The Vegetation of Robinson Crusoe Island (Isla Masatierra), Juan Fernández Archipelago, Chile[1]

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Abstract: Robinson Crusoe Island of the Juan Fernández Archipelago, as is the case with many oceanic islands, has experienced strong human disturbances through exploitation of resources and introduction of alien biota. To understand these impacts and for purposes of diversity and resource management, an accurate assessment of the composition and structure of plant communities was made. We analyzed the vegetation with 106 relevés (vegetation records) and subsequent Twinspan ordination and produced a detailed colored map at 1:30,000. The resultant map units are (1) endemic upper montane forest, (2) endemic lower montane forest, (3) *Ugni molinae* shrubland, (4) *Rubus ulmifolius–Aristotelia chilensis* shrubland, (5) fern assemblages, (6) *Libertia chilensis* assemblage, (7) *Acaena argentea* assemblage, (8) native grassland, (9) weed assemblages, (10) tall ruderals, and (11) cultivated *Eucalyptus*, *Cupressus*, and *Pinus*. Mosaic patterns consisting of several communities are recognized as mixed units: (12) combined upper and lower montane endemic forest with aliens, (13) scattered native vegetation among rocks at higher elevations, (14) scattered grassland and weeds among rocks at lower elevations, and (15) grassland with *Acaena argentea*. Two categories are included that are not vegetation units: (16) rocks and eroded areas, and (17) settlement and airfield. Endemic forests at lower elevations and in drier zones of the island are under strong pressure from three woody species, *Aristotelia chilensis*, *Rubus ulmifolius*, and *Ugni molinae*. The latter invades native forests by ascending dry slopes and ridges. It successfully outcompetes endemic taxa, including its congener *Ugni selkirkii*. The aggressive herb *Acaena argentea* severely threatens to overtake native grassland.

Oceanic islands are fragile ecosystems that are easily modified through natural and human disturbance (e.g., Carlquist 1965, 1974, 1980, Nunn 1994, Kirch and Hunt 1997, Whittaker 1998). The eventual fate of such archipelagoes is disappearance under the surface of the sea after millions of years of erosion through wind and rain and the relentless pounding of the sea. Combined with these natural impacts on oceanic islands are the more recent, and often severe, human impacts. Easter Island provides an excellent, though tragic, case study of the negative effects of human intervention in an island ecosystem (Heyerdahl 1989, Zizka 1991). Both natural and human impacts not only modify the surface of an island itself, but they also bring about changes in the environment. These changes are mirrored in the plants and animals that inhabit the archipelagoes and

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reflected by the vegetation at any point in time. Water, soil characteristics, and erosion patterns are all important abiotic factors that interact with the plants to yield the resultant vegetation.

The Problem

Study of patterns and processes of evolution in island ecosystems requires a good understanding of the underlying vegetation. It is difficult to understand modes of speciation without viewing this process in the context of environmental parameters. Reproductive isolation, an important aspect of speciation, often has an ecological component. Further, adaptive radiation, so prevalent in oceanic islands, is driven in large measure by adaptations to the rapidly changing island environment (Schluter 2000).

A number of studies of the vegetation of Pacific oceanic islands have already been completed. The most recent summary is provided by Mueller-Dombois and Fosberg (1998). Through detailed descriptions of the vegetation, plus photographs of many of the dominant associations and endemic representatives of these fragile floras, a good understanding of the basic aspects of the vegetation can be obtained. This represents a good beginning for more detailed studies on these Pacific island archipelagoes, especially more precise vegetation mapping. Detailed vegetation maps of islands provide patterns of diversity that serve to stimulate evolutionary and biogeographic questions. They also allow more realistic assessment of conservation impacts and possible remedies.

Of the many oceanic island systems of the Pacific Ocean, the Robinson Crusoe (Juan Fernández) Archipelago (Figure 1) is important for evolutionary and biogeographic reasons. This flora of 441 total species contains 125 endemic vascular plants, including the endemic family Lactoridaceae, which is of significance in the context of early angiosperm evolution (Stuessy et al. 1998*c*). Investigations in the archipelago over the past 20 yr have resulted in numerous papers, especially of the endemic taxa, that examine aspects of speciation, genetic differentiation, patterns of phylogeny, theoretical island biogeography, chromosomal evolution, and adaptive radiation. Still lacking, however, are good analyses of the vegetation against which data from such evolutionary and biogeographic studies can be correlated.

The Study Area

The Robinson Crusoe Islands are situated 667 km west of continental Chile in the Pacific Ocean, 33° 40′ S and 79° 00′ W; they were discovered in 1574 by the Spanish sailor Juan Fernández. The archipelago comprises two large islands, Robinson Crusoe (Masatierra) and Alejandro Selkirk (Masafuera), plus a smaller island, Santa Clara, near Robinson Crusoe. The archipelago is of volcanic origin and has never been connected to the continent (Baker 1967). Radiometric data have revealed the age of Robinson Crusoe as approximately 4 million yr and that of Alejandro Selkirk as 1–2 million yr (Stuessy et al. 1984). Politically the archipelago belongs to Chile, administratively attached to the fifth region (Valparaiso), and it is also a national park.

The climate of the archipelago has been described in different ways by various authors. Fuenzalida (1965) treated it as warm-temperate, with equivalent dry and moist seasons; Hajek and Espinoza (1987) described it as a Mediterranean climate with oceanic influence; and Novoa and Villaseca (1989) deemed it as warm-marine with mild winters. The annual mean temperature is 15.18°C and total precipitation is 922.10 mm (Novoa and Villaseca 1989), but these data were taken from the station on Robinson Crusoe at a low altitude of 5 m and do not describe conditions in the native forest at higher altitudes. The data in Skottsberg (1953*a*) from 345 m giving 12.9°C and 1081.2 mm may come closer to conditions in the native forest, but the highest parts of the island above 600 m are often hidden in the clouds, surely receiving much more precipitation and having longer periods of humidity. Kunkel (1957), in describing the quebradas (ravines) leading from the summit to the south of the island, reported high hu-

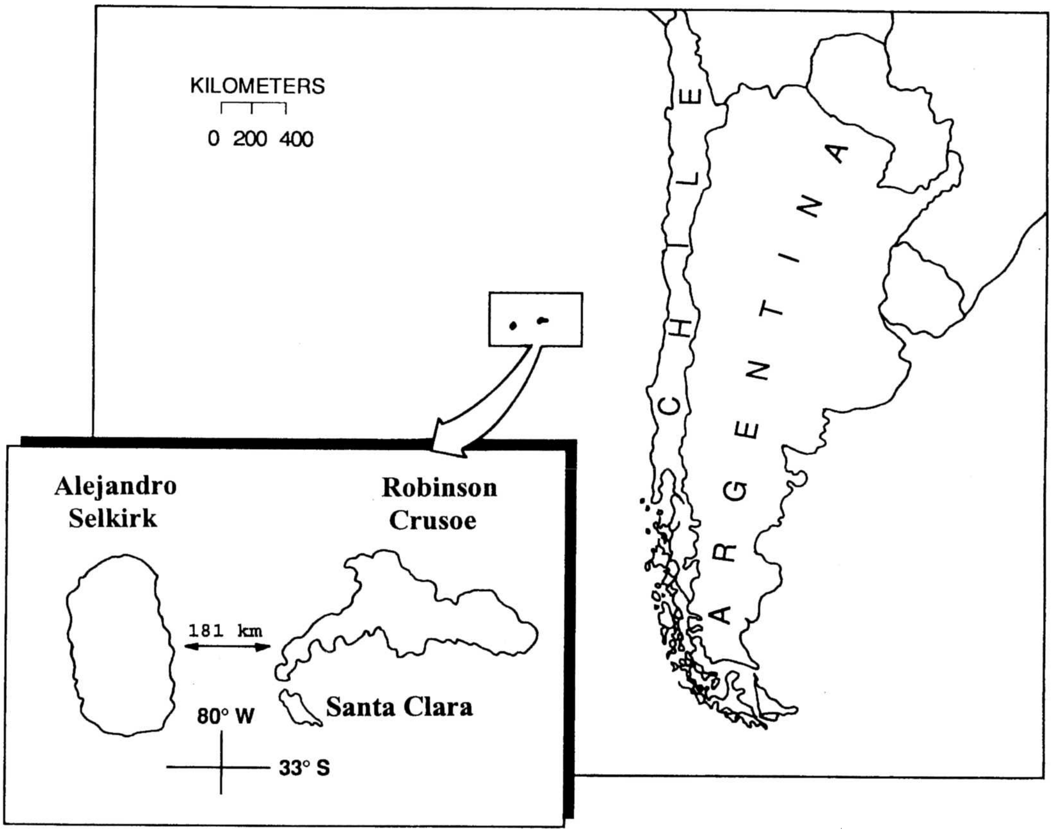

FIGURE 1. Map showing the location of Robinson Crusoe Island (Juan Fernández Archipelago, Chile).

midity in the air, swampy soils, and water dripping constantly from leaves and twigs.

As a Chilean national park (established in 1935) and biosphere reserve (designated in 1977), preservation of the native and endemic species of the Robinson Crusoe Islands is a priority, and this also involves habitat conservation (Corporación Nacional Forestal 1976). Recent positive activities of the park service (Corporación Nacional Forestal [CONAF]) in collaboration with the Dutch government have resulted in construction of numerous fences to contain domestic animals plus barriers for stemming soil erosion, among numerous valuable projects. Fundamental for these activities and for a better conservation management program is an accurate map of the extant vegetation. Because Robinson Crusoe Island receives the majority of tourists to the archipelago, there is an even greater need for a new map of the vegetation that clearly highlights the areas of rich taxonomic diversity in contrast to the degraded areas.

Although a national park, Robinson Crusoe Island houses (and has housed since the early 1700s [Woodward 1969]) a permanent population of approximately 500 people in the village of San Juan Bautista. The inhabitants live mainly on fishery, some tourism, and the management and administration of the national park. Through the past centuries, human impact through cutting of trees for home and ship construction, and accidental fires have greatly reduced the extent of the endemic forest. Further, direct cutting of the endemic palm *Juania australis* (the "cabbage tree") for food substantially reduced its populations, and commercial exploitation of the endemic sandalwood (*Santalum fernandezianum*) for Asian markets led to the extinction of that species early in the twentieth century (Skottsberg 1953*a*, Woodward 1969). Introduced feral and domestic animals as well as introduced fruit and ornamental plants plus numerous weeds have also been and still are a menace to the island's native and endemic flora (Sanders et al. 1982, Wester 1991, Swenson et al. 1997). Proper education of the townspeople, therefore, especially schoolchildren, is obviously fundamental for proper species and habitat preservation in the future. A vegetation map, with accompanying descriptions and explanations, would be most valuable in this regard.

Literature Review

There have been several previous investigations of the vegetation of the Robinson Crusoe Archipelago. The early floristic analyses of Johow (1896) contained good summaries of the general vegetation, but without a map. Based on field studies in 1916–1917, Skottsberg (1953*a*) directly addressed specific vegetation types using Hult-Sernander methods (Braun-Blanquet 1964). This valuable work yielded many informative detailed descriptions of the vegetation, but the only graphic summary was a simple sketch map. Although helpful, it was based on inaccurate base maps of the Islands and had no support from comprehensive aerial photos. Kunkel (1957) gave a detailed report of the vegetation on and around the summit of the highest mountain on the island, El Yunque (916 m). Schwaar (1979) carried out a detailed transect analysis of vegetation on Robinson Crusoe Island, but no comprehensive assessment of the vegetation of the entire island was attempted. Recently, Hahn (1998) provided a few very detailed relevés (vegetation records), which gave good insight into the vegetation structure, but coverage of the island was limited.

A revised map based on Skottsberg's (1953*a*) map and new observations from 1976 and 1979 was provided by Nishida and Nishida (1981). Resolution, however, in that map, displaying only six units, is poor. The most complete previous mapping effort of the vegetation of the entire archipelago was done by Ortiz-Riveros and coworkers (1982). Working from aerial photographs taken in 1980 by the Chilean Air Force, detailed maps of the vegetation of all the Islands were published. Although extremely helpful, the methods of analysis yielded more than 120 different categories of vegetation, many based upon dominance of single species, providing an overly complex evaluation of the vegetational diversity. The practical result of these analyses is that the maps are not useful as a guide for correlation with evolutionary and biogeographic concepts, nor are they suitable as a practical aid for conservation of the native and endemic flora.

Specific Objectives

In this paper, therefore, we aim to (1) use quantitative relevé data, with aerial photographs and computer algorithms, to provide a new classification of vegetation of Robinson Crusoe Island at a scale useful for resource management; (2) analyze composition and dynamics in the designated plant communities; (3) summarize these data in a large-scale colored map; and (4) comment on hazards to vegetation types that still contain concentrations of native and endemic species.

MATERIALS AND METHODS

Field sampling of 106 relevés (Figure 2, details in Appendix 1) was carried out 1–17 February 1999 and 3–18 February 2000 (Table 1). Relevés were taken in places where a substantial change in floristic assemblages was observed during field excursions in different parts of the island. Each relevé contains a record of all vascular plant species seen. Site data include elevation, aspect, slope, area (between 100 and 400 m^2 for forest and shrub communities and between 100 and 300 m^2 for grassland), estimated coverage of trees, shrubs, herbs, and mosses, and observations on soil conditions and disturbance. The numbers and symbols in Appendix 2 represent counts (abundance) and estimates of dominance (coverage) according to the cover-abundance scale of Braun-Blanquet (1964). We modified

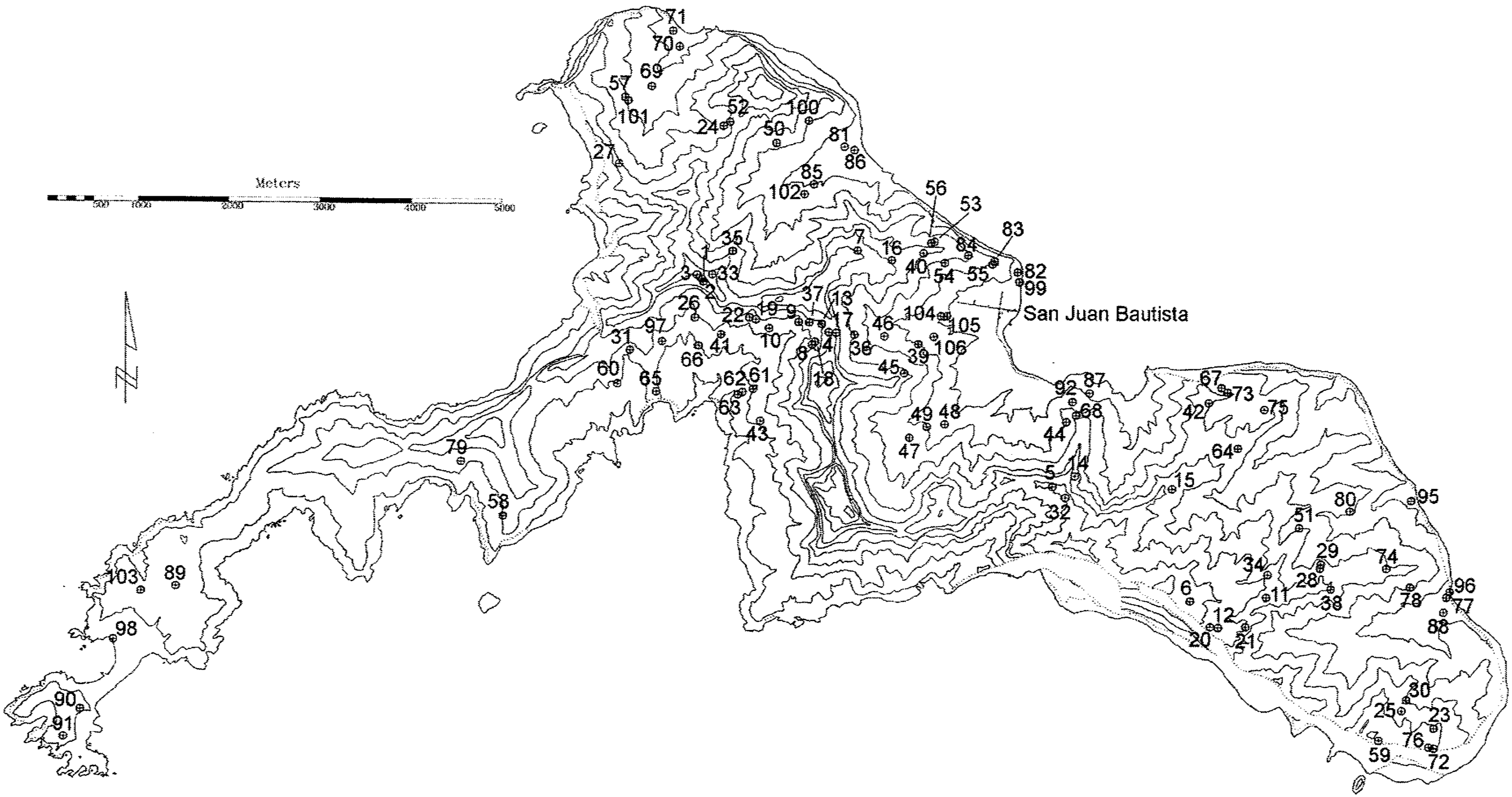

FIGURE 2. Locations of relevés on Robinson Crusoe Island.

TABLE 1

GPS Longitudes and Latitudes for Relevés of the Second Excursion (3–18 February 2000)

Relevé No.	West	South
6	78° 48′ 19″	33° 39′ 40″
8	78° 51′ 03″	33° 38′ 08″
11	78° 47′ 57″	33° 39′ 32″
12	78° 48′ 07″	33° 39′ 49″
18	78° 51′ 03″	33° 38′ 08″
21	78° 47′ 58″	33° 39′ 49″
28	78° 47′ 25″	33° 39′ 27″
29	78° 47′ 25″	33° 39′ 23″
31	78° 52′ 23″	33° 38′ 13″
34	78° 47′ 46″	33° 39′ 26″
38	78° 47′ 22″	33° 39′ 29″
43	78° 51′ 28″	33° 38′ 34″
51	78° 47′ 28″	33° 39′ 09″
61	78° 51′ 30″	33° 38′ 26″
62	78° 51′ 31″	33° 38′ 26″
63	78° 51′ 30″	33° 38′ 26″
64	78° 48′ 07″	33° 38′ 44″
65	78° 52′ 12″	33° 38′ 30″
70	78° 52′ 00″	33° 36′ 24″
71	78° 52′ 05″	33° 36′ 20″
74	78° 46′ 57″	33° 39′ 23″
75	78° 37′ 51″	33° 38′ 35″
77	78° 46′ 32″	33° 39′ 34″
78	78° 46′ 46″	33° 39′ 29″
80	78° 47′ 14″	33° 39′ 02″
88	78° 46′ 31″	33° 39′ 37″
90	78° 56′ 16″	33° 40′ 26″
91	78° 56′ 20″	33° 40′ 36″
93	78° 56′ 33″	33° 42′ 14″
94	78° 56′ 33″	33° 42′ 29″
95	78° 46′ 48″	33° 38′ 58″
96	78° 46′ 28″	33° 39′ 33″
97	78° 52′ 08″	33° 38′ 09″
98	78° 55′ 59″	33° 40′ 01″
104	78° 50′ 09″	33° 37′ 57″
105	78° 50′ 05″	33° 37′ 56″
106	78° 50′ 16″	33° 38′ 04″

this scale slightly using six classes: +, 0–10 individuals; 1, 11 individuals to 5% coverage; 2, 6–25% coverage; 3, 26–50% coverage; 4, 51–75% coverage; 5, 76–100% coverage. Coverage was estimated for trees and tall shrubs even if they were fewer than 11 in number. Taxonomy and nomenclature follow Marticorena et al. (1998), and the status of each taxon (endemic, native, adventive/naturalized) is given.

The relevés were processed and classified using the Twinspan algorithm (Hill 1979). The resulting table (Appendix 2) was slightly rearranged by stronger weighting of the dominant species and grouping of relevés accordingly. Because it proved impracticable to sort out relevés representing mixed units (12–17) (with high presence of invasive species or low vegetation cover in eroded areas), we kept them within the units to which they show the highest affinities. The species are ordered in three groups: (1) dominant and differentiating; (2) common; and (3) those occurring rarely in relevés (but some of them locally common).

Field mapping was also carried out during the periods mentioned using aerial black and white photographs (from flyovers in 1980 by the Chilean Air Force), as well as photographs and hand drawings made during the excursions. Due to lack of orthophotographs, delineation of the field maps was transferred to a geocoded digital elevation model (DEM). The DEM was derived using 50-m contours of a topographic map of the island (copy of the municipal map) and breaklines for abrupt relief discontinuities (e.g., coastal rock faces). For spatial data handling and management as well as map drawings we used the geographical information system ARC-Info.

RESULTS AND DISCUSSION

Classification of Vegetation, Description of Plant Communities, and Comments on Species Composition

Based on analysis of 106 vegetation relevés, the vegetation units, the communities they compose, and the species found in them with their code of abundance and/or dominance are given in Appendix 2 (on back of the map insert). The vegetation units themselves are plotted graphically on a map of the island (Figure 3, folded and inserted in this issue). In Appendix 2, changing floristic composition (i.e., vegetation change) roughly follows an elevational gradient from top left in the table to bottom right, representing upper and lower sites, respectively. More than one environmental gradient obviously is responsible for species and community distribution, however, and associated with a drop in elevation is a notable decrease in moisture. A general increase of soil erosion and disturbance, due to introduced plants and animals and direct human impact, also correlates with decreasing elevation.

In general, our results are largely compatible with previously published analyses, with some exceptions. Nearly all work points to the very dominant role of *Myrceugenia fernandeziana*, as stated in Johow (1896), Skottsberg (1953*a*), Ortiz-Riveros (1982), and Hahn (1998). The only exception is Schwaar (1979), who did not report this taxon in 32 relevés of the lower montane forest, giving instead *Fagara mayu* and *Coprosma pyrifolia* as dominants. We, and also Skottsberg (1953*a*), regard *Fagara mayu* as certainly a common, but not a dominant, element. *Coprosma pyrifolia*, found with low abundance in 2 of 10 relevés in lower elevations by Skottsberg, was not found there by us, which might be a sampling effect or a consequence of enhanced disturbance by introduced plants and animals (or direct cutting) since 1916–1917 (see Sanders et al. 1982, Stuessy et al. 1998*a,b*). We found this taxon to be rather abundant in the upper montane forest (see also Skottsberg 1953*a*, Kunkel 1957).

We restrict comparisons of the vegetation of Robinson Crusoe Island with that of other Pacific archipelagoes to only selected aspects (the reader may wish to consult Mueller-Dombois and Fosberg [1998] for an overview of Pacific vegetation), in part because the composition is often quite different. In eastern Polynesian archipelagoes, lowland and montane forest below 500 m is largely replaced by secondary vegetation and plantations (Mueller-Dombois and Fosberg 1998). Montane rain forest and cloud forest can also be found in some islands with high mountains, especially the Society Islands (e.g., Tahiti). Along the Tropic of Cancer, vegetation of the Hawaiian Archipelago is well documented (e.g., Carlquist 1980, Cuddihy and Stone 1990, Gagné and Cuddihy 1990, Wagner et al. 1990), which although different and highly altered through human intervention, does provide detailed information for discussing some parallels with Robinson Crusoe's vegetation.

Further, comparison of vegetation of the Robinson Crusoe Islands with that of neighboring archipelagoes along the Tropic of Capricorn is, of necessity, limited by several different factors. Vegetation of the Desventurada Islands does not include real trees and is, therefore, physiognomically very different from that of Robinson Crusoe, the former being composed mainly of endemic dwarf shrubs and herbs, and a few small rosette trees. The small island Sala-y-Gómez does not bear any closed vegetation (Mueller-Dombois and Fosberg 1998), and Easter Island is dominated by a highly altered mixed herbaceous grassland of a few native but many introduced species (which Skottsberg [1928] named the "tropical facies of oceanic grassland"; see also Zizka [1991] for more recent descriptions).

Vegetation Map

Classification of vegetation for the purpose of mapping in any terrestrial region is always a compromise between scale, accuracy, and practicability for the desired map. In a vegetation survey of Chile, Gajardo (1993) distinguished only three vegetation units on Robinson Crusoe: *Nothomyrcia-Drimys*, *Cuminia-Azara*, and *Stipa-Polypogon*. These units constitute his "Bosque y Matorral Laurifolio de Más a Tierra." In general terms, the vegetation on Robinson Crusoe Island is composed roughly of upper and lower montane forests of endemics as well as grassland, dry land with mostly aliens, cultivated areas, and two types of shrubland. Skottsberg's (1953*a*) map gave a distribution of some basic vegetation units, but native grassland and other assemblages were merged into one group. Skottsberg's vegetation units have been used until recently (e.g., by Hahn [1998]) for habitat analysis in studying birds of the island).

The units, given in the map, and communities are discussed here in detail with comparisons of earlier investigations.

1. ENDEMIC UPPER MONTANE FOREST

The endemic trees *Drimys confertifolia* and *Myrceugenia fernandeziana* are of high abundance and dominance, and most tree ferns and *Gunnera bracteata* are confined to this essentially upper montane forest. It consists of several different communities, mostly above 400 m along the main ridges, around and on El Yunque and, due to the island's topology, in the high regions of the eastern part of the island. These communities often replace each other depending on microrelief, slope, and aspect, and thus often form a mosaic pattern that is not practicable for resolution on the vegetation map. In the cloud zone of the highest altitudes above 500 m, the soil is rich in organic components. Moisture is maintained constantly in the litter and in old leaf bases/scales of the trunks, which are often covered by epiphytes, especially mosses.

It is important to mention that we use the term "upper montane forest" in a broader sense, deviating from Skottsberg (1953*a*), who restricted it only to communities of highest elevations, the "principal home of the *Robinsonia* assemblage," as he called it on his map. The criteria we used in delimiting upper from lower montane forest are high frequency and abundance of the tall ferns *Thyrsopteris elegans* and *Dicksonia berteroana* plus other taxa typical for the endemic assemblage of higher elevations (see Appendix 2).

1.1. *Thyrsopteris elegans–Dicksonia berteroana* Community

Relevés: 1–8; elevation: 460–630 m; all aspects; slope: very steep, 30–50°, mainly 40–50°; soil: black to slightly brownish, rich in fine organic material, covered by organic litter.

Coverage of trees is mainly below 50%, whereas the tree ferns and *Gunnera* cover 80–100%, some shrubs included. The herb layer is poorly developed, mostly below 20%, but mosses are highly abundant.

This type of upper montane forest is dominated by the tree ferns *Dicksonia berteroana* and *Thyrsopteris elegans*, which either solitarily or in combination (occasionally together with *Blechnum cycadifolium*) form a dense cover usually reaching 3 m in height. Other ferns, including mostly epiphytic species of *Hymenophyllum*, add to the high fern diversity. *Gunnera bracteata* has its optimal distribution in this community as do *Coprosma oliveri*, *Cuminia eriantha*, *Robinsonia gracilis*, *R. evenia*, and *Asplenium macrosorum*. *Drimys confertifolia* and *Myrceugenia fernandeziana* in most cases play a minor role on the very steep slopes. Skottsberg (1953*a*), giving examples for this community in his relevés of different *Dicksonia* associations, also pointed out the steep slopes on which this forest type is usually found. Kunkel (1957) reported similar assemblages from the highest location on the island, the summit region of El Yunque (916 m).

In a similar upper montane forest of Masafuera Island, the endemic *Dicksonia externa* is the dominant tree fern mixed with *Myrceugenia schulzei* and *Drimys confertifolia* (Skottsberg 1953*a*). Physiognomically the *Thyrsopteris-Dicksonia* community, together with the following *Drimys confertifolia–Myrceugenia fernandeziana* community, may most closely resemble upper montane forests rich in tree ferns of other archipelagoes (e.g., the Hawaiian wet forest [Carlquist 1980] or the cloud forest of Tahiti [Mueller-Dombois and Fosberg 1998]). The *Cyathea* and *Cibotium* tree ferns in these archipelagoes, however, can grow much taller, and there are obviously no species nor even genera in common.

1.2. *Drimys confertifolia–Myrceugenia fernandeziana* Community

Relevés: 9–17; elevation: 335–550 m, mainly above 450 m; all aspects; slope: 15–50°, mainly 20–40°; soil: black to brownish, rich in fine organic material, covered by a dense layer of organic litter.

The trees cover 70–100%. Altogether the tree fern and shrub layer is considerably variable, with coverage between 10 and 85%. In the upper parts of the valley (Valle Colonial) containing the village (San Juan Bautista) the introduced shrub *Aristotelia* partly replaces the tree ferns. Coverage of herbs is usually higher than in the dense tree fern community: 10–80%. Mosses again play an important role, in some relevés covering about 50%.

In this community *Drimys*, *Myrceugenia*, *Fagara*, and *Juania* reach heights up to 15 m on considerably steep slopes (30–50°), and up to 25 m on moderate slopes (15–30°). The tree ferns also reach heights of 5 m. Nearly all the ferns present in the *Thyrsopteris-Dicksonia* community (1.1) can be found in this forest, but additional ones are more frequent here: *Lophosoria quadripinnata*, *Megalastrum inequalifolium*, *Polystichum tetragonum*, to mention just the tallest ones. *Rhaphithamnus venustus*, a small tree, and *Dysopsis hirsuta*, an herb, are found mainly in this forest. Altogether, this community contains the highest species diversity among native island plant communities, except for some high-elevational variants of the *Blechnum cycadifolium* community. This upper montane forest community occurs in many variants and corresponds to what Skottsberg (1953*a*) called *Drimys-Nothomyrcia* associations, *Nothomyrcia-Dicksonia* and *Drimys–Blechnum cycadifolium*, as well as *Drimys-Dicksonia* associations. Kunkel (1957) found similar assemblages in the quebradas of the El Yunque summit but without *Myrceugenia* and *Fagara* (missing from the highest elevations). In this *Drimys-Myrceugenia* forest slightly more invasions by the introduced shrubs *Aristotelia chilensis* and *Rubus ulmifolius* occur than in the tree fern community (1.1). In sector Villagra we made two relevés from the lowest sites, both of which are highly threatened by these taxa; even though they are not yet present within the forest, they occur abundantly nearby in the quebradas, forest clearings, landslide areas, and along the central path.

In Masafuera some elements (e.g., *Juania australis*, *Dysopsis hirsuta*) of this community are missing. According to Skottsberg (1953*a*), *Dicksonia externa* indicates a similar type of upper montane forest together with *Drimys confertifolia* and *Myrceugenia schulzei*.

1.3. *Gunnera peltata* Community

Relevés: 18, 19; elevation: 360, 450 m; aspect: variable; slope: 10–20°; soil: black brown and partly loamy patches among rocks.

In the bottom of the quebradas *Gunnera peltata* often forms a monodominant shrub layer nearly excluding the trees. Below the broad leaves of *Gunnera* are found ferns such as *Megalastrum inequalifolium*, *Blechnum chilense*, *B. schotti*, and *Thyrsopteris elegans*. Due to the high amount of *Gunnera* litter and the tall ferns, the herb layer is very poor. Mosses can be abundant on the rocks and trunks. Skottsberg (1953*a*) reported two *Gunnera peltata* associations from rather low elevations. Kunkel (1957) indicated that *G. peltata* on El Yunque is found exclusively in the bottoms of the quebradas, whereas *G. bracteata* is also common in the forest on the slopes. The community can be seen as a linear extension of the upper montane floristic elements following the watercourses downward into the lower montane zone and even lower, where they meet the aliens *Aristotelia chilensis* and *Rubus ulmifolius*.

In Masafuera, *Gunnera masafuerae* similarly grows along streams (Skottsberg 1953*a*) and in deep canyons. Species of *Gunnera* are also present in deep valleys of other archipelagoes (e.g., in Maui [Hawaiian Islands] a similar *Gunnera* community is built up around *G. petaloidea* [Carlquist 1980]).

1.4. *Blechnum cycadifolium* Community

Relevés: 20, 21; elevation: 460, 550 m; aspect: S, SE; slope: 40, 75°; soil: ±degraded, brownish gray, organic layer often eroded.

The tree layer is missing; the few *Myrceugenia* trees remain shrub-sized. The typical *B. cycadifolium* community is densely closed, with this tree fern covering about 100%, so it is difficult to move about. Relevés were taken, therefore, from accessible areas that were not quite so closed.

Blechnum cycadifolium is the tree fern with the highest abundance and the broadest altitudinal and ecological amplitude on the island. It forms huge and rather pure stands on the slopes of higher elevations. Relevé 21 from La Piña is located at the edge of such a community. At this open edge there is also space for the grass *Megalachne berteroana* and the small shrub *Lactoris fernandeziana*, which is an endemic (representing the endemic family Lactoridaceae) found now only in refugial areas on Robinson Crusoe Island (Stuessy et al. 1998*c*). Relevé 20 was recorded while we were climbing down the steep slope of La Piña toward the sea, where *Blechnum* as well as scattered *Myrceugenia* and *Pernettya* are very short in stature. *Blechnum cycadifolium* is very abundant in the upper montane forest; it is also often a codominant in the *Pernettya* and *Ugni* shrub areas on the higher ridges. Skottsberg (1953*a*) described three associations with different combinations of trees, shrubs, and *B. cycadifolium* on Masatierra, and a *Dicksonia externa–Blechnum cycadifolium* association on Masafuera.

2. ENDEMIC LOWER MONTANE FOREST

The lower montane forest is found mostly below 400 m, especially on the dry northwestern and southeastern higher regions of Robinson Crusoe Island. *Myrceugenia fernandeziana* is the dominant tree, often accompanied by *Drimys confertifolia* and *Fagara mayu*. In general there is less moisture in the black or brownish soil due to lower precipitation and higher incoming radiation. On slopes adjacent to the bottoms of the quebradas, *Boehmeria excelsa* is a common tree. Disturbance by cattle and by alien plants is rather high, and for this reason a high proportion of the lower montane forest can be found as a component of the mixed unit 12 (endemic forest with aliens).

2.1. *Myrceugenia fernandeziana* Community

Relevés: 22–30; elevation: 250–410 m; all aspects, but predominantly N; soil: black, brownish, often very dry, powderlike, covered by dry litter.

The trees, with dominant *Myrceugenia*, cover between 50 and 100%. Tree ferns, with the exception of scattered *Blechnum cycadifolium*, are missing, and shrubs usually play a minor role. The herb layer usually is poor, but ferns can be abundant. Cryptogams also play a minor role, but in some relevés lichens and liverworts formed a crust covering the soil.

Species diversity in this forest is much lower than in the upper montane *Drimys-Myrceugenia* forest. *Myrceugenia*, *Drimys*, *Fagara mayu*, and near the bottoms of the valleys *Boehmeria excelsa* compose the tree layer, occasionally accompanied by *Aristotelia chilensis* (as trees and/or shrubs). In the understory the more drought-resistant ferns *Rumohra berteroana*, *Adiantum chilense*, and *Blechnum hastatum* are very common, with *Histiopteris incisa* occurring occasionally, as well as the aggressive alien *Acaena argentea*. This community more or less comprises all the lower montane *Nothomyrcia* associations reported by Skottsberg (1953*a*). He also reported some rare plants (*Robinsonia macrocephala*, *Dendroseris micrantha*, *Sophora fernandeziana*) in some of his relevés, but we saw only one *D. micrantha* in the lower montane forest. This is to some extent a random sampling effect, because this is the most widely distributed species of *Dendroseris* (of 11 species total) in the archipelago (Crawford et al. 1998) although still rare. It is also likely an effect of shrinking population sizes of these taxa since the time of Skottsberg's field observations more than 80 yr ago. In general, the presence of *Aristotelia chilensis*, *Acaena argentea*, *Ugni molinae*, and *Rumex acetosella* indicate increased disturbance from aliens.

In the lower montane forest of Masafuera a similar composition of tree species, of the endemics *Myrceugenia schulzei*, *Fagara externa*, and many other taxa present on both islands, can be found (Skottsberg 1953*a*).

2.2. *Boehmeria excelsa* Community

Relevé 31; elevation: 220 m; aspect: S; slope 15°; soil: black brown, mixed with rocks.

Boehmeria often becomes dominant in the valley bottoms and quebradas of the lower altitudes. In this relevé the only other tree is a single small *Myrceugenia*. The understory is very poor due to the dense cover of *Boehmeria* and the feeding and trampling by cows. Skottsberg (1953*a*) described a similar *Boehmeria* association but also a *Boehmeria-Nothomyrcia* association mixed with other trees, many ferns, and some grasses.

3. *Ugni molinae* SHRUBLAND

These hard-leaved shrub communities occur along ridges and wind-exposed slopes (e.g., near the village [San Juan Bautista] on Cordón Salsipuedes and Cordón Central). In lower elevations introduced *Ugni molinae* is dominant, along with endemic *Pernettya rigida* (disappearing at the lowest elevations). At higher elevations *Blechnum cycadifolium* is highly abundant, and above 600 m the endemic *U. selkirkii* becomes a codominant.

3.1. *Pernettya rigida–Ugni selkirkii* Community

Relevés: 32, 33; elevation: 620, 640 m; aspect: along ridges (E–W, W); soil: black organic covered by much litter.

Trees, when present, do not grow beyond shrub size. The shrub layer (including *Blechnum cycadifolium*) is rather dense, so there are few gaps for herbs, although mosses may be abundant.

The endemic *Ugni selkirkii* is confined to higher elevations. Together with the endemics *Pernettya rigida* and *Blechnum cycadifolium* it forms a dense shrub layer along the ridges up to the highest summits (Kunkel 1957). In both relevés we found also the alien *Ugni molinae* mixed with the endemics, which was not mentioned by Kunkel (1957) on his way up from Cordón Camote (ca. 600 m) to El Yunque (916 m). Skottsberg (1953*a*) did not list this alien in the *Ugni selkirkii–Blechnum cycadifolium* and *Pernettya–Ugni selkirkii* associations, as well as in other *Pernettya* associations, that together form what he summarized as "brushwood and scrub on the exposed ridges." Essentially this community belongs to the endemic upper montane forest. The reason we place it here is due to the current obviously great disturbance from *Ugni molinae*, apparently on an invasive march up into formerly undisturbed zones.

3.2. *Pernettya rigida–Ugni molinae* Community

Relevés: 34–43; elevation: 180–480 m; aspect: all, along ridges; soil: grayish brown, powderlike (rarely black organic), often eroded to rocky subsoil.

Trees, when present, often remain shrub-sized. The shrub layer (including *Blechnum cycadifolium*) covers between 60 and 95%. Coverage of herbs is between 5 and 30%. Cryptogams are few or none; occasionally lichens form a crust over the soil.

In this typical shrub community of the ridges and wind-exposed slopes, *Blechnum cycadifolium*, some smaller ferns, and *Gunnera bracteata* of the upper montane forest can still be found at higher elevations. Among aliens, *Aristotelia chilensis* and *Rubus ulmifolius* occur frequently at any elevation, whereas *Rumex acetosella*, *Aira caryophyllea*, and *Anthoxanthum odoratum* are found at lower elevations. *Ugni molinae* was found around the village by Johow (1896) and Skottsberg (1953*a*: observed 1917); the latter described an *Ugni molinae–Blechnum auriculatum* association near or in the village. Skottsberg (1922:221) also gave a detailed report: "... lower slopes of Cordón Central, and along the path to Portezuelo, to about 200 m; two small shrubs near the Selkirk memorial, 590 m; Q. [Quebrada] Villagra rare." The situation has now changed dramatically. Obviously the introduced *Ugni molinae* is rapidly invading native communities, especially the *Pernettya–Ugni selkirkii* scrub, replacing the latter endemic congener and perhaps also limiting *Pernettya*, which is nearly absent in some relevés at lower altitudes. Anderson et al. (2000) suggested that these two lithophytic and xerophytic species, *Ugni molinae* and *Pernettya rigida*, respectively, are proliferating due to soil degradations in recent decades. On Masafuera only two small populations of the aggressive pest *Ugni molinae* are currently known, and special efforts to eliminate both of them are currently under way by CONAF personnel (Ramón Schiller, pers. comm.).

4. *Rubus ulmifolius–Aristotelia chilensis* SHRUBLAND

Mostly very dense thickets comprising the introduced spiny raspberry, *Rubus ulmifolius*, and the multistemmed arching tree, *Aristotelia chilensis*. *Rubus* (zarzamora) displays highest density around the village, along the path up to Mirador del Selkirk (Portezuelo, with the Selkirk memorial plaque), and down the other side of the ridge into Villagra Valley. This noxious vegetation unit is also frequent in the Plazoleta del Yunque.

4.1. *Rubus ulmifolius–Aristotelia chilensis* Community

Relevés: 44–50; elevation: 140–420 m; aspect: all; soil: blackish brown to gray, more or less loamy, rarely sandy, often stony, eroded.

Larger trees play a minor role, but *Aristotelia chilensis* often forms a low tree layer of about 5 m, overtopping *Rubus* shrubs. Proportions between these two layers change, in total covering between 90 and 100%. Usually there is limited space for herbs (mostly below 10%, once 40%); mosses vary between 0 and 50%.

In lower altitudes and closer to the village, the introduced taxa *Aristotelia* and *Rubus* often form a mixed scrub. In more remote and higher elevations, *Aristotelia* is more abundant, which may be a consequence of being introduced earlier. Johow (1896) stated that *Aristotelia* was the most common plant among introduced woody taxa, forming conspicuous shrub communities. Johow did not mention *Rubus ulmifolius*, but in a list of fruit trees and shrubs he mentioned the introduction in 1892 of a number of *Rubus idaeus* plants for cultivation. In a supplement to the flora, Skottsberg (1953*b*) classified *Rubus ulmifolius*, first recorded by Looser (1927), as a very dangerous weed. Obviously, *Rubus* is a similarly rapid and dangerous invader, as are *Ugni molinae* and *Aristotelia chilensis*. *Rubus* and *Aristotelia* were not seen by Kunkel (1957) on El Yunque. He wrote "... daß der Gipfel dieses Berges absolut frei von eingeschleppten Pflanzen angetroffen wurde." This has now changed for the worse, however, because a recent expedition to the summit of El Yunque in 1999 recorded single individuals of *Aristotelia* and *Rubus* (Philippe Danton, pers. comm., 1999).

In Masafuera *Aristotelia* is also rather common, distributed throughout the entire island, especially in ravines and areas difficult of access. Control of this pest, therefore, is difficult. *Rubus*, however, is less widely distributed and has been detected at approximately nine spots on the island (Ramón Schiller, pers. comm.), such as in the surroundings of the nonpermanent settlement at the mouth of Quebrada Casas. The park management (CONAF) is attempting to eliminate these populations before they spread even further.

The genus *Rubus* causes similar troubles in other archipelagoes (e.g., in the Hawaiian Islands, where at least three introduced taxa [from Asia and North America] are invasive [Cuddihy and Stone 1990]).

5. FERN ASSEMBLAGES

The dominant tall fern, *Histiopteris incisa*, forms large clonal patches through rhizomes. These groups of ferns are found on edges of forests and on drier or eroded slopes.

5.1. *Histiopteris incisa* Community

Relevés: 51–53; elevation: 270–410 m; all aspects; soil: usually degraded, brownish to gray brownish, powderlike or aggregated, often eroded zones.

The shrub layer occasionally contributes up to 10% of coverage. The ferns (assigned to the herb layer because they are not tree ferns) usually cover between 90 and 100%; lower herbs and mosses play a minor role.

The huge clonal systems built up by the native *Histiopteris incisa* often cover some 100 or even up to 1000 m^2. This fern, as well as the occasionally accompanying *Rumohra berteroana*, *Adianthum chilense*, and *Blechnum hastatum*, seems more drought resistant than *Blechnum chilense* and *Lophosoria quadripinnata*, which are usually found in the forests. The shrub *Ugni molinae* also invades this community, together with another alien of the ground layer, *Acaena argentea*.

Histiopteris incisa also occurs in Masafuera and is widely distributed in the Southern Hemisphere. It is not known to form unique communities on Pacific islands near the Robinson Crusoe Archipelago (Mueller-Dombois and Fosberg 1998), but it is found among the principal species of fern bush communities on Gough Island of the Tristan da Cunha Archipelago of the southern Atlantic (Wace 1960).

6. *Libertia chilensis* ASSEMBLAGE

This assemblage of introduced and native plants is found on eroded slopes close to the village.

6.1. *Libertia chilensis* Community

Relevés: 54, 55; elevation: 250, 290 m; aspect: S, exposed; soil: grayish brown, powderlike or sandy, dry.

Libertia chilensis is locally abundant either in small groups or covering larger areas of eroded slopes close to San Juan Bautista. Because it does not form a distinct community, we considered the possibility of including this unit elsewhere. We decided to keep it separate, however, because we suspect it to be a remnant of a native floristic assemblage on eroded slopes before massive invasion of these areas by *Ugni*, *Acaena*, and other introduced herbs and grasses. According to Skottsberg (1922), *L. chilensis* (= *L. formosa*) was not uncommon on barren slopes and rocky ridges in Masatierra and common on cliffs near the sea and in canyons of Masafuera.

7. *Acaena argentea* ASSEMBLAGE

The stolons of *A. argentea* form a dense carpetlike herbaceous thicket. This almost monodominant herb community comprises only a few other species with low abundance and is present everywhere from lower to medium elevations except in the very dry and windy westernmost part of Robinson Crusoe Island.

7.1. *Acaena argentea* Community

Relevés: 56–58; elevation: 200–390 m; aspect: various; soil: gray or brown, stony, partly with boulders.

On the eroded slopes, especially of the western part of the island, *Acaena argentea* forms dense carpets that leave little space for other taxa. Only a few introduced grasses and herbs are scattered within this matrix. Of the native and endemic taxa, only *Blechnum hastatum* and *Haloragis masatierrana* can be found frequently in low abundance. These taxa, as well as occasional native grass species of *Nassella* and *Piptochaetium*, obviously point to very dramatic vegetational changes in lower elevations. According to Johow (1896), *A. argentea* more than 100 yr ago already had been "la maleza mas comun de la isla" and a serious pest in pastureland (most likely comprising much of the *Nassella* grassland with some additional introduced grasses and herbs). Skottsberg (1922) judged this taxon as "one of the most wide spread and noxious weeds"; it was doubtless inadvertently introduced from mainland South America (Matthei 1995). It is also a serious weed on Masafuera (Ortiz-Riveros 1982).

The success of *A. argentea* represents a main act in the tragedy of the island flora. On one hand, this taxon builds large and rather dense "carpets" covering deforested and eroded slopes, protecting those areas from further erosion. On the other hand, it not only outcompetes native taxa but also invades natural communities, predominantly in the native *Nassella* grassland.

8. NATIVE GRASSLAND

The tussock-forming grasses *Nassella laevissima* and *Piptochaetium bicolor* are dominants in this native "steppelike" grassland extending from dry lower areas up to medium elevations. This grassland is absent in the westernmost part of the island.

8.1. *Piptochaetium bicolor–Nassella laevissima* Community

Relevés: 59–72; elevation: 20–460 m; all aspects; soil: grayish brown, stony, dry, often covered by much dry grass litter.

The grasses together with some herbs often cover between 90 and 100% and at least 50%; mosses are missing or play a minor role.

Nassella laevissima is the most common species of the native tussock-forming grasses. These usually compose the steppelike grasslands, which thousands or millions of years ago must have covered most of the dry western part, and more recently the lower eastern parts, of the island. In a few relevés the taller *Piptochaetium bicolor* is more abundant than *N. laevissima*. *Nassella neesiana* (= *Stipa fernandeziana*) occurs occasionally but is never abundant. The native grassland is highly disturbed by aliens, the most serious pressure coming from *Acaena argentea*, which appears to be invading the few remaining "pure" steppes. But many of the Euro-Mediterranean weeds (e.g., *Rumex acetosella*, *Anthoxanthum odoratum*, *Bromus hordeaceus*, *Aira caryophyllea*, *Briza minor*, *B. maxima*, *Vulpia* spp., *Avena barbata*, *Dipsacus sativus*, and *Anagallis arvensis*) are present in many relevés and must also be considered a threat. Skottsberg (1953*a*) reported two relevés of a corresponding *Stipa laevissima* association, indicating that this pure community only covers small areas (back in 1917!) and that some weeds are also usually present (e.g., *Acaena argentea* and most of the taxa just mentioned).

The native grassland is highly impacted by large rabbit populations and other introduced foraging animals. In addition to foraging pressure, these animals help disperse weedy species even more broadly over the island (e.g., as with the hooked fruits of *Acaena*). In maps prepared by Ortiz-Riveros and coworkers (1982), nearly all grassland areas were classified as degraded or severely degraded.

8.2. *Juncus capillaceus* Community

Relevés: 73, 74; elevation: 290, 325 m; aspect: SE, NNE; soil: grayish brown, dry, clay.

The graminoids and herbs cover between 75 and 80%; mosses are absent.

This community never covers large areas, but it locally replaces the *Piptochaetium bicolor–Nassella laevissima* grassland on concave slopes, flat depressions, and other places where moisture can accumulate. Disturbance in this community is also great due to invasion by the aliens *Aira caryophyllea*, *Rumex acetosella*, and *Anthoxanthum odoratum*.

9. WEED ASSEMBLAGES

These include grasslands dominated by introduced (mostly European) taxa, as well as several other herbaceous weedy communities in the drier and lower parts of the island.

9.1. *Rumex acetosella–Aira caryophyllea* Community

Relevés: 75–81; elevation: 15–440 m; aspect: mostly S and E; soil: brownish, often aggregated powder.

Coverage of grasses and herbs is usually below 50%; cryptogams, especially lichens, are often very abundant.

This community is often found on eroded slopes, which seem to be devoid of vegetation when first observed from a distance. In some relevés we found dense crusts of lichens and liverworts protecting the powderlike soil from surface erosion.

9.2. *Briza maxima* Community

Relevés: 82–84; elevation: 40–310 m; aspect: E to SW; soil: gray, sandy or powderlike.

Coverage of grasses and herbs is between 50 and 95%; mosses are absent or in low abundance.

We found this community close to the village, where it seems to represent a transition from native *Nassella* grassland to alien communities, as both species of *Nassella* are found there. It is rich in other introduced herbs and grasses, and might have been used as pasture in earlier historical periods, when more cattle were present near the village. *Acaena argentea*, too, is present in one case in great abundance.

9.3. *Vulpia* Community

Relevés: 85–92; elevation: 20–130 m; all aspects; soil: brown or gray, often aggregated powder, more or less stony.

Coverage of grasses and herbs is between 60 and 100%; mosses are absent or in low abundance.

We found this annual grassland in the dry lower and western parts of the island. Due to recording in late summer, we found the plants mostly with only glumes left in the inflorescences; this made it difficult to discriminate among the three species. As far as we could estimate, especially in the western part of the island, *Vulpia bromoides* is the dominant taxon. In this same dry western region, many of the ruderals are absent, but *Hordeum murinum* is abundant.

9.4. *Avena barbata* Community

Relevés: 93, 94; elevation: 160, 210 m; aspect: NNE, NE; soil: gray brown, dry, stony (at 210 m).

The grasses cover between 50 and 100%.

This is the typical steppelike grassland of the small island, Santa Clara, dominated by *Avena barbata* and *Bromus hordeaceus* in the huge tableland area. These two taxa produce a large amount of litter, which cover the gaps between grasses. That our recordings were made in late summer might be one reason no dicot herbs were found except *Rumex crispus*. On the more open slope *Hordeum murinum* and *H. secalinum* become codominant. Already in 1917 Skottsberg (1953*a*) noticed the high abundance of *A. barbata* and that there was "little or nothing" left of the native flora of Santa Clara.

9.5. Ruderal Communities; Mixed Rock and Coastal Communities

Relevés: 95–99; elevation: 2–230 m; all aspects; between stones, on wet rock faces, and on brownish, sandy soil.

These communities occur near the village (no relevé from there), near huts and landing places, and very often on steep, rocky slopes, especially on the coast. Species composition can vary. For instance, *Ruta chalepensis* on steep faces of the coastal rocks in the northeast part of the island (as judged from boat observations only) appears to form communities similar to those in relevé 95.

10. TALL RUDERALS

This unit includes tall (1–2 m) ruderals, which form occasionally large patches (*Conium maculatum*, *Silybum marianum*, *Centaurea melitensis*, *Papaver somniferum*) and occur in flat areas and valley bottoms at lower elevations.

10.1. Mixed Tall Ruderal Community

Relevés: 100–103; elevation: 110–220 m; aspect: N to SE; soil: gray, brownish.

The tall annuals or biannuals, forming a tall herblike community, cover between 60 and 100%. The lower boundary in coverage certainly is strongly biased by our observations being taken in late summer (plants were already dry). They are mostly found at the bases of slopes, in depressions, and in flattened areas. In addition to *Conium*, *Silybum*, and *Centaurea*, *Papaver somniferum* contributes to similar mixed communities near the airfield (no relevé taken). Other introduced tall weeds (e.g., the perennial *Lobelia tupa*) often form large groups on eroded slopes.

11. CULTIVATED *Eucalyptus*, *Cupressus*, AND *Pinus*

Cultivated areas of *Eucalyptus globulus*, *Cupressus goveniana*, and *Pinus radiata* cover the eroded slopes around the village of San Juan Bautista. These were deliberately planted to help stem soil erosion and to provide needed wood for boats, homes, cooking, and heating. These trees, however, are now maintaining themselves through natural seedling establishment.

11.1. Forest Plantations

Relevés: 104–106; elevation: 110–170 m; aspect: NE to ESE; subsoil: grayish brown (soil eroded).

All tree layers together cover between 80 and 90%. The shrub layer covers 10 to 20%, with usually young trees present, as well as an herb layer, which in general is poorly developed (1–10%). The introduced trees *Eucalyptus globulus*, *Cupressus goveniana*, and *Pinus radiata* form either pure or mixed stands, depending mostly on initial planting. But they also regenerate abundantly, in some places climbing up adjacent slopes. Groups of *Eucalyptus* (Cordón Salsipuedes) and *Cupressus* (ridge to Damajuana) were found up to 400 m. *Eucalyptus* has some features (allelopathy, dense stands with much litter) that can affect or exclude other taxa (Swenson et al. 1997). This species may first have been planted in 1884 (Johow 1896). At least two taxa of *Cupressus* are present on Robinson Crusoe Island (Swenson et al. 1997), where *C. goveniana* is more abundant (*C. macnabiana* was not found on relevé sites). *Acacia dealbata* and *A. melanoxylon* were apparently introduced more recently because they were not mentioned by Johow (1896) nor Skottsberg (1922, 1953*a*,*b*).

12. ENDEMIC FOREST WITH ALIENS

In this unit we could not distinguish between the upper and lower montane forest component in this mixed assemblage of endemic forest and aliens in every part of the island, although it is possible to do so in certain areas or in single relevés (Appendix 2). So this unit contains both the upper montane forest, highly disturbed, and the lower montane forest, highly disturbed by the invasive shrubs *Arisotelia chilensis*, *Rubus ulmifolius*, *Ugni molinae*, and in the herbaceous layer by *Acaena argentea*. Often a small-scale mixture can be found of pure native forest with the invading shrubs on landslides and eroded patches. Relevés 16, 17, 19, and 28 might be classified in this unit.

13. SCATTERED NATIVE VEGETATION AMONG ROCKS

Found at higher elevations, on steep slopes; comprises essentially elements of the upper montane forest. This unit includes some patches of single *Myrceugenia* trees in eroded areas above Puerto Francés.

14. SCATTERED GRASSLAND AND WEEDS AMONG ROCKS

This unit comprises a mixture of native and alien grasses, plus different weedy assemblages, which can homogeneously cover somewhat less than 50% of the ground or may occur in patches. It occurs in lower areas, on eroded slopes and coastal rocks among others.

15. GRASSLAND WITH *Acaena argentea*
Mosaic patterns of dense *Acaena argentea* and mostly native grasses formed in the drier parts of Robinson Crusoe Island, especially on the westernmost portion. Relevés 60, 61 are examples of this unit.

Although the following two categories are not plant communities, they are also presented on the vegetation map because they have high conservation importance.

16. ROCKS AND ERODED AREAS
This unit has no vegetation or only scattered plants that cover less than 10% of the ground surface. Because our data were recorded and the aerial photographs (from the Chilean Air Force) taken in late summer, it is possible that we have overestimated the proportion of these areas. Nonetheless, the great extent of these eroded, bare areas cannot be overemphasized.

17. SETTLEMENT, AIRFIELD
This unit includes the area of the village (San Juan Bautista) with buildings, construction sites, dirt roads, footpaths, horticultural areas, plus the airfield environs in the westernmost part of the island.

Conservation

The vegetation map shows the spatial distribution of the vegetation units, which reflect, in descending order, undisturbed as well as highly disturbed plant communities. The map shows clearly that endemic and native vegetation is endangered at least potentially everywhere on the island except at very high elevations. The most dangerous aliens among the woody species are *Aristotelia chilensis*, *Rubus ulmifolius*, and *Ugni molinae* (Sanders et al. 1982, Swenson et al. 1997, Stuessy et al. 1998*a*,*b*), all with fruits dispersed by birds. *Aristotelia*, long established and evenly distributed over the island, is able to quickly colonize gaps opened by landslides, dying trees, and other causes. *Rubus*, still less frequent in remote areas (concentrated at present in Valle Colonial near the village and along paths), can proliferate from its edges by rapid clonal growth. *Ugni molinae* has invaded *Blechnum cycadifolium* and *Ugni selkirkii* communities. Unless these pests can be controlled, the future of the endemic forest and shrub communities on Robinson Crusoe Island is uncertain.

Recruitment of native trees also seems low in comparison with some aliens and cultivated trees. Young plants of *Myrceugenia* can be found occasionally to frequently in some places, but we rarely found seedlings or small plants in the dry, lower montane forest. In this lower and dryer *Myrceugenia* forest, regeneration seems to be hindered, an observation compatible with that of Skottsberg (1953*a*), who rarely found young plants of *Myrceugenia* and no other young trees in what he called the "field layer." This might be due to local trampling and grazing by cows and is probably a consequnce of the high rabbit population also (Sanders et al. 1982, Stuessy et al. 1998*a*). In the often dense upper montane forest, young plants are difficult to see, but we observed occasional higher proportions of young trees there. Recruitment of some taxa of the rare endemic genus *Robinsonia*, which often occur as epiphytes on the trunks of tree ferns, seems to be good in higher elevations.

Among herbs, the mat-forming *Acaena argentea* is the most serious pest, reproducing prodigiously through fruits that are easily dispersed by animals (and humans!), as well as by spreading clonally through its long stolons. The native *Nassella* grassland is under great pressure from this species, plus from other alien herbs and grasses, such as *Rumex acetosella*, *Aira caryophyllea*, and *Anthoxanthum odoratum* (the highest general frequencies), followed by *Briza minor*, *Geranium core-core*, *Avena barbata*, and species of *Vulpia* mostly in lower and drier parts of the island.

Because the map outlines the distribution of the vegetation units, we hope that it will prove useful as an educational tool for ecotourism and for information on plant resources for current and future generations of islanders. We also hope that the map will aid conservation efforts by CONAF personnel. At its large scale of 1:30,000 it will be useful in completing many projects, such as removing cattle from most sectors, advising tourist guides of ecologically sensitive areas, building soil retention barriers, and propagation of rare and endangered species as outlined in the CONAF Plan for Development and Conservation (1976).

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Appendix 1

Locations of Relevés and Additional Site Data

Unit	Community	Relevé No.	Locality	Altitude (m)	Aspect	Slope°	Area (m^2)	CTot	CT	CS	CH	CM
1	1.1	1	Cerro Agudo, second quebrada, facing south	610	S	40	400	100	10	90	10	many
		2	Cerro Agudo, down to south, bottom of quebrada	580	S	30	300	90	0	80	10	many
		3	Cerro Agudo, up to ridge	580	S	50	400		5	90	10	many
		4	Mirador Selkirk, western flank	560	WSW	40	400	100	25	100	10	many
		5	Corrales de Molina, contact to Cordón Chumacera	620	S	40	200	100	80	80	20	50
		6	La Piña, W farthest parts of Valle Francés, root of small quebrada	630	NE	30	200	100	70	80	10	20
		7	Cordón Salsipuedes	580	NNE	40	300	100	20	100	5	50
		8	Quebrada Villagra, bend of road into ravine, opposite slope	460	N	45	200	100	30	80	20	few
	1.2	9	Villagra, orogr. right of screefield	395	SSW	30	400	100	100	10	80	20
		10	Villagra, road farther down, just below road	335	SSW	25	300	95	95	25	70	10
		11	Cordón Chifladores, inner part, E ridge	460	SE	20	200	90	90	85	30	50
		12	La Piña, W farthest parts of Valle Francés, root of small quebrada	550	NNW	15	300	100	90	70	10	20
		13	Road from Mirador to Villagra	510	S	40	400		95	30	30	50
		14	Quebrada Pangal, above rocks, orogr. right of ridge	490	ESE	35	300	100	90	70	10	50
		15	Between Cerro Centinela and next to the east	460	E	40	200	100	100	20	20	50
		16	Cordón Salsipuedes	480	NW	40	300	100	70	20	30	15
		17	Road to Mirador, upper part, along both sides	510	E	50	400	100	70	85	10	many
	1.3	18	Quebrada Villagra, curva del camino en la quebrada	450	NNW	10	200	100	0	100	10	few
		19	Quebrada, near road down Mirador-Villagra	360	S	20	200	100	30	60	10	50
	1.4	20	La Piña, steep slope down to sea	550	S	75	100	70	0	50	30	few
		21	La Piña, W farthest parts of Valle Francés	460	SE	40	100	80		80	10	30
2	2.1	22	Road Mirador-Villagra	360	S	30	300		80	10	80	none
		23	Puerto Francés, Cerro Pascua, rounded ridge close to sea	410	NE	10	400	100	100	0	2	none
		24	Below Puerta Tranca, down to Vaquería	360	W	20	400	100	100	10	5	few
		25	Puerto Francés, above southeastern quebrada	350	NW	45	200	80	60	30	5	few
		26	Above huts in Villagra	250	SW	25	400	90	90	5	5	none
		27	La Vaquería, rear upper part, slightly below ridge	410	E	30	300	95	90	20	70	60
		28	Cordón del Nispero, just below ridge	360	NW	20	200		50	40	40	few
		29	Cordón del Nispero, slope	325	NNE	20	200	60	50	10	30	none
		30	Puerto Francés, southeastern quebrada	290	NE	25	400		80	10	5	none
	2.2	31	Quebrada Manzano W Cordón La Punta Galpón	220	S	15	100	95	95	0	10	none

3	3.1	32	Corrales de Molina, along ridge, slightly down SW	640	W	15	100	100	0	100	10	50
		33	Cerro Agudo, along ridge	620	E/W	0	300	100	0	100	5	none
	3.2	34	Cordón Pesca de los Viejos, down the ridge	480	NNE	10	200	100	50	70	10	few
		35	Ridge to Cerro Agudo, eastern flank	460	E	40	300	80	0	70	10	few
		36	Road to Mirador, along the ridge	420	E	20	400	100	15	95	5	none
		37	Road down to Villagra, upper part	460	SW	30	200	100	0	90	10	none
		38	Cordón Chifladores, W Valle Francés	400	SE	5	100		0	90	30	5
		39	Road to Mirador, wind-exposed slope to village	180	NE	20	300	80	0	80	5	none
		40	Cordón Salsipuedes, flank to the village, just below ridge	430	SSE	35	200	80	0	60	30	many
		41	E near the huts of Villagra	260	SE	30	300		0	95	10	many
		42	Cerro Centinela, eastern slope below ruin	330	SE	30	300		0	70	10	30
		43	La Campaña, Villagra toward south of El Yunque, above road	230	S	30	150	80	0	70	20	50
4	4.1	44	Cordón Pangal, S ridge, facing Bahía Cumberland	220	SW	45	200	90	65	15	40	few
		45	Cordón Central, orogr. left of ridge	420	NNE	50	300	95	55	40	20	30
		46	Road to Mirador, crossing huge *Rubus* thicket	250	NW	25	300	100	50	70	5	none
		47	Near Plazoleta del Yunque	250	W	10	300	90	70	70	5	20
		48	Road to Plazoleta del Yunque	140	NE	15	200	100	50	60	5	50
		49	Road to Plazoleta del Yunque	200	N	10	200	100	0	100	5	many
		50	Valle Ingles, NW part	220	SSE	20	400		100	0	1	none
5	5.1	51	Cordón Pesca de los Viejos, slope just below ridge	270	NW	35	100	100	0	5	100	none
		52	Puerta Tranca (ridge between Valle Ingles and Vaquería)	410	S	25	100	100	0	10	90	10
		53	Cordón Salsipuedes, flank down to quebrada	390	NE	30	200		0	5	95	none
6	6.1	54	Path to Salsipuedes, ridge over village	290	S	40	400	80	0	30	60	few
		55	Cordón Salsipuedes, above cultivated forest	250	S	50	200		0	0	60	20
7	7.1	56	Cordón Salsipuedes, flank down to quebrada	390	NE	30	200		0	5	100	none
		57	La Vaquería, rear part, near La Cachota	200	ENE	10	200	100	0	0	100	none
		58	Above Punto Blanco, above road	210	SW	0	100		0	0	50	few
8	8.1	59	Puerto Francés, saddle under *Histiopteris* patch	460	SSE	15	300		0	0	100	none
		60	SE Tres Puntos, above road	180	SE	30	200		0	0	95	none
		61	Villagra, E big eastern quebrada	180	W	25	150	100	0	0	100	5
		62	Villagra, E big eastern quebrada	130	W	25	100	90	0	0	90	few
		63	Villagra, E big eastern quebrada	150	W	25	100	80	0	0	80	few
		64	Ravanal, 2nd quebrada E Cerro Centinella, slope	360	WNW	30	100	70	0	20	60	none
		65	Cordón La Punta Galpón, slope to Villagra	240	NE	30	100	95	0	0	95	few
		66	Above the huts in Villagra	200	SW	20	200		0	0	100	none
		67	Cerro Centinela, steep slope to the coast	280	NE	25	300		0	0	70	none
		68	Cordón Pangal, E Grat, hacia Bahía Cumberland	280	N	50	200		0	5	60	30
		69	La Cachota, rear part of La Vaquería	165	E	10	200	95	0	0	95	none
		70	La Vaquería, outer part	65	SW	30	100	100	0	0	100	20
		71	La Vaquería, outer part, close to shore	20	NNW	10	100	90	0	0	90	none
		72	Puerto Francés, Cerro Pascua, close to sea	420	E	25	150		0	0	50	few
	8.2	73	Cerro Centinela, broad slope down to sea	290	NE	10	300		0	0	75	none
		74	Puerto Francés: just below ridge, near first trees on ridge	325	NNE	20	100		0	0	80	none

Appendix 1 (continued)

Unit	Community	Relevé No.	Locality	Altitude (m)	Aspect	Slope°	Area (m^2)	CTot	CT	CS	CH	CM
9	9.1	75	Cerro E 3rd quebrada E Centinela	290	NW	20	100	20	0	0	20	50
		76	Puerto Francés, Cerro Pascua, rounded ridge close to sea	440	E	40	100	30	0	0	30	none
		77	Puerto Francés: slope orogr. left flank close to hut	15	SE	30	100	50	0	0	50	none
		78	Puerto Francés: Alto Francés	225	S	35	100		0	0	30	80
		79	Above Bahía Chupones, above road	230	E	30	200		0	0	20	10
		80	Quebrada Nispero, slope upper part	220	SE	20	200	30	0	0	20	90
		81	Puerto Inglés, ca. 500 m from coast, orogr. left foot of slope	50	SE	20	200		0	0	60	none
	9.2	82	San Juan Bautista, N lighthouse, steep slope, coastal rock	40	E	35	300		0	0	85	10
		83	Cordón Salsipuedes, above cultivated forest	180	SW	40	200		0	0	50	none
		84	Cordón Salsipuedes, above cultivated forest	310	SE	40	400		0	1	95	none
	9.3	85	Valle Inglés, W side of valley	130	NW	20	300		0	0	60	none
		86	Valle Inglés, ca. 100 m from coast	20	SE	15	300		0	0	60	few
		87	Above road to Pangal	90	N	30	200		0	0	70	none
		88	Puerto Francés: slope to valley close to shore	50	N	20	100	70	0	0	70	none
		89	Airfield, ca. 100 m E old runway	110	0	0	400		0	0	100	none
		90	Punta de la Isla, slope to south	115	SE	25	100	70	0	0	70	none
		91	Punta de la Isla, slope to east	130	E	25	100	60	0	0	60	none
		92	Cordón Pangal, broad rounded ridge, facing Bahía Cumberland	170	NNW	25	100		0	0	10	80
	9.4	93	Santa Clara, tableland with little slope	160	NNE	5	200	100	0	0	100	none
		94	Santa Clara, tableland up to ridge	210	NE	20	200	50	0	0	50	none
	9.5	95	End of Quebrada Nispero, close to shore	20	NNE	15	100	50	0	0	50	none
		96	Puerto Francés: strip of weeds behind rounded coastal stones	2	NE	0	20	50	0	0	50	none
		97	Quebrada El Galpón, wet rock face	230	SE	80	20	20	0	0	20	50
		98	Bahía del Padre: on roadside above muelle y casas	15	SSW	70	80	50	0	0	50	none
		99	San Juan Bautista, N lighthouse, coastal rock	10	E	90	100		0	0	5	few
10	10.1	100	Valle Inglés, NW side lower part of slope	220	SE	20	400		0	0	80	none
		101	La Vaquería, rear part, near La Cachota	200	ENE	5	100	100	0	0	100	none
		102	Valle Inglés, W side of valley	140	N	20	400		0	0	80	none
		103	Airfield, 300 m W new runway	110	0	0	400		0	0	60	none
11	11.1	104	San Juan Bautista, above road around village above La Polvera	125	ESE	30	200	80	70	20	1	none
		105	San Juan Bautista, below road around village above La Polvera	110	NE	20	200	80	70	10	10	none
		106	San Juan Bautista, cultivation E road to Mirador	170	NE	10	300	90	90	10	10	none

Note: CTot, total coverage; CT, tree coverage; CS, shrub coverage; CH, herb coverage; CM, moss and lichen coverage. Relevés containing high proportions of invaders and therefore also mentioned in mixed units are displayed within their respective communities.