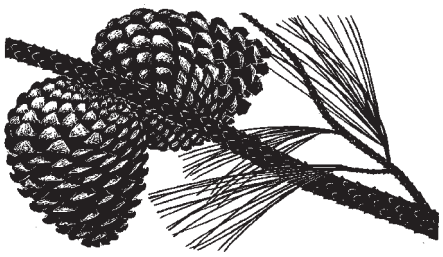

Executive summary

Monterey pine (*Pinus radiata* D. Don) is a species with a very small native range and immense international commercial importance. The extant native forests of Monterey pine currently occupy three disjunct locations on the central coast of California and on two Mexican islands—Guadalupe and Cedros—off Baja California. Internationally, and primarily in the southern hemisphere, Monterey pine grows in plantations that cover over 4 million ha; contributes significantly to the wood supply and GDP of New Zealand, Chile, and Australia, in particular; and, therefore, supports the conservation of native forest tree species in those countries because of its high productivity. In contrast to the broad range and extent of exotic plantations of Monterey pine worldwide, its natural range is restricted and has been reduced considerably by human activity. In California, the native Monterey pine forests have little commercial value, but add æsthetic value to coastal communities and provide source material for landscaping and Christmas tree businesses. Internationally, the native California and Mexican forests of Monterey pine are valued as the original source of seeds for their plantation enterprises, and as an important continuing reservoir of genetic diversity for the improvement of the plantation crop.

The ownership and management of native Monterey pine forests is diverse—including state, county, and city governments; landtrusts, universities, and other nongovernmental organizations; and private owners. This diversity of ownership complicates planning and management processes and has contributed to controversies concerning the status of the species. No species-wide plan or coordination for *in situ* conservation currently exists. Genetic diversity is critical to the long-term survival of Monterey pine in its native habitat. The overall objective of *in situ* genetic conservation of Monterey pine is to provide the best opportunity, given current information and understanding of the species' biology, to maintain the species' adaptive potential and the patterns and levels of genetic diversity that are within the normal range for the species. This report has been prepared to document current knowledge of the genetic structure and diversity of the species, describe its genetic status in relation to current and historical influences, and provide recommendations for genetic conservation. Emphasis is on native populations and *in situ* conservation, although some of the *ex situ* reserves and their essential role in conserving genetic resources also are described. It is expected that this report will assist those in the regulatory, management, education, advocacy, and research communities to make decisions that are better informed by science and more likely to contribute to genetic conservation of this species.

Monterey pine's evolutionary history suggests a dynamic relationship with climate. Historically, the species occupied a wider geographic range than today. The range, size, and continuity of Monterey pine populations have fluctuated over the last several million years apparently in response to climate changes. Genetic diversity within the species is modest compared to other western North American conifers, but high relative to other California closed-cone pines. The five native populations are rather strongly genetically differentiated. The within-population genetic structure is less well known.

Given the genetic differentiation among populations and the different ecological and sociopolitical context for each, *in situ* genetic conservation for Monterey pine is most effectively approached at the population level. Currently, there are no *in situ* genetic reserves for Monterey pine. Forest areas that currently have some protection have not been selected with genetic criteria in mind and are not necessarily being managed to conserve genetic diversity. To have genetic reserves—perhaps including some lands adjacent to existing forests where possible—is particularly critical for the species because of the historically dynamic relationship between Monterey pine and climate. With climate change and other

influences, Monterey pine populations are being severely challenged while having their historic suite of responses—including migration by dispersal—reduced.

Estimates of current and historical areas of native Monterey pine forest vary, but losses in habitat are probably 50% or greater. Habitat has been lost because of intentional conversion to residential, recreational, and other land uses. All populations, the island populations in particular, have been influenced by invasive exotic animal, plant, and fungal species. The Guadalupe Island population has only about 200 trees remaining and no recruitment from regeneration because of grazing by introduced goats. Exotic invasive plant species are pervasive and negatively affecting natural regeneration in the coastal California populations. The mainland California populations are also negatively impacted by other influences. An introduced fungal disease (pitch canker), caused by *Fusarium circinatum*, has caused significant mortality. In addition to other types of forest loss, some pine-dominated areas may be shifting toward oak dominance due, in part, to fire-suppression policies. Forests have been fragmented with transportation corridors and residential developments, with probable although unstudied impacts on genetic diversity. Monterey pines are undoubtedly influenced by genetic contamination from planted nonlocal trees. The mainland populations, particularly the southern two, are highly constrained in range by the ocean to the west and by urbanization or alternative land uses in other directions.

A series of recommendations has been provided to contribute towards *in situ* genetic conservation of Monterey pine (see below). These 18 recommendations are organized into four categories: planning, *in situ* management, outreach needs, and research. Some of the threats to the genetic diversity and integrity of Monterey pine populations are severe, transparent, and can be addressed directly. Examples include the removal of goats on Guadalupe Island and control of exotic invasive plant species in the California mainland populations. Other threats are multifaceted and require long-term planning and coordination. Included in this category are the establishment of *in situ* genetic reserves, protection of existing populations from further fragmentation, and conservation of areas adjacent to some populations that could become future habitat for Monterey pine. Finally, some threats are probable but not clearly defined, and require more research. For example, the extent and significance of genetic contamination in the mainland populations requires study, as does the fire ecology of the species.

With more attention, financial support, and the development of appropriate policies, there is still much potential to conserve the genetic diversity of the native populations of Monterey pine. In addition, the international interest in the native gene pools of Monterey pine can continue to play a valuable role in genetic research and conservation of the native populations.

Recommendations for *in situ* genetic conservation of Monterey pine

1. Biologically significant losses of genetic diversity within the species overall and within each of the five native populations of Monterey pine should be avoided.

2. Native Monterey pine populations should not be allowed to become further domesticated, meaning uncoupled from natural processes and thus requiring constant input and management to ensure standard biological functions such as growth and reproduction.

3. *In situ* genetic reserves should be designated for each of the five native populations, guided by within-population genetic structure. They are critical to genetic conservation and research objectives. A management plan to guide the protection of genetic values and a framework for genetic monitoring should also be established for these reserves.

4. 'Outliers' (trees at edges of populations) should be conserved because some may contain genetic diversity important for adaptation to new environmental conditions and may represent opportunities to expand the natural range or allow the populations some movement.

5. The establishment of *in situ* genetic reserves should be guided by theory such as desirable effective population size. However, given that theory might suggest reserves larger than areas available, efforts should be made to extend the boundaries of genetic reserves through appropriate genetic management of surrounding urban or recreation areas.

6. Additional seed collections should be undertaken in the five native populations using genetic sampling criteria.

7. Protocols for any extant *ex situ* genetic reserves should:

   i. Determine the maintenance strategy for that collection, including risk management by subdividing the collection among several locations;

   ii. Recommend and preferably secure a long-term or perpetual sponsor or steward for the collection(s);

   iii. Establish priorities for the most appropriate uses of the collection (i.e., decision-making criteria for seed distribution for uses such as research, commerce, restoration, or mitigation); and

   iv. Recommend a pricing structure for returning support to the collections based on their use.

In addition to these considerations, plans for any future genetic collections should include an assessment of the effect of the collection on the genetic diversity of the natural population (e.g., risk assessment).

8. Management history, for the mainland populations in particular, should be well documented to allow appropriate site choices and data interpretations for scientific research and for support in forest management.

9. Further fragmentation of remaining Monterey pine forests should be avoided.

10. The genetic and associated demographic risks from planted Monterey pines (e.g., roadside plantings, landscape trees, residential trees, and Christmas trees) within the current reproductive range of native Monterey pine populations should be evaluated. This evaluation should

include an examination of geographic scope, timeframe over which trees have been planted, and genetic source of material.

11. For any planting of Monterey pine within an area where mixing with the native gene pool is possible, the planting stock should be locally adapted and contribute to maintenance of natural genetic diversity of the native pine forests. Seeds should be preferred to seedlings. Clonal material should not be used except in limited scope in situations where this is the only feasible or well-reasoned alternative. For large planting projects, the source for propagules should be chosen so as to create a large effective population size.

12. Any breeding and delivery program aimed at providing disease-resistant trees for use within the genetic sphere of influence for native Monterey pine populations should be well informed about the genetic basis of resistance for that disease, the inheritance of the desired trait, its interaction with the environment, and the overall impact of artificially selected genotypes on the genetic diversity and population viability of Monterey pine and should not unnecessarily screen out potentially valuable genetic diversity.

13. The nature and extent of exotic invasive plants in the range of Monterey pine forests should be determined and an effective approach devised towards the control or elimination of those exotic species considered harmful.

14. The international concern and interest for the Guadalupe Island and Cedros Island populations of Monterey pine should be used by Mexican authorities and scientists to provide support for conservation policies and practices.

15. The Guadalupe Island population of Monterey pine requires immediate attention including removal or control of the goats, an assessment of the impacts of the introduced flora and development of a plan to manage these effects, and a genetic assessment of the remaining pines to determine if direct restoration activities are required.

16. An educational forum on Monterey pine should be organized that provides ongoing opportunities for exchange of ideas, presentation of scientific information, and discussion of applications among managers, scientists, and conservationists.

17. Public outreach, particularly on the importance of maintaining local adaptations in native Monterey pine forests, is critical to enabling an appropriate suite of options for genetic conservation of Monterey pine and should be aggressively pursued.

18. Research, surveys, or reviews that should be undertaken for Monterey pine are:

- A comprehensive vegetation survey of native Monterey pine forests, including associated plant species and extending to the geographic limits of the species.
- Mycorrhizal studies that will illuminate the relationship between forest ecosystem health and mycorrhizal dynamics, and the specificity of this relationship—if any—among the five populations.
- Soil/vegetation/ecological surveys for all populations, acknowledging that much of this has been done for the ecological staircase area of the Monterey population.
- Examination of relationship between microclimate or 'distance from ocean' effect and genetic diversity within the Monterey population.
- Determination of whether the 'outliers' near the Año Nuevo population are planted or naturally occurring.
- Investigation of genetic differences between the main Cambria population and the Pico Creek stand.
- Investigation of phenological differences within and between Monterey pine populations *in situ*.
- Determination of the effects on genetic diversity and structure from various enhanced or artificial regeneration techniques (e.g., mechanical creation of gaps).
- Investigation of the viability of seeds *in situ* over their temporal and spatial range, including persistence and viability in the 'canopy seedbank' over time and the effects on seed viability of site conditions and microclimate.
- Determination of optimum species-specific seed storage conditions that maintain viability and genetic integrity for long-term conservation.
- Research on the amount of genetic diversity in the Guadalupe Island population, losses of genetic diversity since goat introduction, and current level of inbreeding.
- Research on the relationship between fire and function of the Monterey pine forest ecosystem, including the effects of fire on nutrient cycling, litter removal, soil sterilization, seed release and germination, seedling recruitment, age structure, and genetic composition.
- Identification of an array of private or semi-private DNA marker alleles for the three mainland populations to enable identification and quantification of genetic contamination.
- Research on population dynamics including the role of adaptation in genetic structure, the genetic interactions of extant populations, and dispersal rates and efficacy.