

fecundity (LaHaye *et al.*, *in litt.* 2002). North *et al.* (2000) found synchronous low reproductive success of owls in the Sierra National Forest and Sequoia and Kings Canyon National Parks correlated to high spring precipitation (as was found for northern spotted owls by Franklin *et al.* (2000)) and lower spring temperatures, presumably due to effects of weather on prey species. Statistical modeling indicated lower fecundity in years with higher spring precipitation in spotted owls in southern California (LaHaye *et al.*, *in litt.* 2002). Results of a modeling study conducted by Franklin *et al.* (2000) suggested that northern spotted owl populations may experience periods of decline solely due to climatic variation; *i.e.*, even if habitat conditions remain unchanged, northern spotted owl populations may decline. The synchronous declines in reproduction observed by North *et al.* (2000) are of concern because as populations decline, the effects of catastrophes, especially those having a synchronous effect on populations, will have an increasing importance in determining rates of population change (Peery 1999, Franklin *et al.* 2000).

Climate may have greater impacts on spotted owls when working in concert with habitat degradation. Studies by Franklin *et al.* (2000) for northern spotted owls and by North *et al.* (2000) for California spotted owls indicate the important role habitat may play in buffering against the negative effects of climate. Franklin *et al.* (2000) found that the best model to predict adult survival included interactions between climate and habitat. Habitat quality, as defined by an optimal mix of edge and interior habitat, appeared to buffer the effects of climatic variation on survival, presumably because such habitats provided sufficient prey resources. North *et al.* (2002) found that the characteristics of nest site structures can modify microclimate conditions. Despite synchronous low reproduction, certain nests consistently exhibited higher reproductive success. In oak woodlands, these nests were on shrubby, north-aspect slopes in trees or snags surrounded by a well-developed canopy and in conifer forests they were overtopped by a canopy with a high foliage volume. The authors concluded that reproduction is influenced by both regional weather conditions and nest-site canopy structure, which protects fledglings from detrimental weather. Thus, if habitat features that buffer the effects of weather are removed, climate may have greater negative effects on spotted owls.

The last century has included some of the most variable climate reversals, at

both the annual (extremes and high frequency of El Niño and La Niña events) and near decadal scales (periods of five to eight year drought and wet periods) documented (USFS 2001b). These events may have negative effects on California spotted owls. Modeling of population response to climate in northern spotted owls by Franklin *et al.* (2000), suggests that cold high precipitation springs, as would be expected in California during El Niño years, lead to higher mortality. Alternately, low precipitation (as expected during La Niña years) may have negative effects on prey populations (Verner *et al.* 1992a).

Changes in climate that occur faster than the ability of endangered species to adapt could cause local extinctions (United States Environmental Protection Agency (USEPA) 1989). Analysis of the Antarctic Vostok ice core has shown that over the past 160,000 years, temperatures have varied with the concentrations of greenhouse gasses such as carbon dioxide and methane (Harte 1996). Since the pre-industrial era, atmospheric concentrations of carbon dioxide have increased nearly 30 percent, methane concentrations have more than doubled, and nitrous oxide (another greenhouse gas) levels have risen approximately 15 percent (USEPA 1997). The burning of fossil fuels is the primary source of these increases (USEPA 1997). Global mean surface temperatures have increased 0.3–0.7 Celsius (0.6–1.2 Fahrenheit) since the late 19th century (USEPA 1997).

Climate modeling indicates that the overall effects of global warming on California will include higher average temperatures in all seasons, higher total annual precipitation, and decreased spring and summer runoff due to decreases in snowpacks (USEPA 1989, USEPA 1997). California spotted owls are susceptible to heat stress (Weathers *et al.* 2001) and are therefore likely to suffer from increased temperatures. Higher precipitation during the breeding season may increase mortality of spotted owls (Franklin *et al.* 2000). Decreased runoff from snowpacks may cause decreases in the extent or quality of riparian habitats, which are important for California spotted owls, especially in southern California (Verner *et al.* 1992a).

Southern California forests in San Bernardino, Riverside, and San Diego counties are experiencing the worst drought in more than 450 years (Loe *in litt.* 2002). Thus, the spotted owl population in these habitats may be at significant risk. Conifers stressed by drought, combined with overstocked conditions, pollution, mistletoe, root

disease, and insect infestations are experiencing mortalities of up to 40 percent in some areas (Loe *in litt.* 2002). As larger older trees along with canopy layers are lost due to mortality, the effects to spotted owl prey and nesting habitat will likely continue for significant periods. As stated above, the San Jacinto Mountains are experiencing especially high mortality. It is anticipated that most of the nesting and roosting habitat in the San Jacinto Mountains will be lost. This area supports about 10 pairs of spotted owls, all of which could be lost (M. Gertsch, USFS, pers. comm. 2002). Response plans by the Forest Service and CDF include removal of dead and infected trees to reduce spread of disease, harmful insects, and fire; however, these agencies indicated the extent of the impacts far exceed their capacity to respond in the short term (Loe *in litt.* 2002). Planning efforts to address the drought mortality by the agencies are underway. As previously stated the population of spotted owls in southern California are geographically isolated from spotted owls in the north (Sierra Nevada range) and may warrant special management consideration.

**Air Pollution.** Nitrogen oxides and volatile organic compounds are emitted from industrial and automotive sources and transported by wind to California spotted owl habitat (USFS 2001a). These compounds react under sunlight to release ozone. Snow core samples from the Sierra Nevada contain a variety of other contaminants from industrial and automotive sources including; hydrogen ions (indicative of acidic precipitation), nitrogen and sulfur compounds (NH<sub>4</sub>, SO<sub>2</sub>, and SO<sub>4</sub>), and heavy metals (Pb, Fe, Mn, Cu, and Cd) (Laird *et al.* 1986). These pollutants may directly harm California spotted owls. In addition to likely direct effects, pollutants can negatively affect California spotted owl habitat. Air pollution causes damage to trees, which may cause abnormalities and retard growth (USFS 2001a). Air pollution also contributes to tree deaths, especially by making them vulnerable to attack by insects (USFS 2001a). Damage and death of trees may reduce forest characteristics selected by California spotted owls, such as canopy cover, basal area, number of large trees, etc. Tree death also contributes to heavy fuel loading and the risk of severe fires (University of California 1996).

**Human Induced Stress and Mortality.** Spotted owls have died in collisions with vehicles (Verner *et al.* 1992b). They may also suffer from stress caused by human activities and habitat alteration. Wasser *et al.* (1997) measured levels of stress induced glucocorticoid