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# Conservation of the Toromiro Tree: Case Study in the Management of a Plant Extinct in the Wild

MIKE MAUNDER,\*|| ALASTAIR CULHAM,† BJORN ALDEN,‡ GEORG ZIZKA,§  
CATHÉRINE ORLIAC,\*\* WOLFRAM LOBIN,†† ALBERTO BORDEU,‡‡  
JOSE M. RAMIREZ,§§ AND SABINE GLISSMANN-GOUGH\*\*\*

\*IUCN/SSC Reintroduction Specialist Group and Conservation Projects Development Unit,  
Royal Botanic Gardens, Kew, Richmond, Surrey, TW9 3AB, United Kingdom

†Centre for Plant Systematics and Diversity, Plant Science Laboratories, The University of Reading, Whiteknights,  
Reading, RG6 6AS, United Kingdom

‡Stad Botaniska Trädgården, S-413, Göteborg, Sweden

§Department of Botany and Palaeobotany, J.W. Goethe-University and Research Institute, Senckenberg,  
Senckenberganlage 25, D-60325, Frankfurt, Germany

\*\*Laboratoire d'Ethnobiologie-biogeographie, Muséum National D'Histoire Naturelle, 57 Rue Cuvier-75231, Paris,  
France

††Botanischer Garten der Universität Bonn, Meckenheimer Allee 170, D-53 Bonn1, Germany

‡‡Corporación Nacional Forestal Region del Bio Bio, Barros Arana 215, Concepción, Chile

§§Corporación Nacional Forestal, Rapa Nui National Park, Rapa Nui, Chile

\*\*\*Royal Botanic Gardens, Melbourne, Birdwood Avenue, South Yarra, Victoria 3141, Australia

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**Abstract:** *We reviewed the history and conservation of *Sophora toromiro*, a species that has been extinct in the wild since 1960 but has survived as scattered individuals in botanic gardens and private collections. The short-term conservation of *S. toromiro* is dependent on the management of surviving *ex situ* stocks. This is being achieved through international collaboration by a working group established to coordinate the conservation management of the species. Molecular evidence indicates that the species retains greater genetic variability than expected. The greatest amount of genetic variability was located in specimens outside botanic garden collections. No unmodified natural habitat survives on Rapa Nui (Easter Island); so opportunities to establish a viable wild population are limited. Evidence from past reintroductions indicates that the best short-term opportunity for the species is through conventional horticultural management in botanic gardens and traditional farm plots on Rapa Nui. Some extinct-in-the-wild taxa (*sensu* World Conservation Union 1994), such as the Toromiro, retain genetic variability, and appropriate reintroduction sites exist. These taxa represent valid priorities for conservation management.*

Conservación del Arbol Toromiro, un Caso de Estudio en el Manejo de una Planta Extinta en Sitios Silvestres

**Resumen:** *Revisamos la historia y conservación de *Sophora toromiro*, una especie que se ha extinguido de sitios silvestres desde 1960 pero que ha sobrevivido con individuos esparcidos en jardines botánicos y colecciones privadas. La conservación a corto plazo de *S. toromiro* depende del manejo de los organismos sobrevivientes *ex situ*. Esto se ha logrado mediante la colaboración internacional de un grupo de trabajo establecido para coordinar el manejo conservacionista de la especie. Las evidencias moleculares indican que la especie ha mantenido una variabilidad genética mayor de la esperada. La mayor variabilidad genética se ha localizada en los especímenes fuera de las colecciones de los jardines botánicos. Ningún hábitat sin modificar sobrevive en la isla de Pascua de Rapa Nui, por ello, las oportunidades para establecer una población silvestre viable son limitadas. La evidencia de las reintroducciones pasadas indica que la mejor oportunidad a corto plazo para la especie es mediante el manejo hortícola convencional en jardines botánicos y sitios con*

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||Current address: National Tropical Botanical Garden, 3630 Papalina Road, Kalabeo, Hawaii 96741, U.S.A.  
Paper submitted November 4, 1998; revised manuscript accepted April 5, 2000.

*granjas tradicionales en Rapa Nui. Algunos taxones extintos en la naturaleza, como lo es el toromiro, retienen variabilidad genética y aún existen sitios apropiados para llevar a cabo reintroducciones (sensu IUCN, 1994). Estos taxones representan prioridades válidas para el manejo conservacionista.*

## Introduction

Does the Toromiro tree (*Sophora toromiro*), extinct in the wild since 1960, represent a valid conservation target? Its existence in botanic gardens and private collections alone should not be the one governing factor influencing conservation investment; rather, it should be guided by factors such as the likelihood of successful reintroduction (Maunder 1992; World Conservation Union 1998). Although species conservation will be achieved most effectively through retention of habitats and wild populations, for an increasing number of species ex situ management is the only option after extinction of wild populations (Maunder et al. 1998, 1999; Ibáñez et al. 1999). These species are part of the “extinction debt” (sensu Tilman et al. 1994)—a pool of species facing extinction unless habitat is restored or managed and requiring ex situ management until reintroduction is appropriate. We outline the decline of the Toromiro and its survival in cultivation, and we review options for future management, including reintroduction.

## Extinction of the Toromiro Tree

The decline of the Toromiro illustrates the degradation of a Pacific island ecosystem in terms of both taxonomic loss and change in ecological processes. The Toromiro is part of *Sophora* section *Edwardsia*, a group of closely related island tree species that occur across the Pacific, south Atlantic, and Indian Oceans in a classic antarctic-circumpolar distribution. Over the last 30 years, the Toromiro has been recognized as a subject of conservation concern (Schlatzer 1965; Alden & Zizka 1989; Bordeu 1994; Maunder et al. 1999). Earlier authors saw Toromiro as a cultural (Heyerdahl 1958) and phytogeographic curiosity (Skottsberg 1920; Camus 1950; Turrill 1958; Sykes & Godley 1968).

Rapa Nui (Easter Island) shares with St. Helena in the South Atlantic (Maunder et al. 1995) and Rodrigues in the Indian Ocean (Strahm 1989), the fate of near complete anthropogenic transformation of its terrestrial ecology and associated cultural collapse (Brander and Taylor 1998). The island is a World Heritage Site, famed for its spectacular stone megaliths, the *moai*. The Toromiro played an important role in traditional society as a sacred tree valued for its carving wood (Orliac 1990a, 1990b, 1993; Rauch et al. 1996) and is still highly valued by the islanders.

Polynesian and European colonization throughout the Pacific heavily modified the original biota through habitat destruction and introduction of exotic species (Pimm 1996). Prior to Polynesian colonization, between A.D. 400 and A.D. 600, palynological evidence suggests that Rapa Nui was covered by scrub and woodland (Flenley & King 1984; Flenley et al. 1991; Bahn & Flenley 1992). Six endemic bird species are extinct, and the island has lost one of the most diverse sea bird populations in Polynesia (Disalvo et al. 1988; Steadman et al. 1994; Steadman 1995). An endemic monotypic palm, *Paschalococos dispersa* (Dransfield et al. 1984), has become extinct along with other nonendemic tree species (Zizka 1991). Only four endemic flowering plant species survive, three grasses still extant on the island (*Axonopus paschalis*, *Danthonia paschalis*, and *Paspalum forsterianum*), and only one tree, *S. toromiro* surviving in cultivation. A further 25 indigenous plant species survive, some in very low numbers (Zizka 1990, 1991). The terrestrial ecology of Rapa Nui is dominated increasingly by both exotic plants (Alden 1990; Zizka 1990) and invertebrates (Desender & Baert 1997).

The first European visitors commented on the island's treeless state. Gonzalez commented in 1770 that “not a single tree is to be found capable of furnishing a plank so much as six inches in width.” Roggeveen noted in 1722 that the island was “destitute of large trees” (cited in Zizka 1991). The first scientific collection of *S. toromiro* was made in 1774 by J. R. and G. Forster during Captain Cook's voyage. Notes made by J. R. Forster suggest that the species survived as scattered thickets in an open environment, noting that the area of Hanga Roa “was covered with a shrubbery of the ‘Mimosa’ [*S. toromiro*], which grew here to the height of 8 or 9 feet” (cited in Alden & Zizka 1989). A century later in 1880, after the introduction of domestic livestock, Thomson (cited in Zizka 1991) recorded “small clumps of the *Edwardsia* [*S. toromiro*]. . . but all were dead, having been stripped of their bark by the flocks of sheep.” Observations by late-nineteenth-century travelers indicate that the Toromiro was cultivated in household plots (Roussel 1869).

By the 1880s, the established Polynesian social structure had collapsed, traditional land use was largely abandoned, and management of the Toromiro ceased. As a result of smallpox and slaving raids, the island population dropped from between 6000 and 8000 around 1600 to only 111 by 1877 (Dodge 1976; Bahn & Flenley 1992). The last surviving wild Toromiro tree grew in the

Rano Kao crater, protected from introduced livestock by rock screens (Skottsberg 1920). Métraux (1957) noted that the islanders were “watching the growth of this tree, waiting for the right moment to cut it down and turn it into statuettes.” This last tree was chopped down in 1960 (Lucas & Synge 1978), at which time the existence of cultivated trees was unknown. The current World Conservation Union (IUCN) Red Data List for Plants (Walter & Gillett 1998) categorizes the species as vulnerable, despite the well-recorded loss of the wild population. Under the revised IUCN Red List Categories (World Conservation Union 1994) the species is characterized as extinct in the wild.

### Survival in Cultivation

The first records for this species in cultivation date from the early twentieth century. Between 1919 and 1920, plants were grown at the Göteborg Botanic Garden, Sweden, and were derived from seed collected by Carl Skottsberg. In the 1920s, the Royal Botanic Gardens at Kew distributed plants raised from wild seed collected by Catherine Routledge. Both accessions were apparently lost from European collections. The stock currently in cultivation in Europe is derived from seed collected by Thor Heyerdahl in 1958 from the last Toromiro on Rano Kao (Alden 1982, 1991). In 1959, four seedlings germinated from this seed batch at the Göteborg Botanic Garden and three resulting trees were used to provide cuttings to other botanic gardens. Seed from a putative Toromiro cultivated in Victoria Park, Christchurch, New Zealand entered cultivation in the 1980s (Godley 1992). Stock from this source was used in cultivation in European botanic gardens and for at least one reintroduction attempt. In 1994 a previously unknown group of trees was reported from the Royal Botanic Gardens, Melbourne, Australia. Putative Toromiro trees were reported in cultivation in Chile, including the National Botanic Garden, Viña del Mar, Chile, with nine other sources located in Chile by Alberto Bordeu of the Corporación Nacional Forestal (CONAF; Table 1).

The earliest known reintroduction attempts date to 1965 (Schlatzer 1965). All of the 20 recorded attempts manifested high mortality levels, and no trees have survived to fruiting (Maunder 1994). Little importance has been given to taxonomic verification of stocks or to monitoring plantings. A secret reintroduction was undertaken between 1966 and 1968, and claims have been made that trees have survived (Christensen & Schlatzer 1993). These claims are questionable because areas of scrub are few on the island and the Toromiro is well known to the islanders.

### Current Conservation Management

The need for a coordinated management of the Toromiro was recognized by Chilean conservationists (Bordeu 1994) and European botanic gardens, notably Göteborg,

Bonn, Palmengarten, Frankfurt, and the Royal Botanic Gardens at Kew. As a result of this concern, the Toromiro Management Group was established to coordinate the management of the Toromiro and bring together the requisite skills for the successful management and conservation of the species (Maunder 1994, 1997). Accordingly, a multidisciplinary working group was established with the goal of supporting the Chilean authorities (CONAF and the Rapa Nui National Park) to (1) achieve the genetic and demographic security of the species in cultivation and (2) reintroduce viable populations to Rapa Nui.

### Genetic Status of Toromiro

Fundamental to the successful management of the Toromiro is (1) the location of all potential Toromiro trees, (2) the confirmation of taxonomic identity, and (3) assessment of genetic diversity. During the search for surviving trees by members of the TMG, particular emphasis was given to locating trees in Chile, where it was thought more likely to locate lines differing from the European botanic garden stock. In addition to the well-known stocks in Europe, 10 potential founder trees were identified in Chile, with two further sources located in Australasia (Table 1).

The cultivated stocks are characterized by a lack of provenance data, with the majority of collections holding a single tree of uncertain origin and its progeny. Only 4 of the 13 collections cultivate more than 10 trees, Viña del Mar Botanic Garden (Chile), the nursery of Pablo Titze (Chile), Bonn Botanic Garden (Germany), and Royal Botanic Garden, Melbourne (Australia). Of these, only Melbourne has a reproductive group believed to be derived from more than one founder individual.

Following the location of the trees, the taxonomic and pedigree status of the Toromiro trees was assessed by Maunder et al. (1999) based on random amplification of polymorphic DNA (RAPD) (Welsh & McClelland 1990; Williams et al. 1990) and inter-simple sequence-repeat (inter-SSR; Zietkiewicz et al. 1994; Charters et al. 1996) fingerprinting techniques.

The Toromiro is one of 17 species in the *Sophora* sect. *Edwardsia*. The species are distinguished by small differences in shape and number of leaflets and by floral and fruit differences. The recognition of some morphologically constant island endemic species (e.g., *S. toromiro*, *S. bowinsula*) contrasts with the recognition of a few morphologically variable and widespread species (e.g., *S. microphylla*). This has led to taxonomic confusion. Phylogenetic relationships within the section have been studied (Peña et al. 1993; Peña & Cassells 1996; Hurr et al. 1999), but the factors delimiting these species remain obscure. The only sure way to ascribe species identity in some cases is to use geographically authentic material. The only Toromiro accessions of known origin are the two Göteborg trees and the herbarium specimen collected

**Table 1.** Location of putative Toromiro trees.

Name	Location	Origin	No. of individuals	Verified identity
Behn	La Cruz, near Quillota, Chile	possibly originating from the herbarium of Konrad Behn	original tree died about 1985; two seedlings survive	<i>S. toromiro</i>
Titze	nursery of Pablo Titze in Talagante, Chile	origin uncertain	one tree and seedlings from self-pollination	<i>S. toromiro</i>
Sudzuki	private garden of the Sudzuki family, Santiago, Chile	origin uncertain, possibly from specimens collected by Alvaro Montaldo in the 1940s	one tree surviving from an original batch of 11 seedlings	<i>S. toromiro</i>
Pissarro	private garden, in Santiago, of the late Carlos Munoz Pissarro	unknown	one tree, progeny at Missouri botanical garden tested	<i>S. toromiro</i>
Viña del Mar	National Botanic Garden, Viña del Mar, Santiago, Chile	possibly derived from the Sudzuki tree	one tree and seedlings from self-pollination	<i>S. toromiro</i>
Alemparte	private collection of Mr. Alemparte at Renaca, Chile	thought to originate from Viña del Mar	current status unknown	not tested
Valdivia	arboretum of the Faculty of Forest Science at Valdivia, Chile	sent from Göteborg Botanic Garden in 1991	one tree	<i>S. toromiro</i>
Schick	private garden of Schick family in Santiago, Chile	unknown	one tree	not tested
Ingerson	private garden of Ingerson family in Santiago, Chile	unknown	one tree?	not tested
Buin	private garden near Buin, Chile	unknown	one tree?	not tested
Christchurch	Christchurch Botanic Garden, New Zealand	unknown	seed distributed to European collections and sent to Rapa Nui for reintroduction	<i>S. microphylla</i>
Göteborg	Göteborg Botanic Garden, Sweden	two trees derived from seed from last wild tree	seed and cuttings distributed to over 20 European collections	<i>S. toromiro</i>
Melbourne	Royal Botanic Gardens, Melbourne, Australia	unknown	group of 7 trees	<i>S. toromiro</i>

by Skottsberg (Skottsberg, C. & I., 668, 1917) held at the Herbarium, Royal Botanic Gardens, Kew, all derived from the Rano Kao tree. These were used for comparisons with putative Toromiro trees located during the survey.

Both the RAPD (Fig. 1) and inter-SSR (Fig. 2) data clearly show a single Toromiro lineage including the Göteborg trees (collected by Heyerdahl) derived as seed from the Rano Kao tree (Skottsberg herbarium specimen). These data also suggest that several introductions to cultivation have occurred. Globally, eight different lines (Table 1) have been identified in six sites around the world, three private gardens and three botanic gardens. The phenograms suggest the following introductions to cultivation: (1) the European botanic garden trees; (2) the Melbourne trees of unknown origin; and (3) the Chilean trees (Behn, Sudzuki, Vina del Mar, and Titze). Four putative trees in Chile (Table 1) have not been tested.

The European botanic garden stock is documented as derived from seeds collected by Heyerdahl from the tree in Rano Kao crater and subsequently cultivated at Göteborg. The label on the Skottsberg herbarium specimen

indicates that there was only one living specimen at the time (collected in 1917); accordingly, the seed collected by Heyerdahl in 1958 would have resulted from a self-pollination. The Bonn trees should not be considered founders because they are derived from the Göteborg stock and represent a potentially inbred line. The two Göteborg trees are identical in banding patterns and should be regarded as clonal duplicates (Figs. 1 & 2). The Melbourne trees could be derived from an early introduction to horticulture made by either Skottsberg or Routledge in the early 1920s and subsequently lost in European botanic garden collections.

The Chilean trees are likely to represent several separate introductions to cultivation, all of which may be derived from the Rano Kao tree as the female parent but derived through crossing with an unidentified conspecific. The notes on the Fuentes herbarium specimen (collected in 1911) are ambivalent ("rare in the area of Rano Kao") and could suggest the survival of more than one tree. This might explain the banding patterns exhibited by some of the Chilean trees (Sudzuki, Behn, Titze,

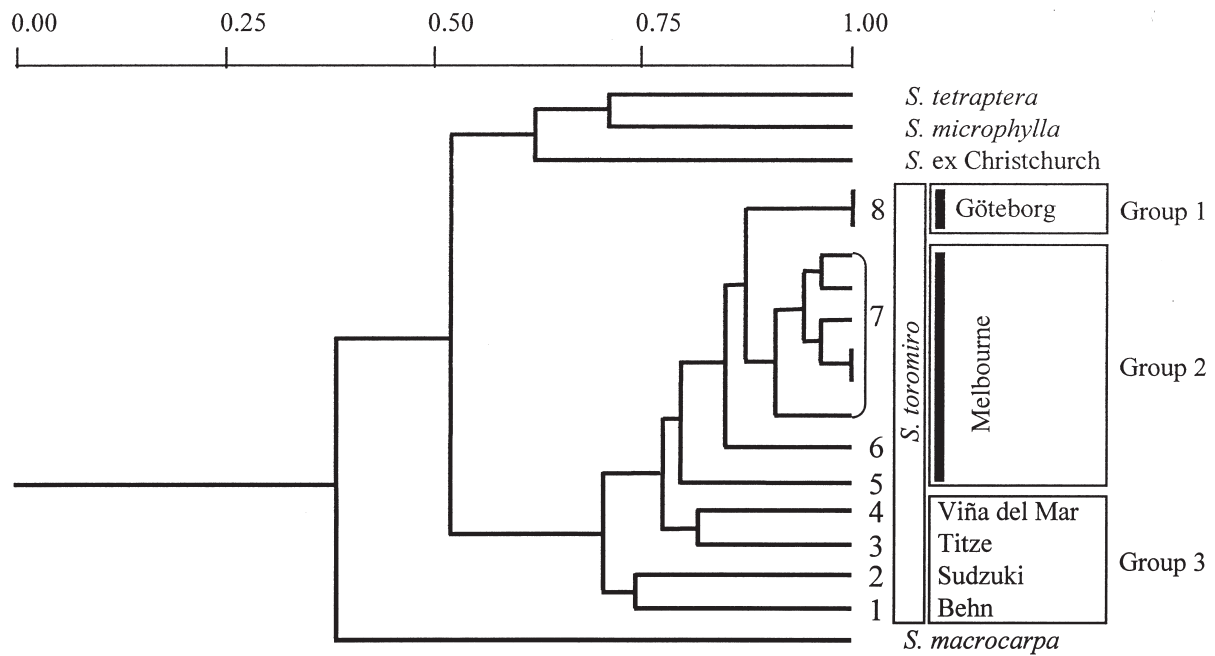


Figure 1. Relationships of *S. toromiro* stocks, as measured by Jaccard similarity, of RAPD data from seven primers, represented by an unweighted pair group method with arithmetic mean (UPGMA) phenogram. Cultivated Toromiro stocks are grouped by geographic origin. Numbers indicate lines previously identified (Maunder & Culham 1999).

and Vina del Mar), which may be exhibiting banding from an unknown male parent. If this is the case, they are of fundamental importance to the Toromiro conservation program. The taxonomic identity of the Missour tree can be inferred from the status of the Missouri tree, but its pedigree needs further resolution and cannot be inferred from available data (Table 1). Both phenograms (Figs. 1 & 2) show the Chilean material to have more interindividual band variation than the rest of the surveyed Toromiro stocks. The four Chilean trees sampled are as different from each other as they are from the Melbourne and Göteborg trees.

The putative Toromiro trees from Christchurch, New Zealand, and the Royal Botanic Gardens, Edinburgh, clustered with verified individuals of *S. microphylla*, confirming the morphological evidence that they are not Toromiro. The molecular studies provide no indication of hybridization with congeners in botanic gardens.

Despite concerns that the species may have gone through a bottleneck of one founder individual (Ricci & Eaton 1997), it now seems likely that some of the extant Toromiro trees predate the Heyerdahl collection of 1958 (Maunder et al. 1999). The cultivated Toromiro stocks in Chile retain some allelic heterozygosity (Ricci & Eaton 1997). The age of the trees and the repeated use of vegetative propagation has slowed the loss of both the original genotypes and alleles. This has been counteracted, however, by the loss of potentially important genotypes in Chile over the last 30 years and the overrepresentation of certain genotypes, particularly the Göteborg stock

in European botanic gardens (Maunder et al. 1999). The generation of large numbers of seeds by self-pollination from isolated trees, as is currently taking place in Chile, will lead to a loss of overall heterozygosity and will potentially result in inbreeding depression.

### Options for Conservation of the Toromiro

The work of the Toromiro Management Group has verified the taxonomic status of Toromiro trees in cultivation and has clarified pedigree relationships. The costs of maintaining the Toromiro will be incurred in different ways at the various sites currently cultivating the tree (in-country versus European facilities). Although European collections have maintained Toromiro trees over a number of decades and hold significant horticultural information about the tree, the cultural and evolutionary future of the taxon will depend on establishing populations on Rapa Nui. The different facilities that cultivate Toromiro have differing conservation objectives, budgets, and opportunities (Table 2). An opportunity exists to utilize their various characteristics—cost-effectiveness for specific activities such as stock management, ecological restoration, public education, and fundraising—in a complementary manner.

The immediate challenge is to manage a “closed population,” self-sustaining in cultivation with no inputs from wild stocks. With a better understanding of the Toromiro pedigree, managers will be better able to retain

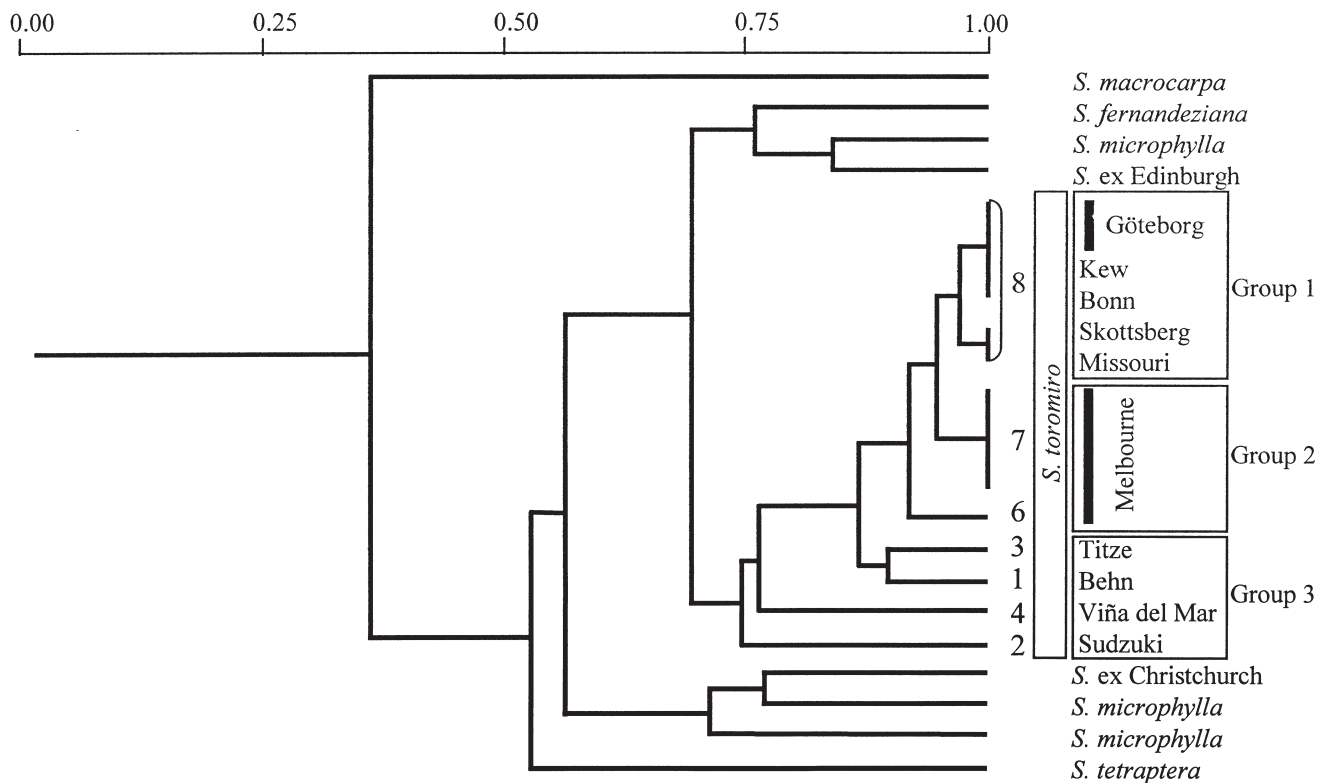


Figure 2. Relationships of cultivated stocks of *S. toromiro*, as measured by Jaccard similarity, of data from four inter-simple sequence-repeat primers represented by an UPGMA phenogram. Cultivated Toromiro stocks are grouped by geographic origin. Numbers indicate lines previously identified (Maunder & Culham 1999).

the existing genetic variation of the located founders rather than simply assuming that the located trees are all equally important or unrelated. Following the guidelines of Guerrant (1996), we propose three population management activities: (1) equalization of founder representation, (2) equalization of family size, and (3) managed immigration. There is an urgent need to balance founder representation within the global stocks through preferentially mating individuals with low founder importance. Currently, the Göteborg stocks are overrepresented and the Chilean founders underrepresented and vulnerable to continued loss. In addition, the global population should be enlarged to buffer against demographic and environmental stochasticity and to retain maximum genetic diversity after any bottleneck. It is likely that as the effective population size of Toromiro decreased over the last 250 years or more, both the rate of inbreeding and genetic drift have increased despite recent buffering through vegetative propagation. Inbreeding depression can be manifested through changes in growth and physiology (Dudash et al. 1997); for Toromiro, however, there are no historical measures of changes relative to the original wild population. Accordingly, the magnitude and effect of genetic erosion and inbreeding depression cannot be fully assessed.

A management plan, consisting of five primary steps, has been prepared for the species by the Toromiro Management Group (1998):

(1) *Locate and use all potential founders.* Clonal duplicates of all verified Toromiro founders will be established at facilities with a proven ability to cultivate Toromiro, with priority given to establishing a field gene bank at Viña del Mar, Chile. Trees of mistaken taxonomic identity will be removed from participating collections. Not only should all parental genotypes be maintained and used in this breeding program, but it is also important to consider the maintenance of both nuclear and cytoplasmic diversity. Male and female input from individual founders will be balanced by using each tree as both a pollen donor and seed parent. To facilitate safe and legal international transport and the medium-term storage of founder genotypes, in vitro cultures will be established. Seed from controlled pollinations will be held in seedbanks for future use as a means of effectively extending generation times.

(2) *Secure the establishment of the tree in cultivation.* This step is necessary to maintain genetic diversity until habitat restoration allows for reintroduction. The initial phase of restoring the Toromiro to traditional plots may not be compatible with genetic management.

**Table 2. Management options and risks for Toromiro.**

<i>Time scale</i>	<i>Type</i>	<i>Risks</i>	<i>Advantages</i>	<i>Issues</i>
Immediate	horticultural management in overseas botanic gardens	high recurrent costs; annual maintenance costs for the 8 European collections are circa \$75,000 (U.S.) poorly coordinated genetic management of European and Chilean stocks Toromiro maintained in mixed collections subject to risk of hybridization and pathogen transfer contrary to both the letter and ethics of the Convention on Biological Diversity (Article 9)	public display with educational and fundraising opportunities opportunities for research demonstrates positive role of botanic gardens in terms of institutional and public relations	potential for northern collections to support overseas conservation through fundraising based on public displays is largely untested
Immediate	in vitro management; tissue and seed storage	does not directly contribute to Rapa Nui conservation and cultural issues hidden ex situ Toromiro could be forgotten retrieving and weaning of plants from in vitro storage (e.g., cryopreservation) is subject to risk potential artificial selection	lower recurrent costs compared with traditional European botanic garden maintenance; storage costs of \$8 (U.S.) per seed accession per annum in seedbank potential ability to store seed samples and clonal duplicates from all founder stocks in a secure manner reduced cultivated costs subsidized by islanders cultural connectivity and ownership established	not a management option but a supporting technique
Medium	cultivation in traditional plots on Rapa Nui	may be difficult to reconcile with genetic management	potential for income to be derived from the Toromiro as a source of carving wood regenerating population under selection pressures assumed closer to natural than ex situ benefits other indigenous and endemic taxa (e.g., potential reestablishment of island sea bird colonies)	effective option for establishing Toromiro on Rapa Nui as a cultivated population; precursor to restoration option
Long term	establishment of regenerating wild population in restored habitats on Rapa Nui	no original terrestrial habitats survive on Rapa Nui; unproven potential for habitat restoration high initial capital and recurrent management costs (e.g., fencing, weeding, rat control)	regenerating population under selection pressures assumed closer to natural than ex situ benefits other indigenous and endemic taxa (e.g., potential reestablishment of island sea bird colonies)	success of restoration dependent on establishing a target habitat as objective and establishing ecological criteria for assessing success restoration could cost per hectare between \$12,000–35,000 (U.S.) per year excluding fencing

The Toromiro can be propagated by seed and cuttings with conventional horticultural techniques, and it has been propagated successfully in vitro from both vegetative tissue (Weimarck 1984; Jacobsen & Dohmen 1990; Iturriaga et al. 1994) and seed (G. Gratton, personal communication). In vitro propagation offers the potential to purge any possible viral load from botanic garden stocks. Toromiro in cultivation is vulnerable to heavy and damaging infestations of insect pests (M. Staniforth, personal communication). This vulnerability to infestation by insect pests is recognized by botanic garden horticulturists as a common problem for island endemics and may reflect a lack of secondary defense compounds (Bowen & Van Vuren 1997). Further work is needed on the horticultural management of Toromiro.

(3) *Establish horticultural facilities on Rapa Nui to support an on-island reintroduction.* Once founder stocks are established in secure facilities, it will be necessary to establish a horticultural facility on Rapa Nui to grow stocks as a local field gene bank and to assess local management needs for trial plantings. Such a facility can also maintain stocks of other threatened wild and domestic indigenous plant taxa for conservation and local education purposes.

(4) *Provide tree seedlings to farmers on Rapa Nui.* The frequent failure of previous reintroductions suggests that the most effective contribution to Toromiro conservation will be the reestablishment of the tree as a component of traditional garden plots for eventual use as carving wood. This will reinforce the cultural value of the tree for islanders.

(5) *Establish habitat restoration areas on Rapa Nui.* The high level of mortality demonstrated by historical reintroductions raises significant concerns about the feasibility of establishing a wild population. The following ecological factors need further investigation: (1) characteristics of the target habitat for restoration in terms of taxonomic components and ecological processes; (2) soil conditions on the island (since colonization soil has undergone changes [Wright & Carlos 1962]); the original soil, enriched by seabird guano [Daugherty et al. 1990] and human middens, has been lost; (3) horticultural care after planting, including weeding, fencing, irrigation, and protection from wind exposure; (4) improved pest management (Toromiro is subject to high levels of insect damage; it is suspected that some of these pests are recent introductions to the island, that the number of invertebrate introductions is increasing [Desender & Baert 1997], and that introduced rats may be seed predators); (5) pollination ecology (no information exists on the original pollination ecology; the closely related *S. microphylla* is partly bird-pollinated on Chatham Island, where it is in decline following the extinction or decline of endemic bird pollinators [Given 1995]); and (6) symbionts (no original wild samples of mycorrhizal or rhizobial symbionts exist).

## Conclusions

The Toromiro, along with other EW taxa, easily could be dismissed as a member of the “living dead” sensu Janzen (1986) and thus considered unworthy of conservation investment. Botanic gardens, commercial nurseries, and private gardens have retained individuals and prevented (or delayed) the extinction of Toromiro. Although representing a unique conservation responsibility for ex situ conservation facilities most EW species possess a reduced chance of successful reintroduction. The chances of a successful reintroduction are influenced by the genetic status of the surviving stocks (extent of original sampling and the effect of prolonged cultivation) and the availability of suitable habitat for reintroduction. The surviving stock of *S. toromiro*, derived from ad hoc horticultural collections, shows genetic variability that was not suspected prior to the TMG investigations. Parallel studies for other taxa extinct in the wild have revealed minimal allelic diversity in surviving stocks (*Lysimachia minoricensis*, Ibáñez et al. 1999) and no reproductive viability for a sole surviving clone (*Kokia cookei*; Woolliams & Gerum 1992). In addition, the original habitat or geographical location of some taxa extinct in the wild may be unknown or obscure (e.g., *Tulipa sprengeri*; Maunder & Culham 1997; Maunder et al. 1998). In contrast, the Toromiro is fertile, has the potential for a breeding program based on a number of genetically different founders, and is of known geographical and cultural provenance.

The cultivation of the Toromiro and any subsequent recovery activities can be justified by (1) retention of a fertile, unique taxonomic entity and endemic lineage; (2) retention of a flagship species whose conservation will promote broader conservation initiatives such as habitat restoration; (3) reintroduction of a culturally important species and valuable carving-wood resource, (4) retention in ex situ display facilities as an educational totem to illustrate ongoing island extinction processes, and (5) the emotional challenge of recovering a species on the edge of extinction (the “last pregnant dodo” syndrome; sensu Gould [1998]).

In the medium term, the tree will survive in conventional horticultural facilities and as a component of the traditional Polynesian agricultural landscape. In the long term, it could survive as a component of restored habitats. At worst, the tree will persist as a taxonomic sample in botanic garden collections. Species such as the Toromiro have a tremendous emotional power and a potent political role as flagship species in both representing the process of extinction and promoting the broader conservation imperatives of the restoration of biodiversity and culture (Caro & O’Doherty 1999). Based on projected extinction rates, botanic gardens are likely to accumulate more samples of the living dead, only a proportion of which are likely to be reintroduced. These



taxa therefore represent a long-term horticultural cost; accordingly, their potential for public education and fundraising should be fully exploited.

## Acknowledgments

We are grateful for the support and encouragement of D. Wyse Jackson of Botanic Gardens Conservation International (BGCI), who provided information from the BGCI database, and of M. Staniforth and B. Parry, who cultivated the Toromiro plants in the Temperate Nursery, Royal Botanic Gardens, Kew. We also thank J. Yves Lesouef, Brest Botanic Garden, France, and P. Titz, Chile, for their advice and enthusiasm on this topic, and J. Hawkins, University of Reading, for critically reading the manuscript. The Friends of Kew Threatened Plant Appeal contributed to the cost of the 1998 Toromiro Management Group meeting at the University of Reading. We thank K. Holsinger, D. Falk, and an anonymous referee for their valued comments on an initial draft. Tribute is given to Jill Gratton, Royal Botanic Gardens, Kew, who before her untimely death spent considerable time and effort working on the micropropagation of the Toromiro and other threatened species.

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