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REVIEW

The conservation of biodiversity in Chile

La conservación de la biodiversidad en Chile

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ABSTRACT

I analyze Chile's biological diversity in terrestrial and marine environments, including information on the magnitude of biodiversity at three levels (ecosystem, species, and genetic). I identify the main values, and the importance of conserving such heritage, making comments about past and current activities of some national institutions interested in biodiversity conservation. I emphasize actions related to increasing and improving knowledge on biodiversity, legislation, some economic and social values, and protection of biodiversity in the field. I identify the main threats to Chile's biodiversity and give recommendations for maintaining and enhancing its conservation. Chile has developed many efforts to avoid biodiversity losses. It has enacted legislation, maintained institutions, and taken actions that favor biological diversity. However, some of the policies, legislation, and actions have been too specific, disperse, and uncoordinated. A system of inter-institutional coordination is urgently required. An efficient approach, through symposia, to identify the most threatened woody plant and terrestrial vertebrate species, was developed. Now, is time to define conservation status for species not included in previous symposia, identify the most threatened species, and begin programs to increase their population size. It is essential to initiate actions concerning the protection of amphibians, reptiles, cacti, and non-woody terrestrial plants. Also, it is urgent to start conservation activities for aquatic environments. Coastal and marine protected areas need to be created to protect their biodiversity.

Key words: natural ecosystems, natural forests, protected areas, threatened species, environmental protection.

RESUMEN

Analizo la diversidad biológica de Chile en ambientes terrestres y marinos, incluyendo información sobre la magnitud de la biodiversidad en sus tres niveles (ecosistémico, específico y genético). Identifico sus principales valores y la importancia de conservar dicho patrimonio, haciendo comentarios sobre las acciones realizadas y lo que están haciendo algunas instituciones nacionales interesadas en conservación de la biodiversidad. Enfatizo las actividades sobre biodiversidad relacionadas con incrementar y mejorar su conocimiento, su legislación, algunos de sus valores económicos y sociales, y su protección en terreno. Enuncio las principales amenazas a la biodiversidad de Chile, y formuló recomendaciones para mantener y mejorar su conservación. Chile ha desarrollado muchos esfuerzos para evitar la pérdida de su biodiversidad. Ha promulgado legislación, mantenido instituciones y ejecutado actividades que favorecen la diversidad biológica. Sin embargo, algunas de las políticas, legislación y acciones han sido demasiado específicas, dispersas y descoordinadas. Su sistematización y coordinación inter-institucional se requiere con urgencia. El método de simposios para lograr consenso y priorizar las especies leñosas y de vertebrados terrestres más amenazadas de extinción ha sido eficiente. Ahora se requieren acciones para definir el *status* de conservación de las especies no incluidas en los simposios previos, seleccionar las especies más amenazadas y comenzar programas para recuperar sus poblaciones. Es esencial iniciar acciones relativas a la protección de anfibios, reptiles, cactáceas, y plantas no leñosas. También es urgente iniciar acciones para la conservación de ambientes acuáticos y crear áreas protegidas costeras y marinas, para proteger su biodiversidad.

Palabras claves: ecosistemas naturales, bosques naturales, áreas protegidas, especies amenazadas, protección ambiental.

INTRODUCTION

The concept of biological diversity, or biodiversity, and associated concepts such as biotic resources, genetic diversity, species diversity, and ecosystem diversity are becoming important throughout the world and are receiving greater attention every year. Biodiversity is comprised of different organizational levels of living organisms, and includes the ecosystems and ecological processes of which they are a part. Three basic levels of biodiversity are recognized: a) ecosystem diversity (differences among systems of living organisms); b) species diversity (differences among species); and c) genetic diversity (genetic differences within a single species) (WWF 1989, McNeely et al. 1990).

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Although all ecosystems are important, some have special value due to their biological diversity, endemism, and genetic resources. Tropical systems are the world's richest in local diversity, but the ecosystems of the Mediterranean-climate regions are also quite rich (di Castri & Mooney 1973). Data on species numbers and degree of endemism for Mediterranean-climate regions form the basis for identifying them as critical sites for conservation (Mooney 1988).

The number of species is not the only reason to protect ecosystems. For example, "arid and semiarid lands harbor only a very small number of species compared with tropical forests. But because of the adaptations of these species to harsh living conditions, they feature many potentially valuable biochemicals" (WCED 1987). If the predicted trend in global warming occurs, plants adapted to more arid climates could become increasingly important sources of food and raw materials.

Although Chile does not have the species diversity of its tropical neighbors, it should receive international attention because of the uniqueness of some of its ecosystems and species. In fact, Chile has: one of the five Mediterranean-climate regions in the world (McNally 1990); arid and semiarid coastal ecosystems dependent on marine fogs; high endemicity of higher plants in the Juan Fernández Archipelago; and most of the only temperate rainforest in Latin America (Ovington 1983, Alaback 1991). Chile has fewer species than tropical countries, but the species present have a high degree of endemism. These species suffer strong pressure due to human activities, especially pollution, exploitation, and reduction of habitat (Armesto & Arroyo 1991). In addition, many native species, especially trees and marine fishes form the basis for important industries and artisanal economic activities.

Here I provide: a) a broad view of the ecological value and extent of Chilean biodiversity; b) a gross estimate of the financial contribution of certain biodiversity elements to the Chilean economy; c) information on actions taken to improve basic understanding of biodiversity; d) information on actions taken to increase public awareness of the need to protect biodiversity and develop its potential; e) a proposal to monitor aspects of biodiversity for a better understanding of its contribution to Chile's economy and human welfare; and f) recommendations of specific actions for the current decade to conserve Chile's biodiversity.

EXTENT OF CHILE'S BIODIVERSITY

Ecosystem level

Chilean ecosystems, especially their plant components, are very diverse because of the extreme range of latitudes and altitudes found within the country. These physical features have resulted in a high diversity of ecological conditions, and have created habitats to which organisms have evolved and adapted. Chile stretches nearly 4,200 km –almost 40° in latitude– along a north-south axis. Other characteristics of Chile contributing to ecological diversity include: a) variable altitudes (ranging from sea level to 6,893 m in the Nevado Ojos del Salado mountain [27o 06' S 68° 35 W]) (IGM 1988); b) diverse slope exposures to the sun; c) variable rainfall regimes (ranging from 0 mm in Los Cóndores, Tarapacá, [20° 15' S - 70° 07 W] to 4,266 mm in San Pedro, Aisén, [47° 43' - 74° 55']) (di Castri & Hajek 1976); d) temperatures with ample variations between day and night; e) intense volcanic activity – more than two thousand volcanoes are located along the Andean cordillera and no less than 50 of them are active (Rottmann & Piwonka 1987, Leitch 1990); f) presence of two mountain chains (Cordillera de la Costa and Cordillera de Los Andes) that extend north to south throughout most of the country; g) remarkable geological and ensuing edaphic diversity; and h) proximity to the ocean for most of its territory.

In addition, the isolation of some parts of the Chilean territory due to the extremely dry Atacama Desert in the north, the Andes Mountain Range in the east, the continental ice caps, fjords, glaciers, and marine channels in the south, and the Pacific Ocean in the west, have caused the country to develop many biological aspects characteristic of an island, wherein many of the terrestrial species and ecosystems are unique to the country. For example, according to Udvardy's classification, four of the 227 world biogeographical provinces are found exclusively in Chile (Udvardy 1984). At the species level, over 55% of the vascular flora is endemic to Chile, a percentage higher than any other continental country in Latin America (Gajardo 1983, Marticorena & Quezada 1985, Davies et al. 1986). Regarding fauna, only Mexico and Brazil have a higher percentage of endemic vertebrates than Chile, with 30%, 24%, and 14% respectively (The Nature Conservancy 1988). This degree of uniqueness is an important indication of the richness of biodiversity in Chile.

The north has a vegetation that varies from the "Lomas Formation" in the coast, to barren lands inland. On the western Andean slopes there are deciduous scrub communities. In the high Andean plateau (puna), over 4,000 m of altitude, the vegetation changes to grasslands and some plant communities endemic to salt lakes and boglands (Gajardo 1983). In central Chile, the Mediterranean climate permits the existence of hard-broadleaf evergreen (sclerophyll) scrub and forest communities in lowlands, whereas the highlands are covered with montane southern beech forests, composed mostly of deciduous trees of the genus *Nothofagus* (e.g., *N. obliqua*, *N. glauca*). The southern part of the country contains large temperate forests. At lower elevations, where high humidity and mild temperatures permit the vigorous growth of vegetation, there is a lush broadleaved evergreen rainforest. It is typically composed of large trees, a dense understory forming two or three strata, and abundant amounts of lianes, mosses, lichens, bamboos, vines, ferns, and epiphytes. Its physiognomy is reminiscent of a subtropical rainforest (UNESCO 1981, Rottmann 1988, Leitch 1990, Alaback 1991). In high elevations there are southern beech (*Nothofagus*) forests mixed with coniferous trees (e.g., *Araucaria araucana* and *Fitzroya cupressoides*). The only glacial tundra in South America is located in the extreme south of Chile, which includes Tierra del Fuego and adjacent islands. This zone has a combination of temperate broadleaved evergreen rainforests and boggy moorlands, found in the lowland slopes near the channels, and evergreen and deciduous subpolar forests found in the mountains and farther inland.

The Chilean flora, besides its affinity to the vegetation of neighboring countries, is also related to vegetation found in places as distant as California, New Zealand and Sub-Antarctic islands, Tasmania, New Caledonia, Australia and Tristan da Cunha Archipelago (Godley 1960, Davies et al. 1986, Valdebenito et al. 1990).

Many classifications have been proposed at the ecosystem level, especially for terrestrial environments. Most of these ecosystem classifications are based on the climate or the type of vegetation cover. Some of the most important classifications which include the terrestrial environments of the entire country are: Reiche (1934, 1938), Pisano & Fuenzalida (1950), Schmithüsen (1956), Mann (1960, 1964), Oberdorfer (1960), Pisano (1956, 1966), di Castri (1968), Donoso (1981), Quintanilla (1981, 1983), and Gajardo (1983). Also, some classification systems based on fauna have been attempted (e.g., Osgood 1943 [mammals]; Johnson & Goodall 1965 [birds]; Peña 1966 [insects]; O'Brien 1971 [insects]; Artigas 1975 [invertebrates]).

As an example of the disparity in the classification of the principal ecosystems, according to Udvardy (1984), the Chilean territory includes parts of 3 of the 8 world realms (Neotropical, Oceanic, and Antarctic) and 12 of the 227 world biogeographical provinces (including the Chilean Antarctic Territory, Juan Fernández Archipelago, and Easter Island). For the same territory, di Castri (1968) defined 16 ecological regions (including the Chilean Antarctic Territory), and Gajardo (1983) proposed a division of eight ecological regions, 17 ecological subregions, and 83 floristic formations. Gajardo's classification system did not include either the Chilean Antarctic Territory or the oceanic islands, such as Juan Fernández Archipelago, Sala y Gómez, San Félix, San Ambrosio, and Easter Island.

Chile's ecosystem diversity is enhanced by its diverse marine life. This diversity is a result of about 10,000 km of coastline, upwelling currents, and national waters surrounding the offshore islands (IGM 1988). For example, 59% (33 species) of the marine mammals in the southern hemisphere are represented in Chile's coastal waters (Sielfeld 1983). Some classifications made for larger regions present some divisions for the Chilean sea (Balech 1954, Darlington 1968, Ray et al. 1984).

Designed for the national level, the description of Chilean marine life by Mann (1954), and the classification of Chilean marine environments proposed by Castilla (1975), are noteworthy attempts.

Species level

Different authors provide different species numbers for Chile. Gajardo (1983) indicated 4,758 vascular species, grouped in 190 families and 965 genera. Of these, 2698 species are endemic to Chile, 1632 are also present in other countries, and 428 species have been introduced and are naturalized. On the other hand, Marticorena (1990) asserted that the number of vascular species is 5,082, grouped in 192 families and 1,032 genera (Marticorena & Quezada 1985). Of the total number of vascular species, 157 are pteridophytes (ferns), including 120-125 continental taxa, 16 gymnosperms (conifers) and 4,946 angiosperms (flowering plants) (Gunkel 1984, Marticorena & Quezada 1985, Rodríguez 1989, Marticorena 1990).

Whatever the source, the endemicity of the Chilean flora is extremely high in many groups, in comparison with other parts of the world of similar size. For example, many genera of plants have restricted distributions; about one third of the 66 endemic genera are located in areas smaller than 3o latitude (Armesto & Arroyo 1991).

Chile's terrestrial and freshwater vertebrates are relatively well known. For the entire country, the number of terrestrial vertebrates is 722 (Simonetti et al. 1992), including 124 native mammal taxa. In addition, there are two domestic species of South American camelids (*Lama gLama* and alpaca *Lama pacos*), 15 introduced and naturalized mammals, and six species still not reported in the Chilean territory but probably found within it (Tamayo et al. 1987, Spotorno 1990). No fewer than eight genera of mammals are endemic to Chile (Osgood 1943). Also, there are 439 bird species (Araya 1985, Sallaberry et al. 1991), 97 reptiles (Donoso-Barros 1966, Veloso & Navarro 1988), and 41 amphibians (Cei 1962, Veloso & Navarro 1988), and 44 freshwater fishes (Arratia 1981).

Kuschel (1960) studied the relationships of southern Chile's terrestrial fauna with that in other countries and concluded that "a large number of elements in the fauna of southern Chile shows no phylogenetic relationship with the rest of the American fauna, but are related to groups in New Zealand, Tasmania, Australia, New Guinea, South Africa, and the Sub-Antarctic islands."

There is no complete compilation of marine species, except for marine mammals (Sielfeld 1983) and macro-algae, with 550 benthic species (Santelices 1989). The estimated number of fishes is 972 (Simonetti et al. 1992), distributed in places as ecologically different as the South Pacific sea, the Antarctic Sea, and surrounding oceanic islands in the Polynesia.

Due to the distinctive characteristics of Chile's oceanic islands, they have received special attention from scientists (Castilla 1987). The marine life of Easter Island and of Juan Fernández Islands, deserve special attention because of their diversity and endemicity. A total of 111 fish species have been recorded for Easter Island and 146 for the Juan Fernández Archipelago. Few species are shared between these two island groups and the percentage of endemics is relatively high (about 20%). Easter Island fish has a greater affinity with forms of the Tropical Indo-Pacific, whereas Juan Fernández has more elements from the Cold Temperate Region and the Eastern Pacific (Sepúlveda 1987). The marine benthic flora of Easter Island includes 166 taxa of algae and that of Juan Fernández has 110 species, but this number may be larger because many places are yet unexplored (Santelices 1987). Although published information is scarce, many invertebrate species likely flourish on Easter Island, given that high species diversity is often associated with warm waters and abundance of coral reefs, both characteristics of Easter Island. For example, of 115 species of littoral mollusks, 42% are endemic to this area (Rehder 1980).

For the whole country, the information on the number of species such as viruses, bacteria, molds, lichens, protozoans, sponges, nematodes, sea stars, corals, and arthropods is incomplete, disperse and obsolete (Simonetti et al. 1992). Some exceptions are fresh water algae (Parra & González 1977), benthic algae (Santelices 1989), fungi (Richatt et al. 1980), mosses (Mahu 1979), crustaceans (Retamal 1981), echinoderms (Larraín 1975), mollusks

(Osorio 1979), and annelids (Rozbaczylo 1985). Because it is difficult to give the exact numbers of species in each group, it would be useful to compile all the available information and identify where gaps exist. These data would indicate the number of species that comprise the biological diversity of Chile's territory.

Up to now no institutions have comprehensive computerized species databanks. The only exception is a databank managed by the University of Concepción's Laboratory of Botany which, in collaboration with the National Museum of Natural History and the University of Chile's Laboratory of Plant Systematics and Ecology, has a database on vascular plants (Armesto & Arroyo 1991).

Genetic level

Scientific knowledge about genetic diversity within species is almost nil, except for the potato (*Solanum etuberosum*), the genus *Nothofagus* (Donoso, 1987), and some genera endemic to the Juan Fernández Archipelago, such as *Dendroseris* (Crawford *et al.* 1987), *Whelenbergia* (Crawford *et al.* 1990), *Chenopodium*, and others (Stuessy *et al.* 1990).

Due to their high-quality timber and rapid growth rate, *N. alpina* and *N. obliqua* have been intensively studied by the Chilean Forest Service (CONAF), several universities, and some private companies. In terms of protection of genetic diversity, a 20-ha seed orchard with genetic material from *N. alpina* plus trees from different provenances was established in 1990, near Valdivia. This nursery will be capable of providing genetically superior seeds for planting 1,500 ha/yr (Chilean Forestry News 1990). Because Chile is a center of potato genetic diversity, all Chilean species and varieties of wild potatoes have been studied by the Austral University of Chile with the support of FAO and the International Board for Plant Genetic Resources (IBPGR). For vertebrates, some studies on genetic variation have been conducted on small mammals (e.g., rodents of the genus *Euneomys* by Reise & Gallardo 1990) and on some endangered species (e.g., vicuña [*Vicugna Vicugna*] by Norambuena 1992).

MAIN BIOLOGICAL, ECONOMIC, AND SOCIAL VALUES OF CHILE'S BIODIVERSITY

Terrestrial ecosystems

Some terrestrial ecosystems deserve special mention due to their unique characteristics and the high percentage of endemism among their component species. They include the Lomas formation in the coastal north (24-29° S), the sclerophyllous shrubland and forest (32-37° S)(IUCN/WWF 1987), the montane forests of northern deciduous *Nothofagus*. (33-37° S), the evergreen hard broadleaved forest (33-34° S), the temperate forest of the Juan Fernández Islands (33° S, 79° W), and the temperate evergreen rainforest (38-47° S).

The communities in the Lomas formation range from desert to mesic woodlands. This formation owes its existence to sea fog condensation on steep coastal elevated cliffs, and is a center of pronounced endemism and species diversity (Johnston 1929). Over 95% of the cacti in the Lomas are thought to be endemic, and over one third of the approximately 250 species of vascular plants are exclusive to this ecosystem (Petrov 1976).

Two of the most diverse ecosystems are the sclerophyllous forest and shrublands. "In open shrublands of the Mediterranean-climate regions of Chile, 108 plant species per 0.1 ha sample area have been reported" (Naveh & Whittaker 1979, cited in Mooney 1988).

The montane deciduous forests of *Nothofagus glauca*, *N. obliqua* var. *macrocarpa*, *N. leonii*, and *N. alessandrii* are found in relatively small and scattered habitats. All these tree species and some of their accompanying species are endemic to that portion of the Chilean territory.

The evergreen hard broadleaved forest is dominated by *Beilschmiedia miersii* and *B. berteroana*, *Persea lingue* and *P. meyeniana*, and contains many other endemic species.

The temperate forest of the Juan Fernández Archipelago is especially important for its diversity and uniqueness, because only a few plant species are related to those on the mainland. Skottsberg (1956) found that these islands contain 147 angiosperms, of which 69% are endemic to the archipelago. More recent information stated that there are 362 vascular plants, of which 210 are indigenous, with 60% of the latter being endemic to the islands (Marticorena 1983, cited in Ricci 1990). Besides the endemism at the species level, the endemicity at the generic level is very high (19%) and there are two endemic families (Lactoridaceae and Thyrsopteridaceae). Many plants from Juan Fernández have relatives in remote places, such as New Zealand, Malaysia, Hawaii, the Falklands, and other islands in the South Atlantic near Antarctica (Rottmann & Piwonka 1987).

The temperate evergreen rainforests of southern Chile –locally called Valdivian forest–, the Pacific Northwest forest in the USA, and the forest in southern New Zealand are the only cold-temperate rainforests in the world (McNally 1990). Southern Chile and the Pacific Coast of North America have the largest expanses of temperate rainforests in the world. The Chilean rainforest still has some unaltered areas and has a rich and varied fauna, with numerous insect, birds, and small mammals species, including marsupials (Kuschel 1960). In comparison with rainforests of North America, the Chilean rainforests possess about the same number of amphibian species, and lower numbers of reptile and mammal species (Meserve & Jaksic 1991). Some estimates indicate 315 genera and 743 plant species for South American temperate forests, with about half restricted to the Pacific slopes of the Andes. Greater endemism and diversity is found in the Coastal Mountain Range between 34 to 43° S (Armesto *et al.* in press).

Native forests were the most important source of timber for domestic consumption and exports. However, native wood production has declined since 1956 when timber from indigenous species represented almost 100% of the commercial harvest (Hartwig 1989). As of 1981, the "potentially productive" native forests, with more than 30 m^3/ha of timber in trees larger than 24 cm in diameter at breast height, are estimated to cover 7.6 million ha (10% of the country's area), with a total timber volume of 940 million m^3 (INFOR 1992). Most of natural forests is in private properties, being less than 1,5 million ha of them in the SNASPE (Ormazábal 1992). In the '80s, the average rate of deforestation was 50,000 ha/yr (0.7% of the total) and the average rate of planting (including afforestation and reforestation) was 93,000 ha/yr (WRI 1990). These figures include both natural forests and plantations.

In 1991, Chile's consumption of industrial wood was 17 million m^3, of which 66% was from Monterey pine (*Pinus radiata*) and 34% from *Eucalyptus*, poplars (*Populus* spp.), and native forests. The contribution of native forests is still low, even though this resource encompasses a potentially productive area about five times the area of plantations. However, the contribution of native forests to total wood consumption is greater when uses such as charcoal and fuelwood are considered.

In 1991, employment in the forestry sector was 103,322 people (2% of the total labor force), including silviculture, forest harvesting, industry, and forestry services (INFOR 1992). However, only a minimal fraction of these workers depend on native forests for their income, because about 90% of the forest production in Chile comes from plantations composed mainly of introduced species (86.5% *Pinus radiata* and 5.5% *Eucalyptus* spp.) (Hartwig 1989). In 1990, while the total value of exports of the forestry sector was US$855.3 million, only US$73.8 million (8.6%) came from native species (CORMA 1991). In 1992, forestry exports totalling US$1.125 billion (INFOR 1992).

Terrestrial species

At the species level, and from the market viewpoint, the most important contributors of biodiversity to the national economy in terrestrial environments are timber trees. Although there are 125 native tree species (Rodríguez *et al.* 1983), including tree-sized ferns and cacti, only 25 species are commercially valuable for timber. They are located mainly in the central-south and austral zones of the country (i.e., south of 35° S). According to data on sawnwood production, in 1991 the most important of these trees were: *Laurelia philippiana*) (88,000 m^3), *Nothofagus dombeyi* (81,000 m^3), *N. obliqua* (72,000 m^3), *N. alpina* (31,000 m^3) and *Nothofagus pumilio* (30,000 m^3). All the remaining timber species, such as *Laurelia sempervirens, Podocarpus nubigena, Saxegothaea conspicua, Eucryphia cordifolia), Weinmannia trichosperma*, and others, account for less than 4,000 m^3 each and for a total of 83,000 m^3. Because several of the Chilean timber trees have been intensively exploited since colonial times, commercially exploitable trees are now scarce, although there are still many stands with immature trees of these species. That is the case for *Persea lingue* and *Austrocedrus chilensis*.

Some tree species of central Chile are very important, especially for economically disadvantaged people, because they represent the main source of energy for cooking and heating. The most popular trees used for fuel and charcoal are *Quillaja saponaria, Lithrea caustica), Cryptocarya alba, N. obliqua*, and *Acacia caven*. Some species are producers of chemical compounds, such as *Quillaja saponaria*, which produces saponin in bark and leaves, and *Peumus boldus*, which produces boldine in its leaves. Raw materials of both trees have been exported in large quantities for many years, giving employment to many unskilled workers.

Some endemic trees and shrubs are good producers of fodder. The most important among these trees is *Prosopis tamarugo*, planted over 20,600 ha (INFOR 1992) in the Atacama Desert and in many other arid and semiarid zones in the world (Habit 1985). A very promising native forage shrub is *Atriplex repanda*, which is planted on 15,000 ha (CONAF IV Region 1990) in the Coquimbo region in north-central Chile, and is being promoted in several other dry regions of the world.

There are also many other plants that are good producers of fodder, of bee forage, seeds, fruits, fiber, natural chemical products (Muñoz 1992), flower arrangements, and others used for medicinal and ornamental purposes. About 30 genera of native plants have relatives that are used in agriculture (Ormazábal 1987).

Unfortunately, the current methods of assessing values or contributions from native ecosystems and species do not take into account the non-timber products extensively used by Chileans, especially by low income people. All these values need to be monitored to understand better the contributions of native ecosystems and species to the national economy.

Marine ecosystems and species

According to Ray's classification, five marine environments are located on Chile's South American coast. Two of them are exclusive to the country (Ray *et al.* 1984). Unique characteristics are also present in the marine environments surrounding the Juan Fernández Archipelago, Sala y Gómez Island, San Félix, San Ambrosio, and especially Easter Island. Many benthonic species of fishes as well as mollusks, crustaceans, and algae are endemic to Chilean waters (Castilla 1975, Santelices 1989).

According to the National Fishing Service (SERNAP), marine species commercially used in Chile for industrial and subsistence purposes number 108 (SERNAP 1991). They are distributed among fish (59) –excluding several introduced species such as salmon and trout–, mollusks (27), crustaceans (11), algae (8), and others (e.g., *Loxechinus albus, Otaria flavescens*). Nevertheless, there are fewer commercially important species. Many of these marine organisms with commercial importance are endemic to zones adjacent to the Chilean coast. Some of them are: *Ostrea chilensis, Pyura chilensis, Mytilus chilensis, Megabalanus psittacus*, and *Genypterus chilensis* (Castilla 1976).

Because of the 200 nautical mile marine Exclusive Economic Zone, from Cape Horn to the Peruvian border, Chile ranks 5th in world fishery landing. Landings in Chile during 1986 represented 7% of world catches of marine fish (FAO 1987). Industrial fishing, especially for fishmeal, is predominant in Chile. In 1990, 97.5% of the harvest was processed, 88.2% as fishmeal and 9.3% was canned and frozen (SERNAP 1991).

The revenues for exports of fish and other marine products were US$ 934 million in 1989 (Achurra 1990). In that year, Chile's landing was 6.3 million metric tons, of which 10.2% was artisanal (Robotham 1990). Pelagic species accounted for 92%, demersals 3%, benthonics and fish farming 5% (SERNAP 1991). In 1990 the catch diminished, to a landing of 5 million metric tons of fish, 228,861 tons of algae, 105,718 tons of mollusks, 26,713 tons of crustaceans, and 19,795 tons of other species (SERNAP 1991). Fishmeal was the main export product with a value of US$ 511 million in 1989 (Achurra 1990).

In 1982, Chile had 41,409 fishermen, composed of 18,455 artisanal fin-fishermen, 11,655 shellfish harvesters, and 11,299 seaweed gatherers. In 1989, the number of fishermen grew to 58,000 (Robotham 1990). The industrial sector is composed of large scale fishing operations on the high seas in vessels larger than 50 gross tons, and land based plants for processing the catch (canning, freezing, or reduction). The industrial fleet in 1985 consisted of 302 purse seiners, 58 trawlers and 11 factory ships (CORFO 1986).

MAIN THREATS TO CHILE'S BIODIVERSITY

Terrestrial environments

The main threats to natural terrestrial ecosystems in Chile are forest fires, mining, fuelwood collection in dry lands, pollution, logging, and land use changes. Minor problems are poaching and encroachment of public lands by squatters. The relative importance of each problem varies according to ecological zones. In some zones, introduced wildlife such as rabbit, beaver, hare, deer, and mink have created ecological disturbances.

Ecosystems in arid and semiarid zones are being altered by mining, pollution, animal husbandry, fuelwood gathering, and water tapping. Cacti are threatened by collectors, and these ecosystems as a whole are being endangered by population pressures (MacPhail & Jackson 1973). The need for conservation is critical here because most of Chile's dryland ecosystems are not represented in protected areas (Ormazábal 1986a).

In the Mediterranean-climate zones, natural ecosystems, especially the sclerophyllous, montane, and hard broad leaved forests are being affected by agriculture, livestock browsing, replacement by forestry plantations with introduced species, forest fires, and collection of fuelwood. All these activities are very intense because about 74% of the country's 13 million population lives in central Chile (32-38° S) (Arzón 1992). Critical sites of Mediterranean-climate ecosystems are located very close to cities. Only a few ones remain relatively untouched, such as those on the southern slopes of the Coastal Range near Lo Prado, and the Macizo de Cantillana.

In the montane forests of the Maule and Bio-Bío regions, northern *Nothofagus* forests have been largely replaced or deteriorated by agriculture, livestock farming and *Pinus radiata* and *Eucalyptus* spp. plantations. Particularly in the Maule Region, these factors have led to the local extinction or endangerment of a multitude of native plant and animal species (Römpczyk 1988, Lara *et al.* 1991). Therefore, these diminishing indigenous forests, rich in endemic species having restricted distributions, increasingly appreciate in strategic value and ecological importance (Ormazábal 1989). One example is the tiny Los Ruiles Forest Reserve, which within its 45 ha protects two of the four most endangered tree species in Chile (*Nothofagus alessandrii* and *Pitavia punctata*).

The reduction of the remaining relatively well conserved forests of the Andean Precordillera of Maule (VII Administrative Region) and Bio-Bío (VIII Administrative Region) could affect the genetic variability of valuable timber species such as *Nothofagus dombeyi*, *N. pumilio*, and *N. alpina*, whose northern distribution boundary is in this zone (Donoso 1987, Ormazábal & Benoit 1987). Scientists that attended the "Symposium on Chilean Threatened Trees and Shrubs" identified the Maule Region as an area with important genetic resources. The Maule Region concentrates the four *Nothofagus* taxa endemic to Chile (*N. obliqua* var. *macrocarpa*, *N. alessandrii*, *N. glauca*, and *N. leonii*) (Rodríguez *et al.* 1983), and the four most endangered tree species in the country (*Beilschmiedia berteroana*, *Gomortega keule*, P. *punctata*, and *N. alessandrii*) (Benoit 1989a).

Within the 1,000 km between Valparaíso and Puerto Montt, private companies are buying lands to plant with pines and *Eucalyptus* spp., because of the good growth rates and closeness to forestry mills and seaports. In this situation, the main responsibility of the Government is to ensure that the new plantations are not replacing native forests appropriate for sustainable management, and to assure through socially accepted mechanisms the conservation of the identified places with high endemism and diversity.

About half of the endemic species of Juan Fernández Islands are endangered (Davies *et al.* 1986). One of the most threatened, is *Lactoris fernandeziana*, in the monotypic family Lactoridaceae. Despite the fact that 95% of the Juan Fernández islands area has national park status, historic deforestation, soil erosion, and domestic and feral animals –including European rabbits, goats, sheep, coatimundis and horses– are seriously threatening the original ecosystems (Stuessy *et al.* 1984). Also, introduced plants pose a serious threat to the native flora. Since the discovery of the islands more than 400 years ago, a number of additional angiosperm species have also been introduced. The number of weedy taxa now equals that of the native flora (Skottsberg 1922, Sanders *et al.* 1982). An important fraction of the original forest is gone from the islands, as a result of introduced plants and animals. The amount of forest area that disappeared between 1917 and 1983 varied from 9% to 67% in seven study sites and natural revegetation is almost non-existent due to the introduced species of flora and fauna (Stuessy *et al.* 1984). Fortunately, CONAF is executing a recovery and protection plan for the most endangered species, with the financial support of the World Wide Fund for Nature, WWF.

In the temperate rainforest, the main threats to biodiversity conservation are inadequate logging, grazing and browsing within the forest, artisanal fuelwood production, change in the land use to agriculture and pasturelands, and substitution of native forests for plantations with alien tree species. "Over 50% of the Chilean endangered or vulnerable species live in the temperate region. Habitat destruction and illegal harvesting are the prime factors diminishing their populations" (Simonetti & Armesto 1991).

Since 1986, exports of wood chips derived from native forests have increased drastically provoking opposition from some Chilean and foreign environmental Non Governmental Organizations (NGOs). The main criticisms have been directed at the limited control on compliance of management plans of native forests that the government can exert, due to the insufficient funds and personnel allocated to this activity. On the other hand, the value of exports has grown drastically, improving employment and economic activity in undeveloped zones. While in 1986 wood chip exports amounted to US$ 3.5 million, in 1991 they reached US$ 151.5 million. US$ 85.5 million (51%) came from 1.7 million m^3 of native wood and the remaining from eucalyptus (US$ 55 million) and *Pinus radiata* (US$ 15 million) (Lagos 1992).

Technically, there is nothing wrong with chip production. On the contrary, it could be the solution for recovering and upgrading the historically selectively exploited native forests of the country by making the urgently needed silvicultural practices profitable, and by providing a market for woody material resulting from thinnings and sanitary cuttings. The real problem is how to assure that high-quality young trees and the genetically valuable parent trees will be left standing, instead of using them as material for chips.

As a way to face these challenges, in April 1992 the Government submitted to Congress a bill on native forests. The discussion process has involved many key players, such as environmental NGOs, university forestry schools, forestry companies, the National Association of Professional Foresters, and other organizations (Chile Forestal 1992). Enacting a law on native forests that clearly defines the role of public and private natural forests, seems to be an adequate approach to reconcile Chilean economic and social needs with the need to conserve and promote sustainable use of these forests. Nevertheless, additional means should be explored, especially for those biomes which do not have (or have insufficient) coverage in the National System of Protected Wildlands (SNASPE, Spanish acronym for Sistema Nacional de Areas Silvestres Protegidas del Estado). In this latter case, general legislation is not enough. An effective way to protect their integrity is to incorporate adequate samples of those forests into SNASPE. Toward that purpose, some proposals have been formulated (Ormazábal 1986a, Valencia *et al.* 1987).

Marine environments

The main problems of preserving biological diversity in Chilean marine environments are: a) over-fishing; b) pollution due to industrial activities and coastal cities; c) ecological alteration because of introduced species (CIPMA 1990).

The central issues in the fishery sector are establishing whether the current rate of exploitation is sustainable, overall and by species, and how to regulate harvests. The strong demand for marine products has stimulated intensive harvesting pressure and requires nearly permanent regulation and control by authorities.

There is some evidence that certain species have been stressed due to excessive fishing pressure (e.g., *Concholepas Concholepas*, *Loxechinus albus*). Some species are clearly over-harvested already (e.g., *Lithodes antarcticus*, *Ostrea chilensis*, *Jasus frontalis*), whereas other species reveal large fluctuations in abundance from year-to-year due to environmental factors (e.g., *Clupea bentincki* and *Engraulis ringens*). The rate of exploitation has an impact on the food chain and thus on species not harvested.

Knowledge of the Chilean fisheries stock is inadequate, and little analysis has been made on whether the commercial harvesting of species is depleting these resources beyond their sustainable levels. Insufficient research is being done about the biology of marine species and ecosystems. This problem is aggravated by the increasing pollution of Chilean marine environments.

Resource management measures include catch quotas, size limits, and seasonal bans, but these are difficult to enforce. SERNAP is responsible for applying the standards but has few officials and no vessels. The National Committee for the Defense of Flora and Fauna (CODEFF), the main Chilean conservation NGO, has demonstrated special concern and contributed to the protection of marine mammals.

Aquaculture, or fish farming, may offer a solution to stock problems, but is not effective for pelagic (open sea) species, such as sardines. Aquaculture is being used effectively to increase production of high value species such as trout, salmon, oysters, mussels, scallops, and algae (SERNAP 1991). However, fish farming in lakes is receiving strong criticisms from environmental NGOs and other social organizations. They argue that this activity brings about pollution and threatens native fish species due to the escape of the introduced salmon and trout.

For marine plants, the protection afforded is insignificant. Strong human pressure is placed on some marine algae (seaweeds), especially on *Gracilaria* spp., *Lessonia nigrescens*), (*Iridaea* spp.), and *Durvillaea antarctica*.

Other fishery sector concerns include: a) lack of management of guano bird colonies in the north; b) under-utilization of some marine resources (e.g, for seals only their fur is used, for crabs only their claws are utilized, and production of fishmeal from high-quality fish); c) illegal killing of dolphins, penguins, and seals for use as bait in king crab extraction.

ACTIONS EXECUTED IN CHILE TOWARD BIODIVERSITY CONSERVATION

Terrestrial ecosystems and species

a. National legislation

In Chile, the concern for protecting nature, including its biological diversity, had its legal origin when the country was a colony of Spain. In the sixteenth century, Spanish rules and laws were enacted to protect the forests. The first Chilean decrees and laws for protecting forests or certain tree species were issued in the nineteenth century. The first supreme decree on "forest cutting" was enacted in 1859. It was specifically targeted to control the exploitation of the *Fitzroya cupressoides* forest (Cabeza 1988).

Lately, several decrees protecting or controlling the exploitation of other plant species (e.g., *Quillaja saponaria, Azorella compacta, Weinmannia trichosperma*) have been enacted. Also, there are regulations that selectively protect some species, declaring them as "natural monuments" (e.g., *Fitzroya cupressoides* and *Araucaria araucana*, through decrees enacted in 1976).

In 1980, the Ministry of Agriculture's Supreme Decree 259 classified the Chilean native forests into twelve "forest types" and defined legally accepted harvesting methods for each type. These standards tend to secure an adequate replacement of the forest, whether through natural regeneration or planting.

In addition to these efforts on plant protection, biodiversity conservation for wildlife has been attempted through other means, such as the enforcement of the Hunting Law (enacted in 1929) and its successive regulations. The latest hunting regulation (Supreme Decree 133, June 1992) prohibits the capture or killing of all vertebrate species, except for those introduced or those indigenous animals that are clearly abundant.

The National Commission on Environment (CONAMA) presented in April 1993 a draft of an "National Action Plan to Protect Biodiversity". In addition, the National Committee on Scientific and Technical Research (CONICYT) created a National Sub-committee on Biodiversity.

b. Protected wildlands

1. Ecological coverage through the SNASPE

Chile is a pioneer in the creation of protected areas in Latin America. The Malleco Forest Reserve was created in 1907 and the Vicente Pérez-Rosales National Park in 1926. Lately, especially during the '60s, many other protected areas have been established. In 1984 a National System of Protected Wildlands (SNASPE) was created by Law 18362 -published in the Official Gazette on December 27, 1984. Most of the existing national parks and forest reserves were integrated into the System. The exceptions were those units that did not comply with minimum requirements to become part of the SNASPE. Article 1 of Law 18362 states the following objectives related to the conservation of biodiversity: "To maintain wildlands, noteworthy for its uniqueness or representation of the country's natural ecological diversity, ... with the purpose of ... securing the continuity of the evolutionary processes, the animal migrations, the patterns of genetic flow ... and ... to maintain and improve wild flora and fauna resources and to rationalize its utilization."

There are 80 land units in SNASPE. They comprise a total area of 13,832,184 ha, equivalent to 18.3% of the national territory. They are distributed in 30 national parks with 8, 358, 367 ha, 39 national reserves with 5, 459, 345 ha, and 11 natural monuments with 14,472 ha (CONAF 1992). Regarding the land gazetted as protected areas, 95% are public lands and 5% remain in private hands (Cunazza 1989). In addition, there are many other legally protected wildlands classified into management categories such as Scientific Interest Reserves and Tourist Protected Areas. They are not considered part of the SNASPE because they are primarily private lands. Also, there are no privately owned protected areas that are legally established or recognized in the country. The new bill on environment, includes the framework for the creation of private protected areas.

Since 1980, the main objective for creating conservation units has been to protect biological diversity. Ten of the 18 protected areas (13 national reserves, 3 national parks, and 2 natural monuments) established between 1980 and 1991, have incorporated floristic formations (Gajardo 1983) previously absent from the SNASPE.

Although Chile is second in South America and seventh in the world in percentage of national territory allocated to protected areas (WRI 1990), the SNASPE's representation of the natural diversity of the country is still inadequate (Ormazábal 1986a, 1986b, Valencia *et al.* 1987). This is due to an inappropriate territorial distribution of protected areas, with 86% of them concentrated in the southern third of the country, from 43° S to south. This pattern of distribution has resulted in the protection of only 54 out of 83 of the floristic formations present in Chile, according to the classification proposed by Gajardo (1983). This means that the SNASPE lacks 35% of the country's floristic formations (Ormazábal 1986a, CONAF 1989a, Benoit 1991). Valencia et al (1987) indicated that coastal, desert, semiarid, and polar regions are poorly represented in the SNASPE.

Even in well represented biomes, such as the temperate zone, some tree species (e.g., *Beilschmiedia berteroana, Gomortega keule*) are not included in the SNASPE (Simonetti & Armesto 1991). Tree species richness is greatest between 37-40° S, and declines sharply toward higher latitudes. Endemic taxa are also found largely in the same region, their presence decreasing both to the south and north. While this area concentrates over 90% of all tree species in the temperate forest, only 3.8% of this land is in the SNASPE (Armesto *et al.* in press).

The number of native tree species in the country has its peak in the Bio Bío and Maule regions. However, in the national context Bio Bío has only 2.23% of its territory allocated to protected areas and Maule has the smallest proportion, with less area included in the SNASPE than any of the 12 other administrative regions of the country, comprising a total of only 794 ha (0.02% of the Maule Region's area). Only 45 ha of those correspond to native forests and the remaining is composed of lakes, sand dunes, pine and eucalyptus plantations (Ormazábal 1986a, 1986b).

2. Reasons for the existing gaps in the ecological coverage of the SNASPE

The reasons vary depending on the zone of the country. For the Central Zone (Coquimbo to Chillán), the main reasons are the lack of public lands and the high degree of alteration of indigenous ecosystems. This zone has the highest population density of the country and it was also the first to be settled by the Spaniards. After almost 500 years of colonization, the pristine or scarcely altered lands are few, except for the high mountains and some of their slopes and creeks. As a result, the process of establishing protected areas in the Central Zone has been slow and spotty. This history is reflected in the small size of the few existing protected areas and in the predominance of national reserves, with flexible requirements and management standards (Weber 1990).

CODEFF, with WWF funding, has surveyed the exploitation of native forests in the two most critical administrative regions (Maule and Bio-Bio). It also identified the remnants of native forests and selected the four best remaining sites for conservation of that type of indigenous forests. Potential areas to protect were visited and given a rating according to several criteria. All these areas are privately owned (Lara *et al.* 1991).

Unfortunately, buying lands for conservation is not a priority for the Government and private actions have been extremely rare in Chilean conservation history. The only private foundation with a focus on conservation, the Lahuén Foundation, was created just in 1991. As of mid 1993, this foundation bought 600 ha of araucaria forest, a type of forest already well represented in the SNASPE.

Some government institutions have rejected CONAF's proposals for them to transfer highly valuable lands for conservation, preferring to sell those lands to the private sector. One outstanding example of this policy is the case of the El Radal farm (7,200 ha with native forests in the Pre-Andean Cordillera of the Maule Region), where a government institution refused, since February 1986 to mid-1991, several official petitions from CONAF and the Ministry of Agriculture, to transfer the El Radal farm to the Ministry of Public Lands; this is the legally necessary step to create a protected area belonging to the SNASPE. That government institution insisted in auctioning the farm to the highest bidder. Fortunately, in October 1991, under strong public pressure including that of local NGOs, politicians, CONAF, the National Tourism Service, and the Ministry of Agriculture, it agreed to transfer the land to the public domain. However, as of July 1993, the transfer has not occurred.

In northernmost Chile, most of the area belongs to the government because there is little private interest in acquiring land there, due to the aridity of that part of the country. Unfortunately, the places with high species diversity and endemism belong to mining companies (e.g., Paposo, near Taltal city, the most noteworthy zone for cacti in the country). In other cases, the interests of mining and water companies conflict with the conservationist interests and have prevented the creation of protected areas (e.g., Laguna del Negro Francisco, east of Copiapó City). Another reason for the lack of representation of arid and semiarid ecosystems in the SNASPE has been the trend in the past toward protection of scenic landscapes with forests, disregarding that dry ecosystems are also worthy of conserving.

3. Species and genetic representation in the SNASPE

It is not possible to make an exhaustive analysis of the species represented in protected areas, because the number of species in each national park or reserve is not adequately known. The protected areas for which there are relatively complete species inventories are few. Vascular species in the national parks of La Campana (Villaseñor 1986), Tolhuaca (Ramírez 1978), Puyehue (Muñoz 1980), and Cape Horn (Pisano 1980, 1982a, 1982b) are the exceptions and have relatively complete inventories. In general, there is some information on vertebrates and vascular plants but data are almost non-existent for invertebrates and lower plants (lichens, algae, fungi, etc.).

At the genetic level information is even more scarce. Evaluations of the protection given to different populations of native species are extremely rare. Distributional studies of species populations included in protected areas have only been done for the 10 tree species in the genus *Nothofagus* (Ormazábal & Benoit 1987).

Despite insufficient information on the genetics of endangered species, CONAF has protected many of their populations, and has tried to cover the maximum morphologic variability. This has been the case for mammals such as *Hippocamelus bisulcus*, *Hippocamelus antisensis*, *Vicugna Vicugna*, *Lama guanicoe*, and *Chinchilla lanigera*, for birds such as *Pterocnemia pennata*, *Cyanoliseus patagonus*, and (*Cygnus melancoryphus*), and for trees such as *Nothofagus alessandrii*, *Beilschmiedia berteroana*, and *Gomortega keule*. The best results in population recovery have been *V. Vicugna*, *L. guanicoe*, and *C. melancoryphus*. For example, *V. Vicugna* in Parinacota Province increased from about 1,000 in 1973 to 7,900 in 1980 (CONAF 1989) and to 26,144 in 1990. *Lama guanicoe* in Tierra del Fuego Province increased its population from 6,663 in 1980 (CONAF 1989) to 14,604 in 1990. *Cygnus melancoryphus* in Laguna Torca National Reserve and surrounding wetlands increased from 296 in 1979 (CONAF 1989) to 1,198 birds in 1990 (CONAF, unpublished census).

4. Threats to biodiversity conservation within the SNASPE

Biodiversity conservation within protected areas is threatened by mining activities, water tapping in dry zones, forest fires, pollution, and resource use pressures from surrounding communities, in a way incompatible with protected area management (e.g., cutting of vegetation, introduction of domestic animals to wildlife habitats).

Juan Fernández Archipelago, the most important Chilean national park from the point of view of plant endemism, is simultaneously the most threatened park in the country. In 1984 this park was included by The International Union for the Conservation of Nature (IUCN) in the Register of Threatened Protected Areas of the World; IUCN identified the threats as "introduced plants and animals and erosion caused by livestock grazing" (IUCN 1988). La Campana National Park is the only protected area that includes hard broad leaved forest, Chilean palm tree (*Jubaea chilensis*) forest, and the northernmost fringe of the distribution of the genus *Nothofagus* in the Western Hemisphere. This park is at the same time the second most threatened protected area in the country, suffering from mining, illegal grazing, and forest fires (once, a single fire burnt more than 15% of its 8,000 ha).

5. Protected areas with special biological values

Some of the current 80 protected areas have higher priority because they have unique or threatened ecosystems, although they comprise a small proportion of the total SNASPE area. In addition they are significant for being units that protect many species with restricted distribution or highly endangered species. These areas are located in northern and central Chile, from the Tarapacá Region to the Maule Region (17° to 35° S). These units include the national parks Pan de Azúcar, Fray Jorge, Juan Fernández Archipelago, and La Campana; and the national reserves Pampa del Tamarugal, Las Chinchillas, Río Clarillo, Río de los Cipreses, and Los Ruiles.

c. New approaches for protecting flora and fauna

The Chilean Forest Service has carried out a participative strategy to assign priorities for conservation of terrestrial ecosystems and species; the latter including some marine mammals (e.g., *Lutra felina*), penguins (e.g., *Spheniscus magallenicus* and *S. humboldti*), and fresh water fishes. The first step of the strategy was to determine an official conservation status for native species of flora and fauna in order to define regulations of permissible levels of use, and to establish priorities for *in situ* recovery and conservation projects or programs. The species conservation status was assigned by experts, from all universities, public institutions, and conservation NGOs.

Three symposia were organized to reach agreements on species conservation status and one symposium for ecosystems. IUCN categories of threats and criteria to determine such status were used. The main conclusions of those symposia are summarized below:

1. Symposium on Chilean threatened trees and shrubs

This meeting was held in August 1985 in Santiago. It brought together the national specialists on vascular flora. Its purpose was to define the conservation status of tree and shrub species. The main conclusions were: 11 species are Endangered, 26 are Vulnerable, and 32 are Rare (Benoit 1989a). Currently, CONAF is taking action in the field to find, protect and recover the remnant populations of these species. In addition, CONAF contracted with the University of Chile a study of 141 sites where those endangered species concentrate (Gajardo *et al.* 1987).

2. Symposium on Chilean threatened terrestrial and fresh water vertebrates

This meeting was held in April 1987 in Santiago. It gathered the national specialists on terrestrial and fresh water vertebrates. Its purpose was to define the conservation status for those species. It concluded that 50 species are Endangered, 92 are Vulnerable, and 53 are Rare (Glade 1988). A consequence of the symposium is that conservation activities on species previously without protection have been started.

3. Symposium on Chilean threatened herbs and succulents

This meeting was held in September 1988 in Valparaíso. This symposium brought together botanists with different specialties. On this occasion conservation status of specific groups of plants were proposed. Hoffmann & Flores (1989) presented a paper on cacti and other succulent plants; Rodríguez (1989) one on ferns; Hoffmann (1989) one on plants with bulbs, rhizomes, corms, or tubers. In addition, a follow-up of the species classified in the 1985 symposium (Benoit 1989b) and a proposal for protecting highly endemic and diverse plant sites (Ormazábal 1989) was issued.

4. Symposium on priority sites for conservation of Chile's terrestrial biodiversity

This meeting was held in April 1993 in Santiago. It gathered the national specialists on indigenous flora, fauna and ecosystems. The symposium was aimed at identifying the highest priority sites for the conservation of biological diversity throughout Chile. It concluded that there are 72 priority sites. Of these, 20 sites are placed in first priority, 26 in second, and 26 in a third level of importance and urgency to integrate into SNASPE. These sites are located mainly in northern and central Chile. Their main values are high diversity and endemism of species. In addition, the floristic formations where these species belong are absent or subrepresented from the SNASPE.

In addition to working on threatened species, CONAF is also focusing on the identification and selection of priorities for sites where fauna is concentrated. These are specific places, generally different from the surrounding areas, such as estuaries, ponds, small islands, etc., where a high diversity of species exists, especially of birds and in some cases of mammals, and where there is a high population abundance per species. CONAF contracted studies on faunal concentration sites in northern and central Chile, which identified, described, and selected priorities for sites located between the Tarapacá (17° S) and Maule (36° S) Regions (Schlatter *et al.* 1987, Chang *et al.* 1989).

Marine resources protection

The responsibility for protecting living resources in marine environments lies in SERNAP, a public institution under the Ministry of Economy. Its mission is to establish and monitor regulations for marine species of flora, fauna, and for fishing and fisheries in marine and fresh waters. In addition, the General Directorate of the Marine Territory and Merchant Navy (DIRECTEMAR) is the institution in charge of protecting the sea and its inhabitants from pollution.

An urgent priority in marine systems conservation, is to establish protected marine units. This necessity has been highlighted in many meetings and scientific papers. Since 1976 scientists have unsuccessfully proposed the creation of marine national parks (Castilla 1976, 1986, Benoit 1982). Castilla (1976) formulated concrete proposals indicating specific sites, stating their natural values, and proposing possible boundaries. A good starting point to protect the marine environments could be the enlargement into the Pacific Ocean of the present littoral borders of certain coastal national parks (e.g., Pan de Azúcar, Fray Jorge, Rapa Nui, Juan Fernández Archipelago, and Chiloé).

International agreements on conservation signed by Chile

Chile is actively involved in the legal protection of biodiversity. Besides internal legislation, Chile has signed most of the international agreements on environmental protection for both terrestrial and marine environments (WRI 1990). The country has ratified nine conventions on flora and fauna protection –including the Biodiversity Convention– and six on pollution and natural heritage protection.

In addition, Chile has seven biosphere reserves in UNESCO's Man and Biosphere (MAB) Program. These reserves encompass a total area of 2,406,633 ha (WRI 1990). However, the degree of representation of Chilean biogeographical provinces in the existing biosphere reserves is insufficient and it seems necessary to create some additional units (Weber 1983).

There are at least three Chilean national parks that meet the requirements to be included in the World Heritage Sites List, under the Convention Concerning the Protection of the World Cultural and Natural Heritage. They are Juan Fernández Archipelago and Torres del Paine for their natural values, and Rapa Nui (Easter Island) for its cultural values.

The only Chilean wetland identified by the UNESCO "List of Wetlands of International Importance" is Carlos Andwandter Sanctuary. This unit has 4,877 ha and meets the requirements of the Convention on Wetlands of International Importance, Especially as Waterfowl Habitat (RAMSAR Convention) (IUCN 1990). However, this area is receiving only sporadic and partial protection because it is not included in SNASPE.

CONCLUSIONS AND RECOMMENDATIONS

Based on what was stated before, I offer the following conclusions:

1) Chile has been collaborating in the global effort to avoid further biodiversity losses. Since the last century it has enacted legislation, developed institutions, and conducted activities that favor biological diversity. Nevertheless, some of the legislation and actions can be characterized as being too specific, obsolete, dispersed, or uncoordinated. Their modernization, systematization, and inter-institutional coordination is urgently required.

2) The approach developed by CONAF to reach consensus and select the most threatened plants, vertebrate species, and ecosystems through symposia is innovative, modern, participative, and efficient. These programs have been developed using internationally recognized and recommended policies, strategies, and criteria. A coherent program will help Chile face the challenge of conserving biodiversity. Other needed actions are to define the conservation status for species not included in previous symposia, and to begin programs to recuperate the populations of the most threatened species. For that purpose, it is essential that CONAF reinforces its present activities and starts actions to protect amphibians, reptiles, cacti, and non-woody terrestrial plants. This strategy entails a strengthening of CONAF's human and material resources.

3) For ecosystems there is no scientific consensus yet about how many, which ones, what their boundaries should be, and what are the priorities for conservation. This lack of agreement suggests that, considering the successes of symposia on plants and vertebrates, a similar scientific meeting is urgently needed to reach consensus about the most appropriate classification system for Chilean ecosystems.

4) No matter which classification system of Chile's natural terrestrial ecosystems is used as a reference to assess their representation or coverage in the SNASPE, there clearly is inadequate protection of some of these ecosystems. About one third of the country's major floristic formations are not included in the SNASPE. Arid and semiarid ecosystems in the northern third of the country and the Me-

diterranean-type ecosystems of central Chile are particularly lacking representation.

5) It is urgent that activities to protect aquatic ecosystems be started. Important steps should include the creation of coastal and marine protected areas, and the strengthening and expanding of functions of public institutions regulating fisheries and controlling the pollution of marine environments.

I also propose that the main challenges for enhancing the protection of Chile's biological diversity during the '90s are (not necessarily in priority order):

1) To stimulate scientific research, surveys, and monitoring to improve knowledge on ecosystems, native species, and their genetic variation. This information is needed not only at the national and regional or provincial levels, but also at the protected area level, trying to meet the requirements of different detail for each level (e.g., scales of maps). Special attention should be given to threatened species, their distribution, abundance, and their protection and propagation methods.

2) To establish and support modern data bases on biological diversity and make them accessible to interested people and institutions. In order to accomplish this aim cooperation among national and international institutions should be promoted to fill in gaps and update information.

3) To complete the ecological coverage of the SNASPE by reducing gaps at the level of major ecosystems and communities still not included (e.g., ecological regions and floristic formations). Also, samples of unique and representative marine ecosystems should be incorporated into the System. The design, size, and management of existing areas should be improved to meet biodiversity needs. Inventories of ecosystems, communities, species, and varieties of flora and fauna should be made within each protected area.

4) To improve, organize and coordinate into a single administrative system, the policies and legislation on indigenous ecosystems and species.

5) To design and implement policies and operational mechanisms for integrating protected areas with the economy and local people of adjacent lands, in order to reduce undesirable pressures on biodiversity from surrounding communities. Also, quantitative data on socioeconomic contribution of biodiversity are urgently needed. The knowledge of local and indigenous people on biodiversity needs to be retrieved and disseminated.

6) To strengthen public institutions in charge of terrestrial and aquatic biodiversity protection by increasing personnel, budgets, and providing access to modern technology. Personnel should be trained in biodiversity conservation; actions to stop or reduce the causes that diminish biodiversity should be implemented.

7) To enhance programs on environmental education, to develop constituencies and raise awareness on the importance of biodiversity for human welfare. These programs should address the entire national community, with emphasis on authorities, political forces, decision-makers, teachers, and students.

8) To establish foundations and create other mechanisms to assure a steady source of funds for supporting programs on biodiversity conservation and development.

9) To develop strategies to protect and preserve biodiversity in lands that are being managed to produce natural goods. For example, to leave untouched strips of native forests in gulleys, ravines and next to streams in forest plantations.

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LITERATURE CITED

ACHURRA M (1990) Exportaciones pesqueras en 1989. Chile Pesquero 57: 23-26.

ALABACK PB (1991) Comparative ecology of temperate rainforests of the Americas along analogous climatic gradients. Revista Chilena de Historia Natural 64: 399-412.

ARAYA B (1985) Lista patrón de las aves chilenas. Segunda edición. Universidad de Valparaíso, Instituto de Oceanología, Publicaciones Ocasionales 3: 1-18.

ARMESTO JJ & MTK ARROYO (1991) El estudio y la conservación de la biodiversidad: Una tarea urgente para Chile. Creces (Chile) 11: 54-60.

ARMESTO JJ, MTK ARROYO, P LEON & C SMITH-RAMIREZ (in press) Insuficiencias del Sistema de Parques Nacionales para la conservación de la biodiversidad del bosque templado de Chile. In: Dirzo

R, D Piñera & MTK Arroyo (eds) Conservación y manejo de recursos naturales en América Latina. México, D.F.

ARRATIA G (1981) Géneros de peces de aguas continentales de Chile. Publicación Ocasional del Museo Nacional de Historia Natural (Chile) 34: 3-108.

ARTIGAS J (1975) Introducción al estudio por computación de las áreas zoogeográficas de Chile Continental, basado en la distribución de 903 especies de animales terrestres. Gayana: Zoología (Chile) 4: 3-25.

ARZON H (1992) Atlas del universo y de Chile regionalizado. Editora Zig-Zag, Santiago.

BALECH E (1954) División zoogeográfica del litoral sudamericano. Revista de Biología Marina Montemar (Chile) 4: 184-195.

BENOIT IL (1982) Las áreas marinas protegidas y su legislación: Factibilidad y problemas de su creación en Chile. In: Actas del III Encuentro Americano de Derecho Forestal, Viña del Mar, Chile.

BENOIT IL, ed (1989a) Red book of Chilean terrestrial flora. Chilean Forest Service (CONAF), Santiago.

BENOIT IL (1989b) Proposal to modify the conservation status classification of 15 tree and shrub species pursuant to data provided by the study "Technical files on specific sites where threatened woody species occur." In: Benoit IL (ed) Red book on Chilean terrestrial flora: 105-106. Chilean Forest Service (CONAF), Santiago.

BENOIT IL (1991) Cobertura actual del Sistema Nacional de áreas Silvestres Protegidas del Estado. Corporación Nacional Forestal. Santiago.

CABEZA A (1988) Aspectos históricos de la legislación vinculada a la conservación, la evolución de las áreas silvestres de la zona de Villarrica y la creación del primer parque nacional de Chile. Corporación Nacional Forestal, Documento de Trabajo 101, Santiago.

CASTILLA JC (1975) Ecosistemas marinos de Chile. Principios generales y proposición de clasificación. Actas del Seminario sobre Preservación del Medio Ambiente Marino, Santiago, Chile.

CASTILLA JC (1976) Parques y reservas marítimas chilenas. Necesidad de creación, probables localizaciones y criterios básicos. Medio Ambiente (Chile) 2 (1): 70-80.

CASTILLA JC (1986) ¿Sigue existiendo la necesidad de establecer parques y reservas marítimas en Chile?. Ambiente y Desarrollo (Chile) 2: 53-63.

CASTILLA JC, ed (1987) Islas oceánicas chilenas: Conocimiento científico y necesidades de investigaciones. Ediciones Universidad Católica de Chile, Santiago.

CEI JM (1962) Batracios de Chile. Ediciones Universidad de Chile, Santiago.

CHANG A, P DROULLY, S PALMA, M RODR_GUEZ & Y VILINA (1989) Prospección de áreas de concentración de fauna entre la I a VII regiones de Chile. Informe Final. Proyecto CONAF/PNUD/FAO-CHI/83/017, Santiago.

CHILE FORESTAL (1992) Proyecto de ley de recuperación al bosque nativo y fomento forestal. Suplemento mayo 1992, Santiago.

CHILEAN FORESTRY NEWS (1990) First seed orchard for native species. Chilean Forestry News 143, Santiago.

CIPMA (1990) Seminario pesquero: La necesidad de buscar acuerdos. Ambiente Ahora (Chile) 2, October.

CONAF (1989) La protección del patrimonio ecológico. Corporación Nacional Forestal, Santiago.

CONAF (1992) Memoria anual 91. Corporación Nacional Forestal, Santiago.

CONAF IV REGION (1990) Plantaciones de CONAF y privados en la IV Región. Corporación Nacional Forestal Región de Coquimbo, January.

CORFO (1986) El sector pesquero chileno. Corporación de Fomento de la Producción, Santiago.

CORMA (1991) Chile, país forestal. Corporación Chilena de la Madera, Departamento de Bosque Nativo. Editorial Interamericana, Santiago.

CRAWFORD DJ, TF STUESSY & M SILVA (1987) Allozyme divergence and the evolution of *Dendroseris* (Compositae: Lactuceae) on the Juan Fernández Islands. Systematic Botany 12: 435-443.

CRAWFORD DJ, TF STUESSY, TG LAMMERS, M SILVA & P PACHECO (1990). Allozyme variation and evolutionary relationships among three species of *Wahlenbergia* (Campanulaceae) in the Juan Fernández Islands. Botanical Gazette 151: 119-124.

CUNAZZA C (1989) Predios privados y ocupantes del Sistema Nacional de áreas Silvestres Protegidas del Estado. Diagnóstico y alternativas de solución. In: Actas de la Reunión Nacional del Programa de Patrimonio Silvestre, Laguna del Laja National Park, April 1989: 114-148. Corporación Nacional Forestal, Santiago.

DARLINGTON PJ (1968) Biogeography of the southern end of the world. McGraw-Hill, New York.

DAVIES S, S DROOP, P GREGERSON, L HENSON, C LEON, J LAMLEIN-VILLALOBOS, H SYNGE, & J ZANTOVSKA (1986) Plants in danger. What do we know?. IUCN Conservation Monitoring Centre, Threatened Plants Unit and The Royal Botanical Gardens, Kew. Gland, Switzerland, and Cambridge, United Kingdom.

DI CASTRI F (1968). Esquisse écologique du Chili. Biologie de l'Amérique Australe 4: 7-52.

DI CASTRI F & E HAJEK (1976) Bioclimatología de Chile. Ediciones Universidad Católica de Chile, Santiago.

DI CASTRI F & HA MOONEY eds (1973) Mediterranean type ecosystems: origin and structure. Springer-Verlag, Berlin. Ecological Studies 7: 308-338.

DONOSO C (1981) Tipos forestales de los bosques nativos de Chile. Proyecto CONAF/PNUD/FAO de Investigación y Desarrollo Forestal. Documento de Trabajo 38, Santiago.

DONOSO C (1987) Variación natural en especies de *Nothofagus* en Chile. Bosque (Chile) 8 (2): 85-97.

DONOSO-BARROS R (1966) Reptiles de Chile. Ediciones Universidad de Chile, Santiago.

FAO (1987) Fishery statistics. Catches and landings. FAO Yearbook N64: 93-95.

GAJARDO R (1983) Sistema básico de clasificación de la vegetación nativa chilena. Universidad de Chile/Corporación Nacional Forestal, Santiago.

GAJARDO R, MT SERRA & I GREZ (1987) Fichas técnicas de lugares específicos con presencia de especies leñosas amenazadas de extinción. Universidad de Chile/Corporación Nacional Forestal, Santiago.

GLADE AA, ed (1988). Red list of Chilean terrestrial vertebrates. Chilean Forest Service, Santiago.

GODLEY EJ (1960) The botany of southern Chile in relation to New Zealand and the Subantarctic. Proceedings of the Royal Society of Botany (London) 152: 457-475.

GUNKEL H (1984) Helechos de Chile. Monografías Anexas de los Anales de la Universidad de Chile. Ediciones de la Universidad de Chile, Santiago.

HABIT MA, ed (1985). The current state of knowledge of *Prosopis tamarugo*. International Round Table on *Prosopis tamarugo* Phil. Arica, Chile, June 11-15, 1984. FAO/CONAF/Tarapacá University.

HARTWIG F (1989) Visión del desarrollo forestal de Chile. Corporación Chilena de la Madera (CORMA). Santiago.

HOFFMANN AE (1989) Chilean geophyte monocots: Taxonomic synopsis and conservation status. In: Benoit IL (ed) Red book on Chilean terrestrial flora: 141-151. Chilean Forest Service, Santiago.

HOFFMANN AE & AR FLORES (1989) The conservation status of Chilean succulent plants: A preliminary assessment. In: Benoit IL (ed) Red book on Chilean terrestrial flora: 107-121. Chilean Forest Service, Santiago.

IGM (1988) Atlas geográfico de Chile para la educación. Instituto Geográfico Militar, Santiago.

INFOR (1988) Estadísticas forestales 1987. Instituto Forestal, Boletín Estadístico, Santiago.

INFOR (1992) Estadísticas forestales 1991. Instituto Forestal, Boletín Estadístico, Santiago.

INFOR (1992) Exportaciones forestales (Enero - Diciembre 1992). Instituto Forestal, Boletín Estadístico 27, Santiago.

IUCN (1988) Proceedings of the 17th Session of the General Assembly of IUCN and 17th Technical Meeting. International Union for Conservation of Nature and Natural Resources. San José, Costa Rica.

IUCN (1990) 1990 United Nations list of national parks and protected areas. The World Conservation Union. Gland, Switzerland.

IUCN/WWF (1987) Centres of plant diversity. A guide and strategy for their conservation. IUCN/WWF Plants Conservation Programme and IUCN Threatened Plants Unit. Surrey, United Kingdom.

JOHNSON AW & JD GOODALL (1965) The birds of Chile and adjacent regions of Argentina, Bolivia and Peru. Vol. I. Platt Establecimientos Gráficos, Buenos Aires.

JOHNSTON IM (1929) Contributions from the Gray Herbarium of Harvard University (Papers on the Flora of Northern Chile). The Gray Herbarium of Harvard University, Cambridge, Massachusetts.

KUSCHEL G (1960) Terrestrial zoology in southern Chile. Proceedings of the Royal Society of Zoology (London) 152: 540-549.

LAGOS E (1992) Astillas: ser o no ser. Chile Forestal 199: 4-7.

LARA A, P DONOSO & M CORTES (1991) Development of conservation alternatives for native forests in South Central Chile. Comité Nacional Pro Defensa de la Fauna y la Flora (CODEFF), Valdivia.

LARRAIN AP (1975) Los equinodermos regulares fósiles y recientes de Chile. Gayana: Zoología (Chile) 35: 1-189.

LEITCH WC (1990). South America's national parks: A visitor guide. The Mountaineers, Seattle.

MACPHAIL DD & HE JACKSON (1973) New directions in the Chilean North. In: Amiran DHK & AW Wilson (eds) Coastal deserts–Their natural and human environments: 123-136. The University of Arizona Press, Tucson, Arizona.

MAHU M (1979) Familias y géneros de musgos chilenos. Bryologist 82: 513-524.

MANN G (1954) Vida de los peces de aguas chilenas. Ministerio de Agricultura/Universidad de Chile, Santiago.

MANN G (1960) Regiones biogeográficas de Chile. Investigaciones Zoológicas Chilenas 6: 15-49.

MANN G (1964) Compendio de zoología I. Ecología y biogeografía. Centro de Investigaciones Zoológicas, Universidad de Chile, Santiago.

MARTICORENA C (1990) Contribución a la estadística de la flora vascular de Chile. Gayana: Botánica (Chile) 47: 85-113.

MARTICORENA C & M QUEZADA (1985) Catálogo de la flora vascular de Chile. Gayana: Botánica (Chile) 42: 1-157.

McNALLY R (1990) The great geographical atlas. Rand McNally & Company, Chicago, Illinois.

McNEELY JA, KR MILLER, WV REID, RA MITTERMEIER & TB WERNER (1990) Conserving the World's biological diversity. IUCN/WRI/CI/WWF-US/The World Bank. Gland, Switzerland and Washington, DC.

MESERVE PL & FM JAKSIC (1991) Comparison of terrestrial vertebrate assemblages in temperate rainforests of North and South America. Revista Chilena de Historia Natural 64: 511-535.

MOONEY HA (1988) Lessons from Mediterranean-climate regions. In: Wilson EO (ed) Biodiversity: 157-165. National Academy Press, Washington, D.C.

MUÑOZ M (1980) Flora del Parque Nacional Puyehue. Editorial Universitaria,Santiago.

MUÑOZ O, ed (1992) Química de la flora de Chile. Universidad de Chile, Departamento Técnico de Investigación, Santiago.

NORAMBUENA MC (1992) Variación genética interpoblacional en *Vicugna Vicugna* (Camelidae). Veterinary Medicine Thesis, Universidad Austral de Chile, Valdivia.

OBERDORFER E (1960) Pflanzensoziologische studien in Chile. Weinheim, Germany.

O'BRIEN C (1971) The biogeography of Chile through entomofaunal regions. Entomological News 82: 197-207.

ORMAZABAL CS (1986a) Representación de la diversidad biogeográfica de Chile en el Sistema Nacional de áreas Silvestres Protegidas del Estado. Segundo Encuentro Científico sobre el Medio Ambiente, Versiones Abreviadas Tomo I: 240-247. Centro de Investigación y Planificación del Medio Ambiente (CIPMA), Santiago.

ORMAZABAL CS (1986b) El Sistema Nacional de áreas Silvestres Protegidas de Chile. Flora, Fauna y áreas Silvestres 1 (1): 10-15.

ORMAZABAL CS (1987) Preservación de recursos fitogenéticos *in situ* a través de parques nacionales y otras áreas protegidas: Importancia, avances, limitaciones y proyección futura. In: Contreras A & J Esquinas-Alcázar (eds) Anales del Simposio Recursos Fitogenéticos: 104-114. International Board for Plant Genetic Resources/Universidad Austral de Chile, Valdivia.

ORMAZABAL CS (1989) Threatened plants sites and vegetation types in Chile. A proposal. In: Benoit IL (ed) Red book on Chilean terrestrial flora: 97-104. Chilean Forest Service, Santiago.

ORMAZABAL CS (1992) Bosques naturales en Chile: ¿cuánto privado?, ¿cuánto estatal?. Ambiente y Desarrollo (Chile) 8: 38-41.

ORMAZABAL CS & IL BENOIT (1987) El estado de conservación del género *Nothofagus* in Chile. Bosque (Chile) 8 (2): 109-120.

OSGOOD WH (1943) The mammals of Chile. Field Museum of Natural History, Zoological Series 30: 1-268.

OSORIO C (1979) Moluscos de importancia económica en Chile. Biología Pesquera (Chile) 11: 3-47.

OVINGTON JD, ed (1983) Temperate broad-leaved evergreen forests. Elsevier Science Publishers, Amsterdam.

PARRA O & M GONZALEZ (1977) Catálogo de las algas dulceacuícolas de Chile. Gayana: Botánica (Chile) 32: 3-102.

PEÑA L (1966) A preleminary attempt to divide Chile into entomofaunal regions, based on the Tenebrionidae (Coleoptera). Postilla 97: 1-17.

PETROV MP (1976) Deserts of the world. Israel Program for Scientific Translations, Jerusalem. John Wiley & Sons, New York.

PISANO E (1956) Esquema de clasificación de las comunidades vegetales de Chile. Agronomía (Chile) 2: 30-33.

PISANO E (1966) La vegetación de las distintas zonas geográficas de Chile. Terra Australis (Chile) 18: 95-106.

PISANO E (1980) Catálogo de la flora vascular del Archipiélago del Cabo de Hornos. Anales del Instituto de la Patagonia (Chile) 11: 151-198.

PISANO E (1982a) Comunidades vegetales de la isla Hornos (Archipiélago del Cabo de Hornos, Chile). Anales del Instituto de la Patagonia (Chile) 13: 126-143.

PISANO E (1982b) Adiciones a la flora vascular del Archipiélago del Cabo de Hornos. Anales del Instituto de la Patagonia (Chile) 13: 156-159.

PISANO E & H FUENZALIDA (1950) Biogeografía. In: Geografía Económica de Chile 1: 271-428. CORFO, Santiago.

QUINTANILLA VG (1981) Carta de las formaciones vegetales de Chile. Universidad de Santiago. Revista Contribuciones Científicas y Tecnológicas 1 (47): 5-32.

QUINTANILLA VG (1983) Biogeografía de Chile. Instituto Geográfico Militar. Colección Geografía de Chile, Tomo III, Santiago.

RAMIREZ C (1978) Estudio florístico y vegetacional del Parque Nacional Tolhuaca (Malleco, Chile). Corporación Nacional Forestal IX Región. Publicación Ocasional del Museo Nacional de Historia Natural (Chile) 24: 3-23.

RAY GC, BP HAYDEN & R DOLAN (1984) Development of a biophysical coastal and marine classification system. In: McNeely JA & KR Miller (eds) National parks, conservation, and development: the role of protected areas in sustaining society: 39-46. Smithsonian Institution Press, Washington, D.C.

REHDER HA (1980) The marine mollusks of Easter Island and Sala y Gómez. Smithsonian Contributions to Zoology 289: 1-167.

REICHE K (1934) Geografía botánica de Chile. Translated by G. Looser, Santiago. Tomo I.

REICHE K (1938) Geografía botánica de Chile. Translated by G. Looser, Santiago. Tomo II.

REISE D & MH GALLARDO (1990) A taxonomic study of the South American genus *Euneomys* (Cricetidae, Rodentia). Revista Chilena de Historia Natural 63: 73-82.

RETAMAL MA (1981) Catálogo ilustrado de los crustáceos decápodos de Chile. Gayana: Zoología (Chile) 44: 1-110.

RICCI M (1990) ¡S.O.S.! para Juan Fernández. Chile Forestal 176: 16-17.

RICHATT FM, C VERGARA & E OEHRENS (1980) Flora fungosa chilena. Segunda edición, Editorial Universitaria, Santiago.

ROBOTHAM H (1990) Sistema de información pesquera artesanal. Chile Pesquero 57: 53-57.

RODRIGUEZ R (1989) Threatened Chilean continental pteridophyta. In: Benoit IL (ed) Red book on Chilean terrestrial flora: 123-139. Chilean Forest Service, Santiago.

RODRIGUEZ R, O MATTHEI & M QUEZADA (1983) Flora arbórea de Chile. Editorial Universidad de Concepción, Concepción.

RÖMPCZYK E (1988) Environmental problems in Chile. German Foundation for International Development. Development and Cooperation (D + C) 2: 10-12.

ROTTMANN J (1988) Bosques de Chile. UNISYS (Chile) Corporation, Santiago.

ROTTMANN J & N PIWONKA (1987) Introducción a la naturaleza de Chile. UNISYS (Chile) Corporation, Santiago.

ROZBACZYLO N (1985) Los anélidos poliquetos de Chile: índice sinonímico y distribución geográfica de especies. Monografías Biológicas (Chile) 3: 1-284.

SALLABERRY M & J AGUIRRE (1991) Sistemática y ecología general de las aves de Chile. Guía introductoria para el reconocimiento de las aves de la zona central. Publicación Ocasional, Unión de Ornitólogos de Chile 1: 1-52.

SANDERS RW, TF STUESSY & C MARTICORENA (1982) Recent changes in the flora of the Juan Fernández Islands, Chile. Taxon 31: 284-289.

SANTELICES B (1987) Marine benthic flora from the Chilean oceanic islands. In: Castilla JC (ed) Islas Oceánicas Chilenas: conocimiento científico y necesidades de investigaciones: 101-126. Ediciones Universidad Católica de Chile, Santiago.

SANTELICES B (1989) Algas marinas de Chile. Ediciones Universidad Católica de Chile, Santiago.

SCHLATTER R, R MURUA & JV OLTREMARI (1987) Estudio sobre la composición y magnitud del recurso faunístico entre las regiones Segunda y Séptima de Chile. Informe Final. Universidad Austral de Chile/ Proyecto CONAF/PNUD/FAO-CHI/83/017. Valdivia.

SCHMITHÜSEN J (1956) Die räumliche ordung der Chilenschen vegetation. Bonner Geographische Hefte 17: 1-86.

SEPULVEDA JI (1987) Peces de las islas oceánicas chilenas. In: Castilla JC (ed) Islas Oceánicas Chilenas: conocimiento científico y necesidades de investigaciones: 225-245. Ediciones Universidad Católica de Chile, Santiago.

SERNAP (1991) Anuario estadístico de pesca. Servicio Nacional de Pesca, Santiago.

SIELFELD W (1983) Mamíferos marinos de Chile. Ediciones Universidad de Chile, Santiago.

SIMONETTI JA & JJ ARMESTO (1991) Conservation of temperate ecosystems in Chile: Coarse versus fine-filter approaches. Revista Chilena de Historia Natural 64: 615-626.

SIMONETTI JA, MTK ARROYO, A SPOTORNO, E LOZADA, CA WEBER, LE CORNEJO, J SOLERVICENS & E FUENTES (1992) Hacia el conocimiento de la diversidad biológica de Chile. In: Halffter G (ed) Acta Zoológica Mexicana, Volumen Especial: La diversidad biológica de Iberoamérica 1: 253-270. México, D.F.

SKOTTSBERG C (1922) The phanerogams of the Juan Fernández Islands. In: Skottsberg C (ed) Natural History of the Juan Fernández and Easter Islands 2 (Botany): 95-240. Almqvist & Wiksell, Uppsala.

SKOTTSBERG C (1956) Derivation of the flora and fauna of Juan Fernández and Easter Islands. In: Skottsberg C (ed) Natural History of the Juan Fernández and Easter Islands 1 (Geography, Geology): 193-437. Almqvist & Wiksell, Uppsala.

SPOTORNO AE (1990) Diversidad de los mamíferos chilenos endémicos y perspectivas para el estudio de sus características reproductivas. Simposio Nacional sobre Reproducción de Fauna Autóctona, Temuco.

STUESSY TF, KA FOLAND, JF SUTTER, RW SANDERS & M SILVA (1984a) Botanical and geological significance of potassium-argon dates from the Juan Fernández Islands. Science 225: 49-51.

STUESSY TF, RW SANDERS & M SILVA (1984b) Phytogeography and evolution of the flora of the Juan Fernández Islands: a progress report. In: Radovsky FJ, PH Raven & SH Somer (eds) Biogeography of the Tropical Pacific. Association of Systematics Collections and B.P. Bishop Museum; Lawrence, Kansas.

STUESSY TF, DJ CRAWFORD & C MARTICORENA (1990) Patterns of phylogeny in the endemic vascular flora of the Juan Fernández Islands, Chile. Systematic Botany 15: 338-346.

TAMAYO M, H NUÑEZ & J YAÑEZ (1987) Lista sistemática actualizada de los mamíferos vivientes en Chile y sus nombres comunes. Noticiario Mensual del Museo Nacional de Historia Natural (Chile) 312: 1-13.

THE NATURE CONSERVANCY (1988) Database on Neotropical Diversity Profile. Washington, D.C.

UDVARDY MDF (1984) A biogeographical classification system for terrestrial environments. In: McNeely JA & KR Miller (eds) National parks, conservation, and development: the role of protected areas in sustaining society: 34-38. Smithsonian Institution Press, Washington, D.C.

UNESCO (1981) Mapa de la vegetación de América del Sur. United Nations Education, Scientific and Cultural Organization. Nota Explicativa. Investigación sobre los Recursos Naturales, París.

VALDEBENITO HA, TF STUESSY & DJ CRAWFORD (1990) A new biogeographic connection between islands in the Atlantic and Pacific oceans. Nature 6293: 549-550.

VALENCIA J, MV LOPEZ & M SALLABERRY (1987) Sistema de áreas de conservación en Chile: Proposiciones para un esquema ecológico integral. Ambiente y Desarrollo (Chile) 3: 139-154.

VELOSO A & J NAVARRO (1988) Lista sistemática y distribución geográfica de anfibios y reptiles de Chile. Bolletino del Museo Regional di Science Naturali (Torino) 6: 481-539.

VILLASEÑOR R (1986) Guía para el reconocimiento de las especies arbóreas y arbustivas más frecuentes en el Parque Nacional La Campana. Ediciones Universidad de Playa Ancha de Ciencias de la Educación - Corporación Nacional Forestal, Valparaíso.

WCED (1987) Our common future. United Nations' World Commission on Environment and Development. Oxford University Press, New York.

WEBER CA (1983) Representación de las provincias biogeográficas por las reservas de la biósfera de Chile. Acción presente y futura de la Corporación Nacional Forestal. CONAF. Boletín Técnico (Chile) 10: 1-23.

WEBER CA (1990) Chile. National parks and nature reserves. In: Allin CW (ed) International Handbook of National Parks and Nature Reserves: 83-103. Greenwood Press, New York.

WRI (1990) World resources 1990-91. World Resources Institute/UNEP/UNDP. Oxford University Press, New York.

WWF (1989) The importance of biological diversity. World Wide Fund for Nature. Yale Press, New Haven, Connecticut.