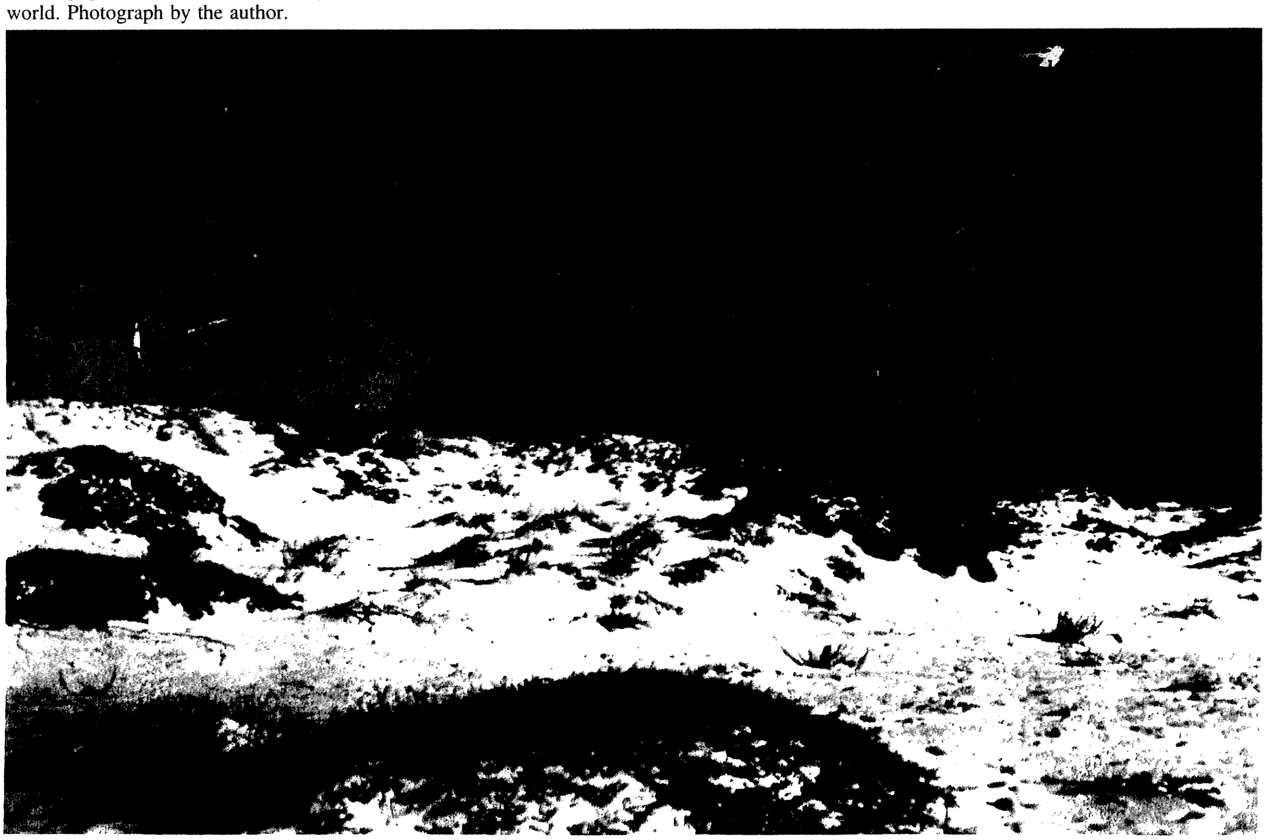
RECONSIDERING THE CONSERVATION OF MONTEREY PINE

by Constance I. Millar

MONTEREY PINE (*Pinus radiata*) is a well known and much loved rare endemic of California and Baja California. Over the past two million years, its distribution has fluctuated regularly in response to climate change. Today, the species is contained in five small disjunct native populations: at Point Año Nuevo, the Monterey Peninsula, and Cambria in central California, and two Mexican islands, Cedros and Guadalupe. Monterey pine has been the focus of increasingly urgent conservation concern (*Fremontia*, 1997, vol. 25 no. 2), with the populations facing various onslaughts of human cause. For instance, the Guadalupe Island population has long been threatened by goats introduced to the island in the late 1800s to provide meat for passing sailors. By 1978 only 320 individual trees remained, and recent accounts indicate that many of these are now dead. The mainland California populations have faced impacts since the mid-twentieth century from land conversion and urbanization, genetic contamination from non-local plantings (including naturalized stock from New Zealand), threats from native pathogens, especially western gall rust (*Peridermium harknessii*) and pine needle cast (*Dothistroma pini*), and fire suppression. Since 1986 threats to the mainland populations have rapidly accelerated due to the appearance and spread of the lethal pitch canker fungal disease, caused by *Fusarium subglutinans* forma *pini*. Pitch canker has spread at an alarming rate, first through planted pines, and more recently in native stands, threatening to decimate Monterey pine forests within the next decade.

The urgency to protect Monterey pine arises from several sources. As a dominant member of some closed-cone pine ecosystems, Monterey pine plays a keystone ecological role in these unique closed-cone California forests. The conservation biology community in California has focused considerable attention on the protection of native forests in their native habitat. In addition, the Monterey pine is an icon of the central California coast, framing beaches and creating dramatic coastal forest scenery. Last but not least, the Monterey pine is also an extremely important commercial species. In the United States its use is primarily for Christmas trees and horticulture, but internationally it is a dominant crop for lumber and paper. Of the more than ninety species of pines in the world, Monterey pine is the most widely planted outside its native range, and a primary timber species in New Zealand, Australia, and Chile. In New Zealand, for instance, Monterey pine accounts for one-twelfth of the country's gross domestic product, and one-eighth of its export receipts, a figure

Native populations of the Monterey pine (*Pinus radiata*), shown here overlooking the Pacific Ocean at Monterey, grow at only five locations in the world. Photograph by the author.



expected to triple within twenty-five years. In most of these countries, active breeding and tree-improvement programs are in place. Several studies have indicated that native populations in California are diverse geneticially. By chance, however, original introductions of Monterey pine to these other countries were quite narrow genetically, giving the diverse and unexplored germplasm in the native California and Mexican populations inestimable value. Many of these countries have expressed urgency, commitment, and concern for conservation of native populations, and are organizing programs of ex-situ conservation (plantations and seed banks) in their own countries, fearing the loss of other native populations. This presents a twist to the more common situation in which northern countries call for conservation of a globally valued species in exploited southern ecosystems. With Monterey pine, we have an opportunity to demonstrate local stewardship of a rare species native to the northern hemisphere that has value widely in southern hemisphere countries.

Current Conservation

California populations of Monterey pine are the primary target of conservation activities, although the most threatened population is that on Guadalupe Island. Prior to the 1990s conservation in California was conducted on a site-by-site basis through the efforts of local conservation groups and public agencies. With the increased threat from pitch canker, coordinated efforts are convening under the auspices of the Monterey Pine Pitch Canker Task Force of the California Forest Pest Council, and combined strategies for conserving the native populations and ecosystems are emerging, such as those prepared by the California Native Plant Society (CNPS) and the California Department of Fish and Game (CDFG).

The focus of these efforts is captured in goals defined by the CNPS/CDFG strategy (*Fremontia*, 1997, vol. 25 no. 2) as "to conserve the full range of species and genetic diversity of the [Monterey pine] forest, to maintain a viable, self-sustaining ecosystem, and to improve and maintain ecosystem health, and to allow for economic growth." In these goals, both Monterey pine itself and its associated animals and plants and their habitats become the target for conservation. Three key aspects of the strategy are to identify relative priority of different sites for forest conservation areas, develop regulatory and planning strategies for protecting the forests, and develop an ecosystem management program for improving and maintaining ecosystem health. This strategy began by evaluating sites within the Californian Monterey pine forests, defining priorities areas for conservation, and developing management strategies, such as natural community conservation planning (NCCP) and a coordinated management and planning (CRMP) process.

Activities to conserve Monterey pine are also underway within the California Forest Pest Council program (*Fremontia*, 1997, vol. 25 no. 2). The action plan, approved by the State Board of Forestry in 1996, identifies key management, research, and education priorities. These focus on reducing the threat to Monterey pine forests from pine pitch canker, including ways to protect native Monterey pine stands from the canker. Other conservationists likewise have focused on preservation of large, unfragmented, genetically intact stands of native Monterey pine forest.

Internationally, the value of Monterey pine and the importance of as yet unutilized natural genetic variation drive a conservation imperative in the forest industries of several countries. In every case the greatest desire is protection of uncontaminated and pest-free Monterey pine in its native habitats. Back-ups (or alternatives, in the event of loss of a native population) include large and heterogeneous germplasm collections outside the native range. In places where Monterey pine is subject to advanced breeding and fiber production, four types of genetic populations are maintained: base (or gene conservation populations), breeding populations, propagation or production populations, and wood-producing populations. New Zealand and Australian breeders, for instance, are working to develop a standardized way for these four Monterey pine genetic groups to be managed in integrated and international genetic conservation programs.

Over the past two hundred years Monterey pine has also been widely planted beyond its native range in California. In many coastal and near-coastal sites it has survived and thrived following both direct planting and aerial seeding. In these non-native sites, Monterey pine is viewed in one of two ways. Where it is intentionally planted (for horticulture, erosion control, wind breaks), it is valued and protected. Where it has escaped cultivation and become naturalized, or where old plantations occur within the bounds of current wildlands or parks, it is viewed as an invasive exotic weed. In these situations, Monterey pine has been aggressively removed through ecological restoration projects, such as at Jughandle State Reserve in Mendocino County.

The general approaches to managing Monterey pine in California—focusing on maintenance and restoration of native populations and controlling or eliminating exotic stands—derive from basic tenets of conservation biology. In the case of Monterey pine they also rely on the widespread acceptance that the species is an evolutionary relict and that the five native populations are its last remnant occurrences. In this article I summarize new information on Monterey pine's evolutionary history and introduce a broader conceptual framework for conserving Monterey pine. With the possibility that Monterey pine will be petitioned for listing as a threatened or endangered species in the near future and conservation strategies formalized, it is vital to review the eco-evolutionary foundations of its biogeography with a fresh perspective.

Traditional Evolutionary Understanding

Monterey pine and its close relative, bishop pine (*Pinus muricata*) have held the attention of California's preeminent paleontologists since the early 1900s. Many fossils, especially seed cones readily identifiable as modern closed-cone pines, have been collected over coastal California sites from Pt. Reyes to the Baja California border. These have been dated from the mid-Tertiary (about fifteen million years ago) to the early Holocene (11,000 years ago). The early Californian paleontologist Herbert Mason first thought that the present locations of Monterey and bishop pines, combined with the additional locations of fossil pines, provided evidence that the closed-cone pines evolved on Tertiary islands. Mason thus interpreted the present locations to be representative of distributions that had been fragmented throughout the history of the pines in California.

The interpretation of Tertiary islands was challenged on several grounds by Daniel Axelrod. Spanning nearly six decades of work, Axelrod has added most of the currently known fossil discoveries, and has developed much of the currently accepted early evolutionary and biogeographic interpretation. Using geological, pine fossil, and associated floristic evidence, Axelrod has suggested that the California closed-cone pines originated in Central America from a diverse progenitor group whose ancestral member most resembled present-day Central American *Pinus oocarpa*. The closed-cone pines migrated to California about fifteen million years ago, by which time Monterey pine was a distinct species. The many coastal sites occupied by Monterey pine over the millennia, together with climate evidence, led Axelrod to infer that Monterey pine found favorable habitat widespread along the California coast. He inferred that the species continuously occupied widespread coastal distribution throughout the Pleistocene (the period of major ice ages, from 2.5 million years to 11,000 years ago). Axelrod postulated that the warm, dry period, which he called the Xerotherm—now commonly referred to as the Climatic Optimum or early Holocene warm period—of 4,000 to 8,000 years ago, caused the extirpation of many Monterey pine populations and the break-up of continuous Monterey pine distribution. Because habitats were no longer widely available, Monterey pine's range was drastically reduced during this hot period, eventually to its five current sites, where local climate conditions allowed the species to persist through the Climatic Optimum.

Monterey pines (*Pinus radiata*) in the fog, Carmel Hill, Carmel. Photograph by William T. Follette.

Revised Evolutionary Interpretations

Recent advances in Quaternary science have led to remarkable breakthroughs in our understanding of earth's climate over the last two million years. High-resolution climate records, sometimes datable to individual years and extending hundreds of thousands of years into the past, have been developed from marine sediments and ice cores taken from the Atlantic, Pacific, and Arctic oceans. From shells of marine organisms and gases trapped in ice, reliable indicators of temperature can be derived. These methods provide, for the first time, a consistent and detailed yardstick for analyzing cycles of glacial and interglacial periods. These records reveal regular patterns of at least eleven ice ages (each of about 90,000 years duration) alternating with warm interglacials (each of about 10,000 years duration) over the last million years. Notably, there is nothing particularly unusual about the current interglacial, what we call the Holocene or modern period (the last 11,000 years). For instance, the Climatic Optimum (Axelrod's Xerotherm) appears to have had analogs in other interglacials, in that each interglacial period has a peak warm period that appears to be at least as warm as the early Holocene. In fact, the previous interglacial period (111,000 to 125,000 years ago) appears to have had peak temperatures at least two degrees C. warmer than the Climatic Optimum of our present interglacial (Holocene). The cores reveal a wealth of information about shorter duration climate periods as well, and have opened the door to understanding complex cycles of climate that operate on thousand-year scales down to decadal, such as El Niño intervals. The most striking pattern is one of regular fluctuations between cold and warm periods of several scales of duration.

Pollen grains and other plant parts are often present in marine cores, as well as in sediment cores taken from terrestrial bogs and lakes. These can be identified taxonomically and provide detailed information about vegetation response to historic climate changes at a scale hitherto unimagined. By and large, wherever cores are analyzed over long periods, changes in vegetation compositions and abundances are documented that correlate with regular fluctuations in climate.

Recent data of this nature about past climates and vegetation in the California coastal area provide new insights into the history of Monterey pine. Cores from marine sediments in the Santa Barbara Basin yield climate and vegetation information that record the same patterns and fluctuations in ice ages and interglacials that have been seen elsewhere in the world. When the data are put together, a more complete story for Monterey pine emerges than has been possible earlier, as follows.

Over the last two million years, the distributional history of Monterey pine—measured by total pollen abundance as well as by number of locations—appears to have fluctuated regularly along the California coast. It was least abundant during full interglacials (i.e., the Holocene and previous interglacials), when oaks dominated coastal habitats, and was also uncommon during the cold periods of the glacials, when junipers dominated. Monterey pine, as well as other coastal pines, increased dramatically in abundance and shifted in coastal location during climate periods intermediate between these extremes—that is, at times such as the end of the ice ages (climate warming), during "interstadial periods" (warmish intervals within the ice ages), and at the end of interglacials (climate cooling). Times of abundance of Monterey pine correlated also with increases in charcoal abundances in the sediment cores, corroborating that fire plays an important role in dispersal and spread of Monterey pines by opening cones and preparing seed beds.

The picture that emerges from analysis of these long cores is one of Monterey pine as a species with a dominant "metapopulation" strategy. That is, its populations likely have been fragmented, small, and discontinuous throughout its history in California. During favorable climate intervals, populations expanded and colonized new sites, aided by fire, which increased also during these intervals. During unfavorable climates, Monterey pine populations contracted, some appear to have gone extinct, and/or shifted in location. There is no evidence that Monterey pine was ever widely or continuously distributed during the last two million years, nor that the warm Climatic Optimum of 4,000 to 8,000 years ago (the Xerotherm, per Axelrod) was either unusual or the cause of even the most recent fragmentation or range reduction. Records suggest that by the time the climate warmed to a peak in each interglacial period, pine populations had already contracted. That they were able to expand and colonize repeatedly when climates turned favorable testifies to their aggressive colonization ability, the importance of fire, and the topographic and edaphic variability of the California coast, which allows favorable spots for pine to persist during regularly adverse climate periods, and potential habitat for expansion during favorable periods. In short, Monterey pine appears to have existed in fragmented populations throughout its Quaternary history in California, and thus to be adapted to small population sizes, to fluctuations in size, to colonizations of new locations, and even to local extirpations.

Implications for Conservation

This revised reconstruction of Monterey pine's history provides a new foundation for conservation strategies of the species and its associated ecosystems. If Monterey pine has long existed in small, disjunct populations and if these have regularly shifted in location and size over the California coast in response to fluctuating climates (i.e., metapopulation behavior), then it would be consistent to extend our conservation scope beyond areas occupied by the five current populations, which represent only a snapshot in time of Monterey pine's dynamic biogeography.

Given the nature of land use and development along the coast, Monterey pine is unlikely to be able to expand in the manner it might naturally. Areas not currently within its native range could be considered suitable habitats for Monterey pine conservation. Many of the areas where Monterey pine has naturalized along the coast coincide with fossil sites for the species. Several of these also currently contain associates that were to be found aligned with Monterey pine fossils (as well as with extant populations), such as bishop pine, cypresses (*Cupressus* spp.), and several shrubs. In many of these coastal sites Monterey pine thrives. The naturalized sites that coincide with Monterey pine's historic range and include many of its historic associates could be considered candidate "neo-native" populations, that is, human-assisted sites for Monterey pine expansion and restoration. High priority areas would include the Point Reyes coast and vicinity, the San Francisco peninsula, Big Sur coast, many locations along the San Luis Obispo/Santa Barbara coast, and coastal areas near San Diego. Such populations could be managed as new native populations, providing opportunity for genetic recombination, divergence, and adaptation. Sites that might be considered for conservation would be specifically selected from among the many where Monterey pine grows. Historic habitat, current floristic composition, soils, and fire regimes would be important elements determining which sites might be valued for conservation.

Concerns that Monterey pine would displace native species in these areas may be allayed by the fact that because they are historically native sites, associated biotic controls (pathogens) are likely nearby, as corroborated by experience with planted pines. If the presence of Monterey pine in these communities causes shifts in other native plant diversities, these would likely be within the range expected based on natural dynamics of pine expansion and colonization under climates similar to those at present. The maintenance of fire in pine ecosystems and the role it would play in pine expansion are also important to foster in both native and neo-native populations.

The rationale for this expanded view of Monterey pine conservation comes from not just the identification of historic habitat, but the recognition that under current climate conditions Monterey pine would likely be expanding. Cooling climates of the late Holocene (the current period) relative to the early-mid Holocene are analogous to historic periods when Monterey pine extended in abundance and location along the California coast. Thus, it might be expected to naturally colonize new coastal sites and perhaps diminish in other areas. The fact that Monterey pine appears not to have expanded naturally during the last 3,000 to 4,000 years, when the climate has been cooling, may relate to Native American land uses, chance events, or natural changes in opportunity for Monterey pine expansion. In the last two hundred years, however, urban development, land conversion, and an attitude that naturalization outside the native range is undesirable, inhibit or seek to reduce natural population establishment of distant sites. Human activities often are accused of fostering unwanted and disruptive invasion of species into native ecosystems. In the case of Monterey pine, however, intentional and accidental planting may be viewed as an assistance to Monterey pine in achieving conditions that natural migration might have promoted.

None of this should be interpreted as recommendation or license for allowing Monterey pine to diminish in any way at any of its present five locations. Nor does it imply that conservation activity shouldn't rightly focus on these areas. Further, this is absolutely not an argument that can be extended simplistically to other species that are acting as exotics. Because ginkgo grew in California fifty million years ago is not license to argue for its nativeness now. The unique history of Monterey pine, especially including its apparent metapopulation behavior, fluctuating range within a fluctuating climate history, and the recency and similarity of these past conditions to those of the present are some of the elements that make Monterey pine's case special. Outside its narrow (but larger than present) recent historic range, Monterey pine may well be treated as an inappropriate exotic. What is offered here is an appeal to expand the conservation strategy for Monterey pine in ways consistent with its eco-evolutionary behavior, and a plea to consider the dynamics of individual species' histories as much as static structure when developing conservation plans. Ultimately, the choice of where to focus conservation priorities is a social one. However, where conservation approaches and goals attempt to ground their actions in evolutionary and ecological theory, then the present information may apply. Further, by better understanding this species' evolutionary history and ecological behavior, we may better anticipate the results of our conservation actions, whether they seek to mimic natural dynamics or not.

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California Native Plant Society

Dedicated to the Preservation of the California Native Flora

The California Native Plant Society is an organization of laymen and professionals united by an interest in the plants of California. It is open to all. Its principal aims are to preserve the native flora and to add to the knowledge of members and the public at large. It seeks to accomplish the former goal in a number of ways: by monitoring rare and endangered plants throughout the state; by acting to save endangered areas through publicity, persuasion, and on occasion, legal action; by providing expert testimony to government bodies; and by supporting financially and otherwise the establishment of native plant preserves. Much of this work is done through CNPS Chapters throughout the state. The Society's educational work includes: publication of a quarterly journal, *Fremontia*, and a quarterly *Bulletin* which gives news and announcements of Society events and conservation issues. Chapters hold meetings, field trips, plant and poster sales. Nonmembers are welcome to attend.

The work of the Society is done mostly by volunteers. Money is provided by the dues of members and by funds raised by chapter plant and poster sales. Additional donations, bequests, and memorial gifts from friends of the Society can assist greatly in carrying forward the work of the Society. Dues and donations are tax-deductible.

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EDITORIAL

In this issue of *Fremontia,* Reid Moran provides readers with an account of his work on Guadalupe Island which is located 165 miles off the peninsula of Baja California. Reid's work, *The Flora of Guadalupe, Mexico, Memoir 19*, was published by the California Academy of Sciences in 1996. His article will be of particular interest to those interested in the flora of the Channel Islands.

Connie Millar has contributed an article with an historic view of the distribution of Monterey pine in California which is part of her research on the origins of forests. Connie's perspective is particularly interesting in view of the current ravages of pine pitch canker on Monterey pine trees.

Following the theme of exploration and historic perspective, we present another chapter, the decade from 1810-1820, of early explorations in California with an account taken from Susan Delano McKelvey's *Botanical Exploration of the Trans-Mississippi West*, 1790-1850.

And finally, Bob Ornduff, professor emeritus at the University of California, Berkeley, provides readers with an account of the vegetational changes taking place at his study site where, in 1995, a disastrous fire occurred on Mount Vision in Point Reyes, Marin County.

Phyllis M. Faber

THE COVER: Cones of the Monterey pine (*Pinus radiata*) are typically closed but open with the heat of fire or long summer days. Drawings are by C.L. Taylor in *Forest Trees of the Pacific Slope* by G.B. Sudworth.