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Project "Conservation, Restoration, and Development of the Juan Fernández islands, Chile"

Proyecto conservación, restauración y desarrollo de las islas Juan Fernández, Chile

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ABSTRACT

From a scientific point of view, the Juan Fernández islands contain one of the most interesting floras of the planet. Although protected as a National Park and a World Biosphere Reserve, 400 years of human interference have left deep traces in the native plant communities. Repeated burning, overexploitation of species, and the introduction of animal and plant plagues have taken 75 % of the endemic vascular flora to the verge of extinction. In 1997, Chile's national forest service (Corporación Nacional Forestal, CONAF) started an ambitious project, whose objective is the recovery of this highly complex ecosystem with a socio-ecological focus. Juan Fernández makes an interesting case, as the local people (600 persons) practically live within the park, therefore impeding the exclusion of the people from any conservation program. Secondly, the relatively small size of the archipelago (100 km^2) permits the observation of the effects of whatever modification in the ecosystem on small scales in time and space. Thirdly, the native and introduced biota are interrelated in such a way that human-caused changes in one species population may provoke unexpected results amongst other, non-target species. The project mainly deals with the eradication or control of some animal and plant plagues, the active conservation and restoration of the flora and the inclusion of the local people in conservation planning. This article presents the park's general problems, the strategy proposed to resolve them as well as some preliminary results. This project shows the complexity of the conservation activities in practice, with diverse and complex interrelations and gaps in ecological knowledge. In this respect, the project may well serve as a model for similar programs in other places.

Key words: conservation of flora, Juan Fernández islands, Robinson Crusoe island, Alejandro Selkirk island, restoration of flora.

RESUMEN

Las islas Juan Fernández albergan una de las floras más interesantes del planeta desde el punto de vista científico. Aunque están protegidas como Parque Nacional y Reserva Mundial de la Biosfera, más de 400 años de intervención humana han dejado una profunda huella en sus comunidades de plantas nativas. Los repetidos incendios, sobreexplotación de especies y la introducción de plagas animales y vegetales, han colocado al 75 % de la flora vascular endémica bajo amenaza de extinción. En 1997, la Corporación Nacional Forestal de Chile (CONAF) dio inicio a un ambicioso proyecto, cuyo propósito es recuperar este ecosistema de alta complejidad a través de un enfoque socio-ecológico. Juan Fernández constituye un caso interesante, debido a que la población local (600 personas) prácticamente vive dentro del parque, por lo que no es posible excluir al humano de los programas de conservación. Segundo, el relativamente pequeño tamaño del archipiélago (100 km^2) permite la observación de los efectos de cualquier modificación en el ecosistema en pequeñas escalas en el tiempo y el espacio. Tercero, la biota nativa e introducida se relaciona de tal manera que la modificación de la abundancia de una especie por acción humana puede provocar resultados inesperados en otras especies no consideradas blanco. El proyecto comprende principalmente programas que buscan controlar o erradicar algunas de las plagas animales y vegetales, adopta medidas activas para conservar y restaurar la flora, así como también inserta al humano en los planes de conservación. En este trabajo se da a conocer la problemática general del parque, la estrategia que se ha seguido para resolver estos problemas, así como también se informan los primeros resultados. Este proyecto ilustra la complejidad para realizar labores de conservación en una situación práctica, con variadas y complejas interrelaciones, y con vacíos en el conocimiento ecológico. Por lo tanto, puede servir como modelo para realizar programas similares en otros lugares.

Palabras clave: conservación de la flora, islas Juan Fernández, isla Robinson Crusoe, isla Alejandro Selkirk, restauración de la flora.

INTRODUCTION

Oceanic islands possess ecosystems of great scientific value due to their prolonged evolution in isolation (Rodríguez 1993, Stuessy et al. 1998b). Pioneer species have established themselves free of intra- and interspecific competition, predation, grazing, and diseases (Crawford et al. 1987, Sanders et al. 1987, Jaksic 1998). Therefore, there exists no evolutionary pressure on the organisms to develop strategies against negative biotic interactions. In some cases species have even lost the traits that would have been useful to face their competitors or predators in a continental setting (Crawford et al. 1993, Sun et al. 1996). This evolutionary phenomenon that has led to very singular flora and fauna on remote islands constitutes their Achilles' heel with regard to the activities of one of the planet's most perturbing species: man. Thanks to his great capacity of dispersion and his thinking completely opposite to the natural order, man has contributed to the voluntary or accidental dissemination of many other species on oceanic islands, usually weeds and plagues (Stuessy et al. 1998a, Bergstrom & Chown 1999). The irrational use of natural resources (burning, clear cutting, and the selective cutting of species) which has traditionally characterized man, has led many taxa endemic to the oceanic islands to the verge of extinction (Spencer & Benton 1995, Yu & Tapling 1997, Stuessy et al. 1998a).

One of these island ecosystems renown for their important flora are the Juan Fernández islands. They comprise 131 endemic species (62.1 % of the vascular native flora), 12 endemic genera, and 1 endemic family (Marticorena et al. 1998). They constitute an ideal natural laboratory for the reconstruction of the phylogeny of their endemic taxa and the testing of the hypotheses concerning their modes of speciation (Stuessy et al. 1984, Pacheco et al. 1985, Stuessy et al. 1990). Moreover, given their human occupation for only 427 years, the islands permit the reconstruction of the vegetation's responses to climatic changes before the arrival of man and the influence of man and climate after their discovery (S. Haberle unpublished results). However, their important botanical uniqueness contrasts greatly with their conservation status, as 73 % of the endemic angiosperms are threatened with extinction (Stuessy et al. 1992). Thirty species, including various ferns, are in a critical state (P. Danton & J. Lesouef unpublished results). Four centuries of human influence have left deep traces in the native flora through the introduction of animal and plant pests, burning, and overexploitation (Sanders et al. 1982). With the intent to revert this situation, the Chile's national forest service, Corporación Nacional Forestal (CONAF), started in 1997 an ambitious project with the title "Conservation, Restoration and Development of the Juan Fernández islands". The governments of Chile and The Netherlands for a period of six years finance the project, whose objective is to maintain and recover the native flora, while contributing to the socio-economic development of the local people which is so intimately linked to the islands' natural resources.

This article presents the islands' general conservation problems (with emphasis on flora), the measures taken as recommended by numerous authors (Muñoz 1974, Matthei et al. 1993, Swenson et al. 1997, Stuessy et al. 1998b) as well as some preliminary results. Data that are more specific can be obtained from the project's technical reports available from the park administration.

Geographical and historical context

The Juan Fernández islands are located in the Pacific Ocean, some 670 km west of Valparaíso, Chile. The two principal islands are: Robinson Crusoe, with an area of 47.9 km^2 (78° 51' W, 33° 37' S) and Alejandro Selkirk, with an area of 49.5 km^2 at 187 km west from Robinson Crusoe (80° 45' W, 33° 45' S). There is a third, smaller island called Santa Clara, 2.2 km^2 large, at a distance of 1.2 km south-west from the first.

Although the islands were discovered in 1574, they only served as a refuge for occasional privateers and pirates in the XVII and XVIII century (Orellana et al. 1975, Brescia 1979). Spanish attempts to colonize have been recorded since 1591 (Castilla & Oliva 1987). Until the first part of the XIX century, Robinson Crusoe island served as a place of exile (Brescia 1979). Only since 1877, the island started to be inhabited permanently, laying the foundations of the present village of San Juan Bautista with 600 residents (Orellana et al. 1975). Santa Clara is uninhabited, while Alejandro Selkirk offers refuge to a temporary population of around 50 people in the period October-May (D. Arredondo personal communication).

With respect to the environmental problems, many human interventions have taken place: introduction of goats, pigs, dogs, sheep, various plant plagues, clear cutting, burning, erosion (Hoffmann & Marticorena 1987, Stuessy et al. 1998a). The sandalwood (*Santalum fernandezianum*), an endemic tree species, has

disappeared due to indiscriminate extraction (Skottsberg 1953). It made little difference or the same had happened to the Juan Fernández fur seal (*Arctocephalus philippii*), endemic to these and the Desventuradas islands, and whose population was estimated at only 459 individuals in 1969 (Aguayo & Maturana 1970, Torres 1987). In spite of early warnings by eminent scientists about these threats to the islands biota (e.g., Skottsberg 1911, 1922, Muñoz 1974), little or nothing had been done to effectively redress the situation up to the second half of the last century. Although the islands have been a Chilean national park since 1935 (Brescia 1979), the Administration did not arrive until the end of the sixties. Until then, practices incompatible with national park objectives continued (Skottsberg 1953, Muñoz 1974). In 1977, UNESCO declared the park a World Biosphere Reserve (Hoffmann & Marticorena 1987). As of 1976, CONAF, charged with the administration and protection of the state wildlife areas, started with the propagation of endemic plant species in order to halt the decline in population sizes (R. Schiller, personal communication). Between 1988 and 1991 these activities gained impetus through a World Wide Fund for Nature funded project entitled "Program for the Conservation and Recovery of Endangered Plants of Juan Fernández" (Ricci & Eaton 1994, Ricci 1996). What follows is a detailed analysis of the ongoing project.

THE PROJECT

Man has traditionally been left out of ecological studies, rendering uncertain his future impact on the ecosystems (Castilla 1999). Adding to this the gaps in ecological knowledge (Towns & Ballantine 1993), the weak links between basic and applied research and the reticence amongst some ecologists to mix anthropological with ecological issues (Castilla 1999), it is no wonder that it is so difficult to solve environmental problems that directly affect man. This becomes all the more complicated when different political, ecological, social, economical and cultural interests enter the arena. Recently, ecological concepts have started to include man (Steadman et al. 1984, Veblen & Lorenz 1988, Veblen & Markgraf 1988). The Juan Fernández National Park represents an example in optima forma of this integrated concept, because of its island character and the local population's dependence on natural resources. The principal economic activity on the islands is lobster (*Jasus frontalis*) fishing (Arana 1987). This focus on the marine resources at present fortunately turns people's attention away from the park and its flora. In the long term however, overexploitation of the lobster (Arana 1987) may cause the inhabitants to engage in agriculture and animal husbandry at the expense of the national park. In fact, the abundance of this crustacean has declined over the recent years (Arana 1987). A ban on its capture has therefore been declared for the period from May to October.

The local population's dependence on the resources of the islands has led to the inclusion of various programs in the project with a social emphasis besides the natural resources management programs. Nevertheless, all programs have the same goal in common: preservation of the native flora. Figure 1 shows the problem causing factors on the islands and their interrelations. It should remain clear, however, that the majority of these interactions have not yet been quantified in terms of their impact on the native flora. Up until now, positive and negative effects have been noted during field observations and in some cases they could be established through more detailed studies (see below). It remains to be determined whether these impacts affect the native ecosystem's sustainability, and if so, how long it will take before species will become extinct.

The following programs within the framework of the project have been formulated to face these problems. The programs have been grouped in the following way:

(i) Socio-economic component: development of island women, ecotourism, environmental education.

(ii) Management of natural resources component: exotic tree plantations management, native forests protection, rabbit control, goat control, control of plant plagues, restoration of degraded areas.

(iii) Research and conservation component: in situ and ex situ conservation.

The island women

Since fishing is primarily a man's job, women play a minor role in the Juan Fernández household economy. In order to develop the creative potential of the female population, and to increase their contribution to a family income otherwise depending on solely fishing, CONAF has started a series of courses for women on fish skin art, painting, tailoring, food preservation, home gardening, personal development and business administration. The response to these courses was very positive; 83 women, nearly half of the adult female island population, participated in

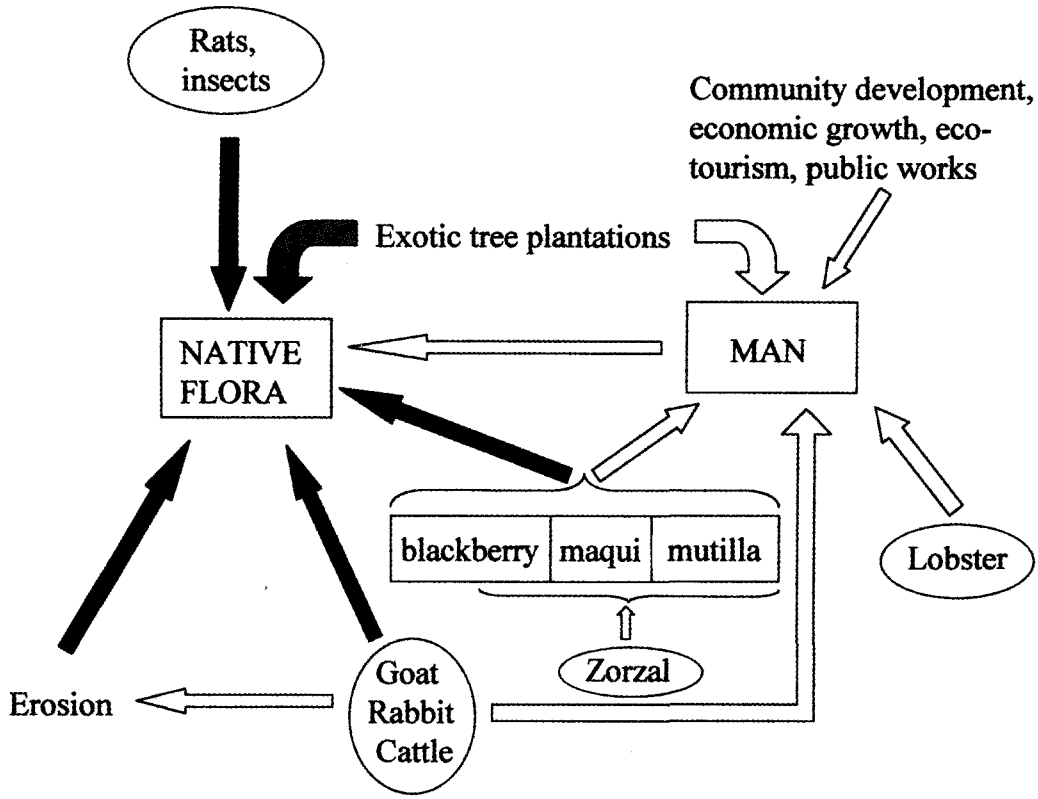

Fig. 1: Some ecological interactions that positively (white arrows) or negatively (dark arrows) affect the flora and man in the Juan Fernández Archipelago. The grey arrow is a potentially negative interaction. Detailed explication in the text. Scientific names: rats = *Rattus norvegicus*, *R. rattus*; rabbit = *Oryctolagus cuniculus*; goat = *Capra hircus*; blackberry = *Rubus ulmifolius*; maqui = *Aristotelia chilensis*; mutilla = *Ugni molinae*; lobster = *Jasus frontalis*; zorzal = *Turdus falcklandii magellanicus*.

Algunas interacciones ecológicas que afectan positiva (flechas blancas) o negativamente (flechas negras) a la flora y al hombre en el Archipiélago Juan Fernández. La flecha gris es una interacción potencialmente negativa. Explicación detallada en el texto. Nombres científicos: ratas = *Rattus norvegicus*, *R. rattus*; conejo = *Oryctolagus cuniculus*; cabra = *Capra hircus*; zarzamora = *Rubus ulmifolius*; maqui = *Aristotelia chilensis*; mutilla = *Ugni molinae*; langosta = *Jasus frontalis*; zorzal = *Turdus falcklandii magellanicus*.

one or more courses. Approximately three quarters of the women have used the newly acquired knowledge to begin a business, to improve their ongoing economic activities or to start a productive activity at household level. Fish skin art had the greatest commercial response, whereas food preservation had the biggest impact at household level.

The change in the attitude of island women with respect to CONAF is remarkable, since in the past the island people had a poor perception of the institution. The local people feel that they are rewarded for living virtually in a protected area where human activity is restricted.

Ecotourism

After fishing, the service sector (State organizations, commerce, hotels, and restaurants) is the largest employment source on the island (IREN-CORFO 1982). Fish processing or other industry is virtually non-existent. Considering the scarce economic opportunities and in order to create a commercial consciousness with respect to the existing natural resources among the local population, the project has started to develop guided ecotourism in the Park, which should generate income among the islanders and safeguard the existing flora. Island residents who like to become Park guides took courses in history of the islands, natural resources, English, communica-

tion, risk prevention, first aid and mountain climbing. In addition, the project constructed an Environmental Information and Education Centre for the residents and the 2,000-3,000 visitors the island receives yearly. Subsequently, owners of restaurants and guesthouses were trained in the basics of hospitality.

Due to the difficulty of harmonizing the courses' requirements with time constraints and the varied educational backgrounds of the students, total or partial desertion was 74 % in the first year (1998). In the second year (1999) this level decreased to 43 %. At present, some 20 guides have successfully followed the courses. Only 10 % of these are fishermen. Nevertheless, many fishers gain additional income by transporting tourists to several places in the park. The net gain of the program is limited as some of the newly graduated guides were already active in tourism and the majority of the course participants remain employed in other sectors. Most of these guides can at present only act as part-timers.

Subsidiary measures like improvement of access routes (island roads and airstrip) are supposed to promote tourism. Consequently, any initiative directed at social, economic or cultural development of the islands will contribute directly or indirectly to the conservation of the park flora.

Environmental education

The island population acknowledges the National Park and its objectives of flora and fauna protection. This is not just a trivial assertion, as 30 years of administration of the park have been marked by a problematic relation. This was the inevitable consequence of the prohibitions to use park resources and space, which the island population had traditionally considered theirs after a century of free occupation. This situation has improved ostensibly with time, although additional measures to strengthen the ecological conscience of the population are required. The Environmental education program addresses the adult residents with pamphlets and courses, but children are the prime target group. Children make up more than one third of the population and form an excellent group amongst which to create a consciousness about the uniqueness of the islands. These children will be the future guardians of the island nature long after the project has finished and will transmit their knowledge to new generations and tourists.

About 140 children attend nursery and elementary school, and are participating in the project's educational activities. A manual has been developed for grade one to six, focusing on the comprehension of the natural, social, and cultural environment of the islands. Manuals for the remaining grades are in preparation and in accordance with current educational programs in Chile. So far, the children's response has been remarkable. At the age of six, they are already capable of distinguishing between endemic and introduced species. This context-sensitive environmental education is a novelty in Chile (L. Bunney personal communication). The Charles Darwin Scientific Station on the Galápagos islands has already shown the virtues of such a program (Rodríguez 1993).

Exotic tree plantation management

With the arrival of a park administration, cutting of native tree species for heating and the construction of houses, boats, lobster traps, and fences became prohibited. In search of alternative timber sources and erosion control, CONAF initiated a massive tree-planting program with exotic species (*Pinus* spp., *Eucalyptus globulus*, and *Cupressus* spp.) around the village. Although it would have been preferable to plant native species (unfortunately with slower growth rates than the exotic species), the present plantations greatly decrease the pressure on the Park resources. Furthermore, the large volumes of nectar produced by amongst others *Eucalyptus* and *Albizia* form an important dietary supplement for the endemic hummingbird, the Juan Fernández firecrown (*Sephanoides fernandensis*) (Colwell 1989).

The introduced tree species have growth rates higher than those do in the area of origin (personal observation). Local people can dispose freely of the timber. A permit from CONAF is necessary to regulate the cutting and protect watersheds and hillsides from erosion. Management of these plantations now becomes an obligation as their vigorous natural regeneration may start to compete with the native forests at higher altitudes, as seems to occur on other oceanic islands as well, like for instance Madeira (P. Danton personal communication). Moreover, Swenson et al. (1997) claim that *Eucalyptus globulus* is an aggressive species suppressing neighbouring plants through allelopathy. To provide the necessary management of these plantations some impetus, the project has carried out an inventory and produced a thinning plan, seeking the participation of the local people. Furthermore, exotic tree species are at present propagated in the park administration's nursery for planting programs.

At least a 5 % increase of the plantation area is foreseen during the project period.

Control of livestock (protection of native forests)

Animal husbandry is one of the principal problems affecting wildlife areas in the vicinity of human settlements, worse even when the areas are of a great biological importance, like for instance in the Galápagos (Rodríguez 1993) or in New Zealand (Porteous 1993). In the case of Juan Fernández, animal husbandry is forbidden in the park and yet it Robinson Crusoe island has a livestock population within the park boundaries, which largely exceeds its carrying capacity (IREN-CORFO 1982). This has led to the pasture's gradual impoverishment, hillside erosion (IREN-CORFO 1982), and poor quality livestock. The owners have repeatedly refused to reduce their stock, although exorbitant prices have been offered for the sale of their cattle. The strategy of forced eradication in the past has had little success, but not because of the necessity to maintain a stock of animal proteins. Local meat contributes insignificantly to the residents' diet as good quality meat periodically arrives from the continent. The real reason for keeping cattle is that they constitute an easy ever-increasing savings account and have become an important recreational activity.

The project proposed a reduction and management of the animal population and the modernisation of the present slaughterhouse. This proposal was turned down and a new, in fact old strategy of fencing had to be turned to. Presently, 60 % of the valleys and hillside bottoms are fenced (8,286 m in total) to prevent livestock from entering the native forests and destroy tree seedlings in the forest/grazing area ecotone.

Rabbit control

The European rabbit (*Oryctolagus cuniculus*) is a well known predator of native flora all over the world and its impact has been studied on islands such as New Zealand, San Juan, Middleton, Citadel and many others (Couch 1929, O'Farrel 1965, Towns & Ballantine 1993, Pridell et al. 2000). Rabbits eat seedlings and young individuals of native species (Acevedo 1990), fatally damage the bark of small trees and erode the hillsides with their extensive warrens (Pridell et al. 2000), that are subsequently trampled by cattle. The rabbit was introduced on Juan Fernández in 1935 (Zunino 1989). Its introduction has turned into a plague with around 20 rabbits per hectare. Extrapolation to all pasture and denuded lands leads to a total population of 50,000 individuals for Robinson Crusoe island alone. On Santa Clara, the density has even been estimated at 89 rabbits per hectare and 19,000 individuals in total. This exacerbates the carrying capacity already exceeded by goats and cattle (Sáiz & Ojeda 1988). Their predation on the native forest is most apparent in the forest-prairie ecotones, where they especially affect the restoration plantations carried out in the area (see below).

The project began a systematic rabbit control on the two islands with three professional hunters in September 1998. Some 41 local inhabitants also take part in the program at the cost of ammunition and a bonus of US$ 0.60 per tail. Up to August 2001, more than 34,000 rabbits have been captured. The density on Robinson Crusoe has dropped from 23 to 17 rabbits per hectare, although this could not be proven statistically (one-way ANOVA, $F_{3,20} = 0.56$, $P = 0.64$) (Fig. 2). On Santa Clara, where the whole island is covered by the program, the density decreased sharply to 26 rabbits per ha.

Sáiz & Ojeda (1988) established a negative correlation between rabbit density and hunting pressure. They also found that combined hunting and trapping led to a decrease in weight and size of the rabbits as well as a recuperation of the herbaceous vegetation. However, the use of shotguns and snares is relatively inefficient and costly if the objective is eradication of the rabbit. Alternatives that are more powerful have been tried on smaller islands in Australia and New Zealand, applying the myxomavirus and calicivirus with some success (ANZRCDP 1996, Pridell et al. 2000). The first has also been tried in Chile and with good results (Tierra del Fuego in 1954) (Jaksic 1998). The application of myxomavirus is now controlled by the Government and a possible introduction on the Juan Fernández islands may therefore be difficult, as Chile has been declared virus-free.

Goat control

Just like the rabbit, the goat (*Capra hircus*) is considered one of the herbivores most destructive to the natural ecosystems (Towns et al. 1997, Jaksic 1998). It is believed that goats were introduced to the Archipelago upon its discovery (Hoffmann & Marticorena 1987). They constitute the biotic factor that has perturbed the native flora longest, not knowing to what extent they have affected the original composition, structure,

and dynamics of the plant communities on the islands. On Robinson Crusoe island, live between 200 to 500 goats, which are hunted occasionally by the islanders. On Alejandro Selkirk, however, a very conservative estimate revealed a population oscillating between 2,000 and 2,500 individuals (May 1998). These numbers mean a serious threat to the native flora (Miller & Rottmann 1976, Jaksic 1998). The grazing on several endemic species (*Myrceugenia schulzei*, *Gunnera masafuerae* and *Dendroseris litoralis* among others) has been observed. Grazing is especially fatal amongst some very rare species that grow in places only accessible to goats.

The project has hired three hunters who remain on Alejandro Selkirk from October to May. In addition, the island residents collaborate actively, to supplement their diet. As from September 1998, 3,100 goats have been hunted. Up until August 2001 there were 1,900 goats left. The effects of hunting remain unclear, as the previous count (May 1998) does not seem to be very reliable.

Plant pest control

The problem of competition between introduced plant plagues and native vegetation is a common problem amongst the ocean islands where man has intervened (Rodríguez 1993, Meyer 1996, Bergstrom & Chown 1999). In each case, however, the identity of the plants that cause the problem changes. On Juan Fernández there are nearly 212 introduced species, which represent about 50 % of the vascular plant species, not including the garden plants (Marticorena et al. 1998). Many of these species are reported elsewhere to have converted them into severe plagues (Stuessy et al. 1998a). Now, the invading plant species most harmful to the native flora are blackberry (*Rubus ulmifolius*), "maqui" (*Aristotelia chilensis*), "mutilla" (*Ugni molinae*) and "retamilla" (*Teline monspessulana*). The first three species have a vigorous vegetative growth, superior to their continental origin (Stuessy 1992). They form vast areas of dense bushes, suppressing regeneration of native species (Johow 1896, Sanders et al. 1982, Stuessy et al. 1998b). With respect to *R. ulmifolius*, Colwell (1989) postulated that the consumption of its nectar largely favoured the 4,000-8,000 native green-backed firecrown (*Sephanoides sephaniodes* = *S. galeritus*), at the expense of the 200-400 endemic Juan Fernández firecrown. He consequently proposes the eradication of the blackberry to revert in part the decline of the Juan Fernández firecrown.

The fleshy fruits of the three species are eaten and dispersed by the austral thrush ("zorzal", *Turdus falcklandii magellanicus*) to infestation-free zones, which was confirmed by stomach analyses (Skottsberg 1953). If it would not be for the biotic dispersion, it would be unlikely for these plagues to invade the most inaccessible sites, which incidentally already proliferate with one or more of these three species. Currently the project focuses on the control of blackberry on Robinson Crusoe and on Alejandro Selkirk through a combination of mechanical (cutting the stem) and chemical methods (pencilling of 3-5 % triclopyr in diesel on the stem). Chemical treatment is necessary due to the species' tendency to resprout from cut stems and roots. An alternative could be the application of the fungus *Phragmidium violaceum* (Oehrens & Garrido 1985), which has been noticed to attack the species in various places on the Robinson Crusoe island. The loss of foliar mass resulting from this pathogen would reduce the plant's vitality, but it is not clear to what extent this biological control would solve such a serious problem on its own. Probably a control strategy integrating manual, chemical and biological methods, would be the solution to the problem as indicates Smith (1990) for the national parks on Hawaii. The project primarily focuses on the eradication of hotbeds and has so far treated an area totalling approxi-

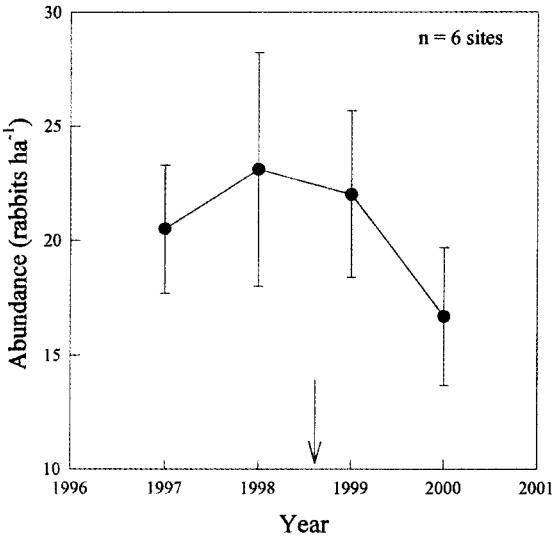

Fig. 2: Rabbit abundance (mean ± standard error) on Robinson Crusoe island before and after the start of the hunting program (September 1998, arrow).

Abundancia de la población de conejos (media ± error estándar) en la isla Robinson Crusoe antes y después del inicio del programa de control (septiembre 1998, flecha).

mately 5.5 ha of "retamilla" and 34 ha of blackberry, representing a clearing of 30 % of the 800-850 ha infested by *Rubus*. Recently this program has gained a major impetus with the recruitment of 40 persons through a grant by the Chilean government.

In addition, the local population also contributes to the control of "maqui" by using its straight stems for lobster traps and artwork. Moreover, the islanders consume the fruits of *Rubus*, *Aristotelia* and *Ugni*. Recently, the local population has been informed of the most important garden plants that might turn into a plague. This is for instance the case for *Lantana camara*, *Lonicera japonica* and *Ipomoea indica*, among others. The first has been classified as one of the most harmful weeds in the world, causing severe damage to the native flora (for instance, in Galápagos, Australia and South Africa; Cruz et al. 1986, Lawesson & Ortiz 1990). The other two species are climbers that invade native forests and suppress their regeneration in places like New Zealand (Porteous 1993). The collaboration of the local people will permit the eradication of these species at an early stage. This is another example of how people's daily routine can contribute to the solution of a problem.

Many of the problems that might arise in the future could be avoided by installing a sanitary control at the airstrip and in the harbour, which would prevent the introduction of more animal and plant plagues from the continent.

Restoring degraded areas

About 40 % of the Robinson Crusoe island area is affected by severe or extremely severe erosion (IREN-CORFO 1982), which threatens the native forest remnants located at the hilltops. Human activity (slash and burn, livestock) combined with natural erosion factors such as abundant precipitation, strong winds, steep slopes, and soils with low water retention capacity (IREN-CORFO 1982) have caused this situation. In order to investigate the best methods for erosion control, mechanical and biological treatments have been implemented. The first method consists of the construction of dikes, trenches, and terraces for the infiltration of water and retention of sediments. The biological treatment implies the planting of ground cover species in these same areas. Usually native herbaceous and shrub species are used, but non-aggressive introduced species already present in the area have also been planted. This program also covers the areas where the plant pest control has left the soil barren. The program covers close to 10 % of the area where these measures might have significant effect.

In situ conservation of endangered species

This is the program in which all aforementioned activities converge and is therefore considered the project's paramount program. Its general objective is to assure the perpetuation of all endemic vascular plant populations in their original associations. A complex of factors threatens the natural regeneration of the native plants (Fig. 1). Herbivory by rabbits (Acevedo 1990), by goats and by cattle as well as seed predation by rats (J. Cuevas unpublished results) are amongst the most important. The strategy that turned out to be the most effective is to help the regeneration overcome the aforementioned factors with the following sequence of operations: seed collection in the field, germination in laboratory or greenhouse, initial growth in greenhouse, hardening-off in nursery, and planting out with protection against predators and abiotic stress. The planting spots correspond with the same sites where seed have first been collected. These methods are in line with recommendations made by various authors (Akeroyd 1995), and with experiences in various countries like Spain (Muñoz & Hernández 1995) and New Zealand (Porteous 1993).

Sixty endemic species have been raised in the nursery, of which 13 are in a critical state of conservation. *Wahlenbergia larrainii* is for instance one of these species. It is extinct in natural habitats (Ricci & Eaton 1994) and has so far not been propagated in important quantities (525 plants). At present, the species has been reintroduced in its natural environment. The project has collected seeds and raised seedlings from various other species of which remain only a handful of individuals in their natural environment (*Dendroseris litoralis* and *D. neriifolia*). Moreover, in the Park Administration's arboretum a few specimens are kept of very rare species such as *Plantago fernandezia*, *Chenopodium sanctae-clarae* and *Yunquea tenzii*. So far 1,800 plants have been planted out. Another important achievement is the gradual replacement of exotic plants in private gardens and public areas in the village by endemic species.

Ex situ conservation of endemic species

Ex situ conservation is a complementary strategy to the efforts within the in situ conservation program. The program keeps the endemic flora of the

islands in the National Botanical Garden in Viña del Mar, continental Chile. Here, germplasm is propagated in greenhouses and nurseries, safe from the pests, animal grazing, landslides, risk of forest fire on the islands and permitting the reintroduction in case of local extinction. The botanical garden today contains 53 endemic species from the islands, of which seven are in immediate danger of extinction. In addition, experiments concerning the genetic variability are presently carried out on three species of the *Wahlenbergia* genus (*W. larrainii*, *W. berteroi*, and *W. grahamiae*) to assess their Minimum Viable Population Size (Soulé 1987). This information is important for possible future reintroduction of species or population restocking (sensu Akeroyd 1995).

Finally, this program is charged with the task to communicate the importance of the Juan Fernández flora to a continental audience, among which, unfortunately, very little knowledge exists about the Chilean oceanic islands.

Interactions between the various factors and between programs

As has been shown, the project adopts a holistic approach in the restoration and conservation of a highly complex ecosystem. However, as the project develops, the great interdependency among the various damaging factors starts to create severe conflicts between the various programs. For instance, in the social sphere, the project might certainly meet with growing resistance among the local population if the eradication of goats, rabbits and the three fruit-bearing pests achieves its final goal and people's sources of free food become endangered. Further economic development may stimulate the importation of goods from the continent and replace local gathering and hunting.

However complete the project seemed at the beginning, the necessity to attack other, unforeseen but potentially more devastating problems has become increasingly apparent. Some examples are seed predation by introduced rats (Roy et al. 1999, J. Cuevas unpublished results); seed dispersal of invasive species by birds; attacks on native species by introduced mildew; plant-eating insects (Homoptera and Coleoptera); coatimundi (*Nasua nasua*) feeding on the eggs of the native petrels (*Puffinus creatopus*) (Miller & Rottmann 1976); and lastly cats preying on the Juan Fernández firecrown (Roy et al. 1999), but which also control the number of rats. Some of these problems are already considered to be addressed in the second half of the project period. Nevertheless, it is important to mention that these are only some of the environmental problems that affect Juan Fernández, and that there exists considerable uncertainty about the ecology of the species. Additional scientific research (e.g., monitoring plans, quantification of the interactions and population densities) is required to determine the real impact of these factors on the insular ecosystem. Any control strategy should be conservative and selective in order not to harm nontarget species. These control strategies should therefore be considered ecological experiments with unexpected outcomes (Taylor 1968, Pridell et al. 2000).

So far positive results of eradication programs have been reported from islands considerably smaller than Juan Fernández and in many cases without human settlement (Towns & Ballantine 1993, Pridell et al. 2000). Eradication on Juan Fernández therefore puts enormous constraints on financial means and technologies available.

In summary, through the ongoing project it has become clear that far greater and more integrated efforts are needed to tackle the problem of eradication of plagues and conservation of endemic species on the islands. Several new potential problems have been identified in the course of this project. The size of the islands and the human presence represent a new challenge in the history of eradication of insular plagues. This paper clearly shows that the island inhabitants may alternately assist with the eradication and impose obstacles. Clearly, man remains the determining factor in the destiny of the Park and therefore any appeal at the local population's consciousness is of vital importance. Most work actually carried out would be of no use if not continued after the end of the current project, as it will not be feasible to fully eradicate or control the present plagues within the project period. Without continued pressure over these plagues, they will recuperate their habitual levels in short time. Much work still needs to be done to secure the ecological as well as the economic and social sustainability of the islands. Therefore, as the conservation, restoration and development of Juan Fernández will have to be a long-term activity outlasting the present project, the park administration's upgraded infrastructure of offices, workshops, laboratory and high technology terrain equipment welcomes any scientific and applied work initiative from Chilean as well as foreign institutions.

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