworks of the California Environmental Protection Act and federal Clean Air and Water Acts.	NEJAC (2002) CA-AB52 (2013)
Cultural Heritage Aesthetic Value Spiritual Value	U.S. & California	Sense of Place, Agrarian & Urban Values, Bioregionalism	The literature of W. Stegner, G. Snyder, W. Berry, D.M. Masumoto and many others established a style that is rooted in and (contributes to) one's "sense of place" and the environmental, agrarian, urban and spiritual values that exist in regional sub-cultures.	Berry (1977) Masumoto (1995) Snyder (1993)
Recreational Value Aesthetic Value	California	Air Quality Legislation, Bird Habitat Conservation, Agricultural Practices	Following the Rice Straw Burning Act of 1991, collaborative efforts by California farmers, scientists and bird conservation organizations helped to reduce straw burning, improve air quality, expand habitat for migratory waterfowl, and support bird watching and hunting.	Elphick (2000) Hill (2006)
Spiritual Value	Chesapeake Bay Watershed	Eutrophication, Soil Nutrient Management, Overexploited Fishery	Shared religious values led to a joint "covenant" between Christian watermen in the Chesapeake Bay and farmers in Pennsylvania. Watermen promised that they would abide by various crab harvesting regulations and upstream farmers promised to adopt nutrient management practices to reduce eutrophication and water pollution.	Emmerich (2009) Hitzhusen et al. (2013)