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A GIS ASSESSMENT OF ECOREGION REPRESENTATION IN CHILE'S EXISTING AND PROPOSED INTEGRATED NETWORK OF PROTECTED AREAS

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A GIS ASSESSMENT OF ECOREGION REPRESENTATION IN CHILE'S EXISTING AND PROPOSED INTEGRATED NETWORK OF PROTECTED AREAS

By

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ABSTRACT

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Chile's state designated protected areas are reported to show representation bias and to be unable to meet conservation goals. Private protected areas are considered an important tool to resolve these issues, which has led to support for increasing the role of private protected areas in Chile and creating an integrated public-private protected area network. But the validity of the capacity of private protected areas to fix Chile's state protected area network bias, and the advantage of creating an integrated protected area network, have not been assessed. This study uses the most recent data on Chile's state, private, and international protected areas to conduct a GIS gap analysis to measure the representativeness of Chile's terrestrial ecoregions under four scenarios. Scenario 1 assesses state protected areas including SNASPE and public and private nature sanctuaries. Scenario 2 assesses Scenario 1 and private protected areas. Scenario 3 assesses Scenario 1 and international protected areas. Scenario 4 assesses state, private, and international protected areas. All scenarios show representation bias and failure to protect the most threatened Chilean matorral and Atacama Desert ecoregions. State protected areas are heavily biased toward southern Chile. Private protected areas show representation bias similar to state protected areas. Both private and international protected areas do little to fix state representation bias or help Chile reach conservation goals. Based on the findings of this study and an assessment of other private protected area limitations, an integrated protected area network may not be the most appropriate method of fixing state protected area network representation bias, protecting priority conservation areas, meeting conservation goals, enhancing the overall effectiveness of Chile's protected area networks. Rather, this study points to other interventions that would be appropriate for the Chilean context, including finding a new best fit for private protected areas, creating a private protected area institute, and expanding the state protected area network through the increased and systematic designation of private nature sanctuaries.

Keywords: Representativeness, biodiversity representation, ecoregion representation, protected area, private protected area, integrated protected area network, SNASPE, conservation, gap analysis, GIS, Chile, systematic conservation planning

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LIST OF ABBREVIATIONS

AR	Administrative region
BH	Biodiversity hotspot
CBD	Convention on Biological Diversity
CI	Conservation International
CNSPA	Comprehensive National System of Protected Areas
CONAF	Corporación Nacional Forestal de Chile (National Forestry Corporation of Chile)
CS	Coordinate system
G200	Global 200 (priority ecoregions)
GCS	Geographic coordinate system
GIS	Geographic information system
Ha	Hectare(s)
ICP	Iniciativas de Conservación Privada (National Private Conservation Initiative)
IPPPAN	Integrated public-private protected area network
IUCN	International Union for Conservation of Nature
Mha	Million hectares
MMA	Ministerio de Medio Ambiente (Ministry of the Environment)
NBSAP	National Biodiversity Strategies and Actions Plan
NGO	Non-governmental organization
NM	Natural/National Monument
NP	National Park
NR	Nature Reserve
NS	Nature Sanctuary
PA	Protected area
PAN	Protected area network
PCA	Priority conservation area
PCS	Projected coordinate system
PPA	Private protected area
SCP	Systematic conservation planning
SNASPE	Sistema Nacional de Áreas Silvestres Protegidas del Estado (National System of Protected Wild Areas)
UNESCO	United Nations Educational, Scientific and Cultural Organization
WDPA	World Database of Protected Areas
WPC	World Parks Congress
WWF	World Wildlife Fund

CHAPTER 1: INTRODUCTION

1.1 General Introduction

Human-induced biodiversity loss as a result of exploitation and habitat degradation has been more rapid in the last 50 years than any other time in history (MEA 2005; WWF 2014). Studies show and scholars agree protected areas[1] (PA*s*) are an effective way of safeguarding the earth's biodiversity from damaging or irreversible anthropogenic disturbances (Boucher, Spalding, and Revenga 2013; Chape *et al.* 2005; Dudley 2008; Durán *et al.* 2013; Izquierdo and Grau 2009; Jenkins and Joppa 2009; Joppa, Loarie, and Pimm 2008; Krug 2001; MEA 2005; Pauchard and Villarroel 2002; Rodrigues *et al.* 2004a; SCBD 2014; WWF 2014). Regrettably, literature is increasingly revealing bias in the type of biodiversity represented in protected area networks (PAN*s*) (referred to as *representativeness.)* That is, some ecosystems, landscapes, or species are over-represented in PAN*s* while others are under-represented or not represented at all (Brooks *et al.* 2004; Chape *et al.* 2005; Dudley 2008; Dudley and Pressey 2001; Durán *et al.* 2013; Hoekstra *et al.* 2005; Hogan 2013; Holmes 2013; Izquierdo and Grau 2009; Jenkins and Joppa 2009; Joppa and Pfaff 2009; Juffe-Bignoli *et al.* 2014; Lunney *et al.* 1997; Margules and Pressey 2000; Pressey 1994; Pressey *et al.* 1993; Rodrigues *et al.* 1999, 2004a, b; Soutullo, Castro, and Urios 2008). Throughout this paper, representativeness will measure ecoregion (see Section 3.1) protection.

Representation bias could jeopardize the effectiveness[2] of conservation and fail to preemptively protect habitats before irreversible habitat destruction or species loss occurs (Durán *et al.* 2013; Pressey 1994). Studies show representation bias is particularly characteristic

1 - In this report "protected area" (PA) is used when the idea under discussion includes all forms of PA governance and management. "Private protected area" (PPA) is used when the idea under discussion is unique to, or only refers to, privately owned and managed PAs. "Public PA" is used when the idea under discussion is either unique to, or only refers to, PAs established and governed by a government body.

2 - Effectiveness refers to the ability of a PA to contribute to the successful protection of species and habitats in perpetuity or "the fulfillment of whatever the protected area objective is" (Matteucci and Camino 2012:25). Effectiveness is influenced by management and "good governance." See Dudley 2008 for a more detailed discussion.

of government established PA*s* (also referred to as public or state PA*s*), making them inadequate at protecting biologically important and highly threatened priority conservation areas (PCA*s*) or achieving national and global conservation goals (Dudley and Pressey 2001; Holmes 2014; Núñez-Ávila and Corcuera 2014; Pauchard and Villarroel 2002; Pliscoff and Fuentes-Castillo 2011; Pressey *et al.* 2002; Squeo *et al.* 2012).

Private protected areas (PPA*s*) are assumed to be effective at enhancing the conservation of PCA*s* and adequately protecting biodiversity the government PA*s* are not (Borrini-Feyerabend *et al.* 2013; Corcuera, Sepúlveda, and Geisse 2002; Holmes 2013; Krug 2001; Juffe-Bignoli *et al.* 2014; Langholz and Lassoie 2001; Pasquini *et al.* 2011; Stolton, Redford, and Dudley 2014). Globally, these "PPA effectiveness" theories are used to support the establishment of PPA*s* and the creation of national integrated public-private protected area networks (IPPPAN*s*) that bring public, international, and private PA*s* into a single legal framework (Boucher *et al.* 2013; Chacon 2005; Corcuera *et al.* 2002; Núñez-Ávila and Corcuera 2014; Squeo *et al.* 2012). However, the PPA effectiveness claim is anecdotal and many claims supporting IPPPAN*s* are based on theory and speculation. This is because PPA*s*, as a global phenomenon, are not well researched or understood. Data regarding PPA location, management, and other factors related to development, objectives, and on the ground activities are lacking (Holmes 2013; IUCN 2005; Langholz and Lassoie 2001; Mitchell 2007). Some studies and literature have suggested though that PPA*s* may not be as conducive to effective conservation as they are thought to be (Corcuera *et al.* 2002; Pliscoff and Fuentes-Castillo 2011; Tecklin and Sepúlveda 2014). But without reliable data, it is difficult if not impossible to assess and reveal the validity of PPA effectiveness assertions, which means PPA*s* will continue to be promoted based on theoretical optimism and unverified claims.

1.2 Scope of Research

In keeping with global trends, studies show public PAs in Chile have not been systematically established and are ineffective at protecting the most threatened PCA*s*[3] or equally representing the country's biodiversity (Corcuera *et al.* 2002; Durán *et al.* 2013; Hogan 2013; Pauchard and Villarroel 2002; Pliscoff and Fuentes-Castillo 2011). Following the global trend of PPA expansion, PPA*s* in Chile have increased in accordance with the conviction they can fix public PAN representation biases. In turn the increase of PPA*s* has spurred national interest to create an IPPPAN referred to as a Comprehensive National System of Protected Areas (CNSPA) (Fundación Senda Darwin 2013). But the Chilean government does not legally recognize PPA*s*, and there is no central database that officially records the existence of PPA*s.* Without comprehensive and reliable PPA data, it is difficult to know if PPA*s* are currently filling or have the ability to fill PAN representation gaps or enhance the protection of PCA*s* as they are assumed, expected, and hoped to (Langholz and Lassoie 2001).

Third parties have attempted to collect Chilean PPA spatial data in the past but it has been very unsystematic and the data has been highly unreliable. In 2013, for the first time, new systematically collected, comprehensive, PPA data with good geographic information system (GIS) records was released to the public. The data has yet to be used in representation analysis or to determine if PPA*s* are contributing to the protection of Chile's biodiversity to the degree or in the manner they are presumed to be. It is important to assess the PPA effectiveness theory in Chile to ensure the long-term protection of Chile's PCA*s* and determine if a CNSPA is the most advantageous route to fix Chile's previously reported PAN shortcomings.

This study is limited to the terrestrial ecoregions of Chile. Chile is ideal for this analysis as it contains distinct ecoregions ranging from the world's driest and highest desert in the north, to the icecaps and glaciers of Patagonia in the south. Many of Chile's ecoregions are considered global PCA*s* due to high levels of endemism and threat. But Chile also relies heavily on

3 - In this study, PCA*s* refer to priority *ecoregions.* Ecoregions are defined in Section 3.1.

resource extraction in these PCA*s* and has an economy rooted in the free-market ideology of limited environmental governance. This has led to environmental degradation and at times made the creation of public PA*s* problematic. Chile's biodiversity, growth of PPA*s*, and a push for a CNSPA makes Chile an ideal location to conduct this research.

1.3 Purpose and Objectives

The purpose of this research is to measure the coverage and representativeness of Chile's terrestrial ecoregions to meet the following objectives:

1) Determine if representation bias is present in Chile and, if so, in which ecoregions and under what PA classification (i.e. state, private, or international PA designations).

2) Conduct the first gap analysis using Chile's most recent PPA data.

3) Determine if Chile's PPA*s* are filling state PAN representation gaps or enhancing conservation in PCA*s* (to determine if an IPPPAN is a worthwhile effort.)

4) Determine if Chile is meeting, or making progress toward meeting, global conservation targets.

This study assesses Chile's conservation under four PAN scenarios to understand the influence state, international, and private PA classifications have on the country's protection efforts by comparing their coverage and representativeness. The scenarios are as follows:

S1) *State protected area network*: Government established public protected areas (SNASPE) and government designated public and private nature sanctuaries.[4]

S2) *Comprehensive National System of Protected Areas:* S1 plus private protected areas.

S3) *Existing protected area network:* S1 plus UNESCO and Ramsar sites.

S4) *Complete protected area network*: All protected area classifications.

S1 is the baseline of state PA coverage in Chile. This scenario represents the coverage of all PA*s* legally recognized, designated, and regulated by the Chilean government. S2 shows what a CNSPA in Chile would look like if PPA*s* were integrated into the state PAN. S3 shows

4 - This scenario is not called the "public" PAN because NS*s* can be either public or private. Some private NS*s* are designated and recognized by the Chilean state though. It was therefore inappropriate to refer to the collection of these PA classifications as public.

Chile's *de jure* (legally recognized) PA coverage used in national and global PA analyses. S4 represents the combined coverage of Chile's state PA*s*, PPA*s*, and international UNESCO and Ramsar sites. S4 shows Chile's current *de jure* and *de facto* protection and what a complete Chilean PAN would look like in national and global databases if the Chilean government legally recognized PPAs.

1.4 Thesis Structure

This thesis consists of six chapters. Chapter two explains the theoretical ideas central to this study. These concepts are defined early because they are important to understand in subsequent chapters. Chapter three presents the background of international and Chilean biodiversity, PA activities, and representation bias. Chapter three also provides the historical context of Chile's economy and environment to demonstrate the importance of assessing the PAN. Chapter four outlines the methodology of research design, data processing, and data analysis. Chapter five gives a detailed presentation of results under the four PAN scenarios and within each of Chile's terrestrial ecoregions. Chapter six interprets and discusses the results with a particular focus on scenario trends, representation bias, and the effectiveness of PPA*s* in Chile. Chapter six then concludes with recommendations for how to enhance conservation in Chile, ideas for future research, and an overall conclusion.

CHAPTER 2: THEORETIC FRAMEWORK

This study employs three key concepts: Representativeness (also simply called "representation"), systematic conservation planning (SCP), and gap analysis. Representativeness is the foremost way of setting PAN conservation goals and determining PAN success and effectiveness by assessing ecoregion representation within a PAN (Coad *et al.* 2008a; Juffe-Bignoli *et al.* 2014; Pliscoff and Fuentes-Castillo 2011; Rodrigues *et al.* 2004a). Measuring representativeness shows if Chile's terrestrial ecoregions are adequately, moderately, or inadequately protected and if ecoregion protection bias exists and where. Measuring and comparing the representativeness of each scenario and PA classification allows me to evaluate each PA classification contribution and under which scenario Chile is meeting, or making progress towards meeting, conservation goals. The tool used to measure representativeness is gap analysis. Gap analysis also identifies PCA*s* for PA expansion and facilitates PAN SCP. SCP is used to guide decisions about the establishment of PA*s* (i.e. location and type of land-use activities permitted) to create an effective and representative PAN that ensures the equal and adequate protection of ecoregions. SCP is necessary to consider in the discussion chapter of this report when I examine the implications of, and provide recommendations based on, the results of conducting a gap analysis and assessing representativeness.

2.1 Representativeness

Representativeness refers to the extent to which a PAN protects a range of biological diversity (Boucher *et al.* 2013; Lunney *et al.* 1997). Success and effectiveness of a PAN is evaluated on the theory of proportional representation. Proportional representation means a PAN has captured an equal percentage of a variety of biodiversity across biological scales (species and ecosystems) and within biological terrestrial, freshwater, or marine realms (WWF 2014). The more significant and the greater the range of biodiversity contained within a PAN, the more successful conservation, and the more effective a PAN, is (Juffe-Bignoli *et al.* 2014; Olson and Dinerstein 2002). Pliscoff and Fuentes-Castillo (2011) explain, "[T]he representativeness approach has arisen from the need to assess the effectiveness of ecosystem protection, establish conservation priorities and guide investment" (p. 303).

The theory of representativeness is not scientifically grounded and its usefulness is debated. Some argue representation percentage targets are arbitrary, blind to the uneven distribution of species across the planet, or simply inadequate (Coad *et al.* 2009; Jennings 2000; Pressey *et al.* 2002; Rodrigues *et al.* 2004b; Stewart *et al.* 2007). But how much conservation is enough conservation is an impossible question to answer. Percentage goals can easily be measured, understood (Coad *et al.* 2009), and "justified for political expediency [as they] enable the decision-making process to proceed and protection strategies to be implemented" (Stewart *et al.* 2007:2). Representativeness also sees PA classifications as part of a broader, connected landscape, working toward a common end; not as isolated efforts (Dudley 2008). The representativeness debate has been put aside in this study and it is presumed to be a best method for assessing PAN effectiveness.

It is important to measure representativeness to avoid bias. Representation bias is when some ecosystems or species have high levels of protection while other ecosystems or species have low or no protection. Representation bias is also when the least threatened ecoregions are over-represented in conservation efforts while the most threatened biologically significant ecoregions are under-represented (Dudley and Pressey 2001; Hoekstra *et al.* 2005; Izquierdo and Grau 2009; Jenkins and Joppa 2009; Joppa and Pfaff 2009; Margules and Pressey 2000; Pressey 1994; Pressey *et al.* 2002; Rodrigues *et al.* 2004a, b). The quantitative nature of representation goals is fundamental to SCP. Likewise, SCP is fundamental to representativeness.

2.2 Systematic Conservation Planning

SCP focuses on strategically identifying PCA*s* for PAN expansion and developing a representative, effective, and enduring network (Boucher *et al.* 2013; Brooks *et al.* 2004; Dudley and Pressey 2001; Groves *et al.* 2002; Juffe-Bignoli *et al.* 2014; Langhammer *et al.* 2007; Margules and Pressey 2000). SCP is increasingly important for PA site-selection because the options to enlarge existing or establish new PA*s* are diminishing due to population growth, increased demand for natural resources, and a reduction in the amount of intact habitats (Boucher *et al.* 2013; Pressey *et al.* 1993:124). The goal of systematically developing a PAN through deliberate site-selection is "capturing spatial patterns of connectivity such as migration and dispersion across land and seascapes, ensuring sufficient population sizes and genetic diversity, and securing against loss due to natural stochastic events or anthropogenic influences by replicating protection in multiple locations" (Boucher *et al.* 2013:487). A lack of SCP may create a biased PAN that fails to preemptively protect habitats before irreversible habitat destruction or species loss occurs (Groves *et al.* 2002; Joppa and Pfaff 2009; Matteucci and Camino 2012; Pressey 1994). Pressey *et al.* (1994) expound:

> [I]f a chance process of reserve selection continued, it could produce a network of reserves that is very inefficient in terms of preserving a diversity of ecosystems . . . The resources for conservation are limited and activities that are destructive to nature are expanding. The success of eventual reserve networks in representing the elements of biodiversity will therefore depend largely on how carefully the individual reserves have been located. (P. 663)

SCP also enables global cooperation, decision-making, and initiative implementation. If there are multiple actors, SCP helps avoid conflict and project failures because it necessitates actors agree upon definitions, measures of success, and a system of analysis (Gordon *et al.* 2013; Groves *et al.* 2002; Margules and Pressey 2000). SCP "enable[s] users to visualize social, economic, and biodiversity information together . . . to design systems of protected areas that would accommodate all societal needs and maximize . . . benefits" (Boucher *et al.* 2013:488).

The requirements of successful SCP are clear quantifiable conservation goals (set by representativeness), methods for PA site-selection to ensure new PA*s* help meet goals and complement the existing network, and a method of measuring and assessing those goals (Margules and Pressey 2000). This method is gap analysis.

2.3 Gap Analysis

Gap analysis measures PA coverage and representativeness to identify areas of low proportional representation (i.e. "gaps") to determine where new PA*s* should be established.

Gap analysis is also used to set and measure progress toward conservation goals and engage in various stages of SCP, such as the reconsideration of CPA*s* (Brooks *et al.* 2004; Chape *et al.* 2005; Groves *et al.* 2002; Hoekstra *et al.* 2005; Izquierdo and Grau 2009; Jenkins and Joppa 2009; Jennings 2000; Langhammer *et al.* 2007; Margules and Pressey 2000; Pliscoff and Fuentes-Castillo 2011; Rodrigues 2004a, b; Scott *et al.* 1993). In the most basic sense, gap analysis uses GIS to overlay biogeographic unit maps (i.e. ecoregions and biomes) with PAN maps to calculate how much and which kind of ecological systems are present in a PAN. Overlay analysis may also incorporate layers of population density, land use change, and species richness (Boucher *et al.* 2013; Izquierdo and Grau 2009; Scott *et al.* 1993).

Gap analysis has received criticism for its inherent shortcomings (Langhammer *et al.* 2007). There are concerns gap analysis overestimates the amount of true protection because it does not: 1) accurately depict the presence or absence of species (Langhammer *et al.* 2007); 2) pay attention to changing trends in land use or habitat loss (Jennings 2000); or 3) consider the type and quality of PA management (Chape *et al.* 2005). Another concern is gap analysis traditionally measures "pure" ecological models that ignore how humanity has replaced historical compositions of flora and fauna with mosaics of human activity (Ellis and Ramankutty 2008). Nevertheless, gap analysis gives surveyors a method of assessment and, like representativeness, facilitates SCP and the implementation of conservation initiatives (Chape *et al.* 2005; Scott *et al.* 1993).

CHAPTER 3: BACKGROUND

This chapter presents the concepts of ecological classifications, global pressures on biodiversity, PA establishment, and international efforts to reduce those pressures and increase PA establishment. These concepts paint a broad picture of global conservation that is useful for the section six of this chapter, which discusses these concepts specific to Chile. The section on Chile also presents the historical context of Chile's economy and environment as well as previously reported representation bias in the Chilean PAN to establish the importance and difficulty of protecting Chile's biodiversity.

3.1 Ecological Land Classifications: Ecoregions and Biodiversity Hotspots

Bailey (1983) says, "The purpose of ecological land classification is to divide the landscape into variously sized ecosystem units that have significance both for development of resources and for conservation of environment" (p. 365). Ecological classifications include biomes, ecoregions, and ecozones. WWF's ecoregion classification has become the internationally accepted standard unit of scale for environmental analysis (Boucher *et al.* 2013; Soutullo *et al.* 2008; WWF N.d.a.). Ecoregions are defined by Olson *et al.* (2001) of World Wildlife Fund (WWF) as "relatively large units of land containing a distinct assemblage of natural communities and species, with boundaries that approximate the original extent of natural communities prior to major land-use change" (p. 933). The WWF (N.d.b.) explains that ecoregions:

1) Share a large majority of their species and ecological dynamics,
2) Share similar environmental conditions, and
3) Interact ecologically in ways that are critical for their long-term persistence.

The collection of ecoregions captures a full range of biodiversity by each individual ecoregion singularly representing a geographical group of similarly functioning ecosystems (Bailey 1983). Bailey (1983) elucidates that ecoregion "evaluation is based on the hypothesis that all replications of a physically defined and characterized ecosystem or component class will respond in a similar way to management for any specified level of use" (p. 365). This is thought to make ecoregions more useful for environmental assessment and SCP than broader ecological classifications such as biomes, biogeographic realms, or biodiversity hotspots (BH*s*) (CI 2014; Olson *et al.* 2001; WWF 2014), which contain multiple ecoregions and therefore multiple management and conservation needs within one biome, realm, or BH. Conversely, fine-scale ecological classifications (such as ecosystems) overlook the greater processes that support interwoven species and habitats.

WWF[5] compiled an ecoregion map based on distinctiveness and homogeneity of biotic communities, vegetation, ecological processes, species migration, and other environmental aspects (Olson *et al.* 2001). The current version records 825 terrestrial and 658 freshwater and marine ecoregions (WWF 2006). WWF also identified 238 ecoregions (142 terrestrial and 96 freshwater and marine) as CPA*s* based on the presence of significant biodiversity and ecosystem representation as well as vulnerability and irreplaceability. These ecoregions are the "Global 200" or "G200*s*" (Olson *et al.* 2000; Olson and Dinerstein 2002; WWF N.d.c., 2012). Each G200 may include multiple ecoregions and is renamed accordingly (Magin and Chape 2004).

A BH is not an ecological classification per say, but BH*s* are common in gap analysis as over 90% of global BH*s* overlap with G200*s* (Olson and Dinerstein 2002). BH*s* are extents of land considered ecologically significant based on a high level of endemism, habitat loss, and degree of threat. To qualify as a BH at least 70% of the area's primary vegetation must have been lost and at least 0.5% (or 1,500 of the world's 300,000 plant species) must be endemic (Myers *et al.* 2000). Conservation International (CI) identified 35 BH*s* covering 2.3% of the planet (Mittermeier *et al.* 2004). These 35 BH*s* collectively contain 44% of the world's plants and 35% of the world's terrestrial vertebrates in only 1.4% of the land area (Myers *et al.* 2000).

5 - WWF was initially established by the IUCN as a fund-raising tool. WWF now functions independently and is considered an IUCN sister organization.

3.2 Global Pressures on Biodiversity

Biological diversity refers to the variety of life on Earth: the variation in genes, species, microorganisms, ecosystems, and habitats (CBD 2007). Biodiversity is important for countless reasons, including erosion and pollution control, nutrient cycling, water security, and the services it provides humanity (Durán *et al.* 2013; Juffe-Bignoli *et al.* 2014; MEA 2005; SCBD 2010; WWF 2014). Humanity has greatly altered the composition, processes, and at times very existence of Earth's biodiversity, leaving very few patches of historically "pure" ecological systems. Anthropogenic disturbance, principally agricultural expansion, is the single greatest reason for global habitat loss and degradation (Groves *et al.* 2002; SCBD 2010). More land was converted to crops between 1975 and 2005 (30 years) than between 1700 and 1850 (150 years) (MEA 2005); deforestation is continuing at an alarming rate mainly due to plantation forestry in temperate regions (SCBD 2010); and the world is in the midst of a human induced mass extinction (Heinen 2012; MEA 2005). WWF's 2014 Living Planet Report says between 1970 and 2010 vertebrate species declined by 52%, freshwater species by 76%, and terrestrial and marine species each by 39%. Furthermore, about 60% of ecosystem services are used unsustainably (MEA 2005). Because of this "biodiversity crisis", "[M]ost of the world's nations have been working together on an inspirational conservation goal: To complete an ecologically representative network of protected areas as the cornerstone of an effective global biodiversity conservation strategy" (Stolton *et al.* 2014:viii).

3.3 Protected Areas

Dudley and Pressey (2001) explain, "The basic role of PA*s* is to separate natural values (like biodiversity, scenery and naturally functioning catchments) from processes that threaten their existence" (p. 2). PA*s* have been established for over a 1,000 years by various societies for religious, cultural, scientific, and environmental reasons (Chape *et al.* 2005). Within the last few decades, PA*s* have grown at the fastest rate in history. PA*s* expanded ten-fold between 1970 and 2000 due to a global recognition of the ecological, social, and scientific value of the environment;

concern for dwindling ecosystem services, species, and habitats (Boucher *et al.* 2013); global, post-Cold War political and economic reconfiguration; and international environmental agreements and treaties (Zimmerer, Galt, and Buck 2004). Two recent reports (Deguignet *et al.* 2014; Juffe-Bignoli *et al.* 2014) identified over 209,000 PA*s* in more than 193 countries and territories covering 15.4% of the planet's terrestrial and inland waters, 3.4% of the oceans, and 8.4% of marine areas within national jurisdiction. Today PA*s* are globally the largest form of planned land-use (Coad *et al.* 2009).

PPA*s* are partly defined as land "owned or otherwise secured by individuals, communities, corporations or non-governmental organizations" (Stolton *et al.* 2014:66). PPA authority remains with the landowners "who determine conservation objectives, develop and enforce management plans and remain in charge of decisions, subject to government legislation" when applicable (Borrini-Feyerabend *et al.* 2013:36). PPA*s* have existed for centuries, but it wasn't until the 1990s that they flourished globally in both number and distribution (Stolton *et al.* 2014). PPA growth can be attributed to, among other things, neoliberal policies, land ownership liberalization, recognition they can complement or potentially stand in for public PA*s*, and international promotion for their increased establishment (Holmes 2014; Langholz and Lassoie 2001; Mitchell 2007; Pasquini *et al.* 2011).

3.4 International Protected Area Activities

International PA efforts include establishing global standards for PA management and governance categories, holding conservation conferences, creating a global PA database, and working to create a global PAN that equally represents the variety of ecosystems, habitats, and species on Earth. These efforts aim to make the global PAN effective and enduring.

3.4.1 International Union for Conservation of Nature

The International Union for the Conservation of Nature (IUCN)[6] was founded in 1948 as the

6 - IUCN permanent link: www.iucn.org.

world's first (and largest) international nature conservation organization (Dudley 2008). The IUCN's mission is to " . . .influence, encourage, and assist societies throughout the world to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable" (Dudley 2008:ii). The IUCN has established PA definitions and governance and management categories widely considered international standards (Borrini-Feyerabend *et al.* 2013; Dudley 2008; Mitchell 2007; Stolton *et al.* 2014).

A PA is defined by IUCN as a "clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (Borrini-Feyerabend *et al.* 2013:5). There are four types of PA governance:

1) Government: Governed by a federal, national, or sub-national (state, region, or municipality) agency or by a government-delegated non-governmental organization (NGO) or private company.

2) Shared: Trans-boundary governance between territories and collaborative or joint governance between a diversity of actors, boards, parties, and/or institutions with various levels of influence. Trans-boundary PA*s* straddle country boundaries and thus require cross-border cooperation. Shared governance may be a combination of government, private, and community-based governance.

3) Community-based: Governed by local and/or indigenous peoples.

4) Private: Governed by individuals, organizations, corporations, or institutions either for or not-for profit.

The IUCN only recognizes the existence of a PA if it meets certain standards. A PA must first be legally recognized *de jure* ("in law") by the host country, or be recognized under international conventions such as UNESCO and Ramsar. Then, a PA must maintain that the main objective of the site is conservation (Dudley 2008). Finally, among other standards, a PA must conform to the IUCN definition of a PA and fall into one of the following management categories. Categories I-IV are for strict biodiversity protection and V-VI are for multi-use. (See Appendix I for definitions and primary management objectives.):

I Strict protection as either a) Nature Reserve or b) Wilderness Area

II National Park

III Natural Monument or Feature[7]

IV Habitat/Species Management Area

V Protected Landscape/Seascape

VI Protected Area with Sustainable Use of Natural Resources

3.4.2 World Parks Congress

Every 10 years the IUCN hosts the World Parks Congress (WPC),[8] the foremost global forum on PA*s*. The WPC is often when international conservation targets, such as representation percentages, are set. In 1962 the IUCN held the first Congress in Seattle, Washington. The meeting "defined the basis, definitions and standards for building representative national systems of PA*s*" (Deguignet *et al.* 2014:3). Thirty years after the first conference, the Congress decided that by the year 2000 PA*s* should contain at least 10% of each of the earth's biomes. The purpose was to build a global PAN that captured and proportionally represented the greatest range of biodiversity (Langhammer *et al.* 2007). But as 2000 approached, it became evident the targets would be missed and they were pushed to 2010 (SCBD 2008).

During the 2003 WPC stressed the importance of conducting gap analyses to evaluate representativeness and determine where PA coverage should be expanded to reach the 2010 targets (Coad *et al.* 2008a; Dudley 2008; Jenkins and Joppa 2009). As 2010 approached, a global gap analysis revealed only 13.4% of the world's terrestrial area was under IUCN PA status. This was most likely because PA*s* around the world were being established in an ad hoc manner without SCP (Coad *et al*. 2008a). Again, the 2010 targets were not met (SCBD 2010).

The sixth WPC was held in November 2014 in Sydney, Australia. The Congress concluded with "The Promise of Sydney". The Promise sets new conservation goals and outlines a pathway to meeting 2015 and 2020 targets established by the United Nations Convention on Biological Diversity (CBD) (Juffe-Bignoli *et al.* 2014; SCBD 2014).

7 - Chile uses the term "National Monument".

8 - WPC permanent link: worldparkscongress.org.

3.4.3 Convention on Biological Diversity

The CBD[9] is a country-level, member based, international treaty to conserve, sustainability use, and equally share the benefits of biodiversity with the overall purpose of reducing the rate of biodiversity loss (CBD 2007; Heinen 2012; Juffe-Bignoli *et al.* 2014). The CBD sets conservation goals and provides guidance to member countries for what and how much biodiversity should be protected. Member countries are responsible for developing and implementing a National Biodiversity Strategies and Actions Plan (NBSAP) to meet goals and maintain minimum coverage and effectiveness (Boucher *et al.* 2013; CBD 2007). The CBD treaty was first opened for signatures in 1992 at the Earth Summit in Río de Janeiro. Today, leaders in over 192 countries (including Chile) have signed the convention (Juffe-Bignoli *et al.* 2014).

The CBD works closely with the IUCN. In 2002, to help the IUCN meet the 2010 10% biome conservation target, CBD members agreed to conserve at least 10% of each of the world's ecoregions (CBD 2007) by 2010. But by 2010, only 56% of 825 terrestrial ecoregions and 29% of G200 terrestrial ecoregions met the 10% target. Twenty-seven terrestrial ecoregions had no protection at all (Coad *et al.* 2008b).

At the 2010 CBD, 20 new 2015 and 2020 targets called the Aichi Biodiversity Targets were set and later adopted into the Promise of Sydney (Juffe-Bignoli *et al.* 2014) at the 2014 WPC. Target 11 reads (SCBD 2014):

> By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected networks of protected areas and other effective area-based conservation measures . . . (P. 2)

PPA*s* are considered essential to meeting Target 11 and the IUCN has written extensively on their integration into public PAN*s* and the World Database of Protected Areas (WDPA) (Stolton *et al.* 2014). The WDPA is the single most comprehensive source of information available on the location of terrestrial and marine PA*s* around the globe.

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9 - CBD permanent link: www.cbd.int.

3.4.4 World Database on Protected Areas

One of the most notable contributions of the IUCN is the WDPA[10] (Deguignet *et al.* 2014; Juffe-Bignoli *et al.* 2014; UNEP-WCMC 2012) The WDPA consortium was established in 2002 to officially define and "maintain a freely available, accurate, and current [PA] database that is accepted as a global standard by all stakeholders" (Hoekstra *et al.* 2005:24). The aim "is a common standard to allow the sharing of PA data between organizations, countries and industry ultimately resulting in a globally complete and accurate dataset for PA*s*" (UNEP-WCMC 2012:1). Scientists, governments, academics, and NGO*s* use the database to determine CPA*s*, conduct gap analyses and environmental impact assessments, and assess progress toward global conservation targets such as CBD Target 11 (Boucher *et al.* 2013; Chape *et al.* 2005; Coad *et al.* 2008a,b; UNEP-WCMC 2012).

Even though the WDPA is the world's most comprehensive source of PA information, it is criticized for both overestimating protection and being far from comprehensive (Joppa *et al.* 2008). The WDPA overestimates protection in the sense it assumes all PA*s* are equally effective, which is unrealistic. Some PA*s* are under threat of encroachment, poorly managed, too small to sustain a habitat or species, or are under strict protection while others are multi-use (Boucher *et al.* 2013; Corcuera *et al.* 2002; Dudley and Pressey 2001; Rodrigues 2004b). The WDPA also surely includes paper parks. Paper parks are PA*s* offering little or no actual ecological protection (Borrini-Feyerabend *et al.* 2013; Boucher *et al.* 2013; Joppa *et al.* 2008) yet are still calculated in gap analysis. On the other hand the WDPA underestimates PA coverage, primarily due to the underreporting of PPA coverage (Boucher *et al.* 2013; Juffe-Bignoli *et al.* 2014; Mitchell 2007). To be in the WDPA the PA must be recognized by the IUCN. Because most of the world's PPA*s* are *de facto* ("in practice") due to a lack of host country recognition (like Chile), PPA data in the WDPA is a fraction of what it is in reality. This poses a problem as researchers and planners primarily pull PA spatial data from the WDPA (Deguignet *et al.* 2014),

10 - The database is available on the interactive host website Protected Planet: www.protectedplanet.net.

which means PPA*s* are largely left out of WDPA based analyses and are not included in regional, national, or global systematic conservation planning. The limitations of the WDPA make it nearly impossible to make accurate calculations on how many PPA*s* exist or their rate of growth and spread (Chacon 2005; Stolton *et al.* 2014). The lack of PPA data also means it is difficult, if not impossible, to verify or discredit common beliefs regarding the role and effectiveness of PPA*s*.

3.4.5 UNESCO (World Heritage Convention)

The United Nations 1975 UNESCO (United Nations Educational, Scientific and Cultural Organization) World Heritage Convention[11] serves to conserve natural and cultural areas of outstanding universal value (Dudley 2008; Heinen 2012; Magin and Chape 2004). Outstanding universal value means the site "is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity" (UNESCO 2008:14). Natural World Heritage sites, such as those found in Chile, include "natural features consisting of physical and biological formations or groups of such formations . . . geological and physiographical formations and precisely delineated areas which constitute the habitat of threatened species of animals and plants . . . and natural sites or precisely delineated natural areas" (Magin and Chape 2004:1). World Heritage sites are established and maintained by international agreements and conventions.

3.4.6 Ramsar

Ramsar[12] sites protect important wetlands and are recognized under the Convention on Wetlands of International Importance (Boucher *et al.* 2013; Dudley 2008). Ramsar's purpose "is to recognize the interdependence of humans and the environment and to consider the ecological and economic functions of wetlands as fundamentally important" (Heinen 2012:11). To

11 - UNESCO World Heritage Convention permanent link: whc.unesco.org.

12 - Ramsar permanent link: www.ramsar.org.

designate a Ramsar site, the host country develops a strategic management and monitoring framework and national wetlands policy. However, countries are under no legal obligation to implement or maintain those frameworks or any minimum standards of protection. Given the lack of legally binding protection, Ramsar designation is often seen as a method of awareness, collaboration, and a first stage toward national protection (Dudley 2008; Heinen 2012).

3.5 Global Protected Area Biodiversity Representation Trends

An endless amount of literature shows PAN*s* almost consistently display the following representation bias trends: Marginal lands with low threat or conflict with other land uses are likely to be the most strictly protected (human disturbance is prohibited). These lands are the least economically valuable because they are remote, uninhabitable, or unsuitable for commercial activities (i.e. at higher elevations, on steep terrain, or away from roads). Conversely, areas with the richest biodiversity tend to be under the highest threat of land conversion but be the least protected (Dudley and Pressey 2001; Groves *et al.* 2002; Holmes 2013; Izquierdo and Grau 2009; Joppa *et al.* 2008; Joppa and Pfaff 2009; Lunney *et al.* 1997; Margules and Pressey 2000 1994; McDonald and Boucher 2011; Pauchard and Villarroel 2002; Pressey 1994; Pressey *et al.* 2002). These rich biodiversity, high threat, low protection ("rich, high, low") areas are generally economically valuable due to land competition between urbanization, agriculture, and resource extraction activities (Krug 2001).

Low-income countries, where the population is dependent on natural resources, tend to have the least PA*s* and highest concentration of multi-use PA*s* because the population cannot loose access to resources (Heinen 2012; McDonald and Boucher 2011). Governments in low-income countries are also less likely to have the means to establish or maintain a public PAN (Boucher *et al.* 2013; Durán *et al.* 2013; Krug 2001; Rodrigues *et al.* 2004a). Conversely, richer and/or democratic countries make up 90% of global PA spending (Soutullo *et al.* 2008). These countries are more likely to establish strict public PA*s* (McDonald and Boucher 2011). But as noted, strict PA*s* tend to be in low threat areas (Joppa and Pfaff 2009).

Representation bias is considered to be particularly characteristic of public PA*s*, thereby reducing their effectiveness (Durán *et al.* 2013; Joppa and Pfaff 2009; Juffe-Bignoli *et al.* 2014). PPA*s*, on the other hand, are thought to fill many of the same functions as public PA*s* but more effectively (Krug 2001; Langholz and Lassoie 2001). It is believed PPA*s* show less bias, enhance the resilience of an existing PAN (Borrini-Feyerabend *et al.* 2013), fill public PAN representation gaps (Stolton *et al.* 2014), and reduce government burden to establish PA*s* (Mitchell 2007). Holmes (2013) says PPA*s* not only "add to the total area under protection, but . . . may be conserving areas and biomes that are under-represented in state PA systems, or that contain higher levels of endangered or endemic species" (p. 11). It is also suggested PPA*s* are effective because there is less bureaucracy, more flexibility, and lands can be purchased and protected more quickly (Juffe-Bignoli *et al.* 2014; Krug 2001; Stolton *et al.* 2014). These theories have spurred global interest in various countries to create IPPPAN*s* with the belief the inclusion of PPA*s* in the public PAN will enhance the country's conservation effectiveness and progress toward conservation goals (Fundación Senda Darwin 2013; GEF-SNAP 2010; IUCN 2005; Squeo 2012; Stolton *et al.* 2014). The IUCN has even stated PPA*s* "often protect and restore habitat that is under-represented in national protected areas systems and focus on the conservation of specific highly threatened species" (Juffe-Bignoli *et al.* 2014:14). The report goes on to say, "PPA*s* may thus have a disproportionately important contribution to make to conservation." This statement is not well supported as PPA*s* are not well researched or understood.

It is difficult and at times impossible to research PPA effectiveness claims as PPA data is often limited, unreliable, or nonexistent (Boucher *et al.* 2013; Krug 2001). Few countries have formal systems in place to recognize, document, or regulate PPA*s (*Borrini-Feyerabend *et al.* 2013; Holmes 2013; Langholz and Lassoie 2001; Mitchell 2007; Pauchard and Villarroel 2002; Stolton *et al.* 2014). Without the ability to document PPA*s*, it is difficult or impossible to assess PPA claims, measure the contribution of PPA*s* to a nation's existing PAN, or compare the contribution of PPA*s* to other PA classifications such as those established by the government or international organizations (Boucher *et al.* 2013; Krug 2001). PPA*s* that are not legally recognized are also left out of important global PA databases that are used to measure global PAN biodiversity representation and set global conservation targets.

If PPA establishment is promoted without understanding their true capability and the impact of their establishment, PPA*s* may not be located in the most appropriate place for species and habitat protection. Ultimately, despite popular belief to the contrary (Pasquini *et al.* 2011; Pressey 1994), this could prove problematic. Ongoing unregulated PPA establishment may negatively influence existing PA*s* and conflict with reliable methods of meeting conservation targets. This includes PPA*s* failing to preemptively protect the priority ecosystems, species, or habitats they are thought to be protecting before irreversible destruction occurs (Durán *et al.* 2013; Matteucci and Camino 2012; Pressey *et al.* 1993; Pressey 1994; Rodrigues *et al.* 1999). Fortunately, as PPA*s* become more popular, and there is increased interest to integrate PPA*s* into public and international PAN*s*, new databases are being created and existing datasets are being updated.

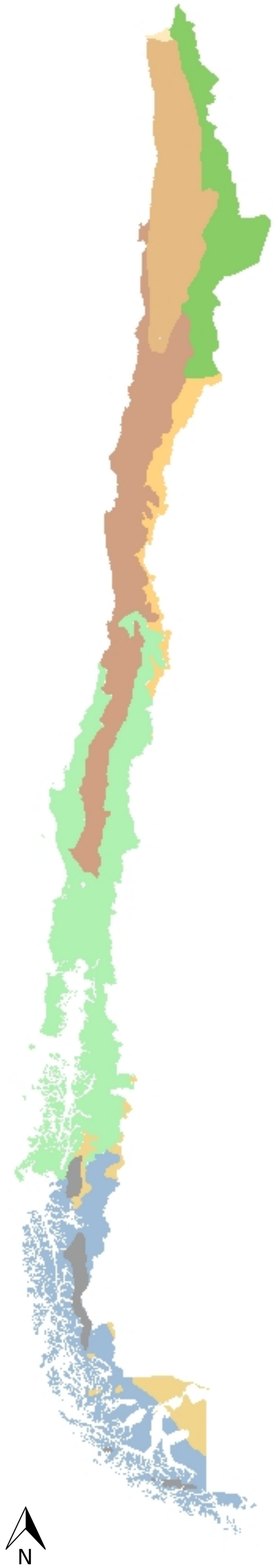
3.6 Chile

3.6.1 Biodiversity

Chile is home to 152 species of mammals, 131 reptiles, 50 amphibians, 67 freshwater fish, 479 birds, and about 5,000 plants. Though the number of plant species is relatively low, nearly 50% are endemic; the highest percentage of native plant taxa of any South American country. Chile's large endemic plant population is due to distinctively unique habitats and microclimates, and the Andean range that inhibits species migration (Royal Botanic Garden N.d.).

Ecoregions and Global 200: This study only addresses mainland terrestrial ecoregions and G200*s* (Fig. 1). Chile has eleven ecoregions[13]; eight are on the mainland. Chile also has nine G200*s*; six are on the mainland (Hogan 2013; WWF 2006; WWF 2012).

13 - WWF Wildfinder interactive map available at: www.worldwildlife.org/science/wildfinder.



<u>Figure 1:</u> Chile's terrestrial ecoregions and G200 designations

Sechura Desert (G200)
Atacama Desert (G200)
Central Andean dry puna (G200)
Southern Andean Steppe
Chilean matorral (G200)
Valdivian temperate forests (G200)
Patagonian Steppe (G200)
Magellanic subpolar forests
Rock and ice

The Atacama and Sechura Desert are distinct ecoregions but are a joint G200 called the Atacama-Sechura Desert.

141,260 of approximately 18.8 million hectares (Mha) (.008%) of the Sechura Desert are in Chile (Hogan 2013). In this study, the Sechura is only included to calculate Chile's total PA and country terrestrial coverage. Sechura representativeness and PA coverage is not ranked against other ecoregions because such an insignificant amount of the Sechura is in Chile that any conclusions drawn from this study about the Sechura would distort the reality of its protection status.

"Rock and ice" is not an official ecoregion but it is in the WWF ecoregion GIS shapefile. Measuring rock and ice coverage is important for assessing representativeness and, as such, is treated as a ninth ecoregion in this study. Rock and ice is not always ranked in analysis.

The unlabeled Andean dry puna has less than 94,000 hectares (ha) in Northern Chile and is not considered an official Chilean ecoregion. There is no PA coverage. The dry puna is only mentioned here to acknowledge it is part of Chile's total terrestrial area used in this study's calculations.

Biodiversity Hotspot: Central Chile: Central Chile[14] covers approximately 40% of Chile's territory (including the San Félix, San Ambrosio, and G200 Juan Fernández Islands) (CI 2014). Terrestrially, Central Chile is composed of the G200 Chilean matorral to the north and G200 Valdivian temperate rainforests to the south (Fig. 2). The BH hosts three-quarters of Chile's endemic plant species and approximately 4,000 vascular plants; half are endemic to the BH territory. Bird and mammal species representation is low, but reptile and amphibian endemism levels are high. Only 30% of the original extent of primary vegetation remains, most of it in the temperate forests, due to deforestation, plantations, fires, and development (CI 2014).

Figure 2: Map of the Central Chile biodiversity hotspot
Source: CI 2014.

14 - Central Chile is also referred to as the Chilean winter rainfall-Valdivian forests, Chilean Mediterranean and temperate ecosystem, or Chilean temperate forests.

To the north, the G200 Chilean matorral is characterized by a Mediterranean-type climate and winter-rainfall regime (Corcuera *et al.* 2002). It is one of only five Mediterranean scrub ecoregions in the world and the only one in South America (Olson *et al.* 2000). About 95% of plant species are endemic. A number of mammal, bird, and amphibians in the matorral are on the IUCN Red List of Threatened Species,[15] including the endangered Andean Mountain Cat (*Leopardus jacobita*) (Hogan 2013). The matorral is classified as critically endangered due to its under-representation in the global PAN (WWF 2014), environmental degradation, and threats including agricultural exploitation, overgrazing, mining, and urbanization such as coastal tourism development (Aronson *et al.* 1993; Hogan 2013; Olson *et al.* 2000).

To the south, the G200 Valdivian temperate rainforests is one of the world's five major temperate rainforests and the only one in South America (WWF N.d.d.). It is estimated 45% of vertebrates, 76% of amphibians, 50% of freshwater fish, 33% of mammals, and 30% of birds are endemic (Hogan 2013). Mammal species of importance include the endangered pudu (*Pudu pudu*) and Huemul deer (*Hippocamelus bisulcus*) (Olson *et al.* 2000). Ninety percent of plant species are endemic. Two tree species of importance are the monkey-puzzle tree (*Araucaria araucana*) and Alerce (*Fitzroya cupressoides)*, which were declared Chilean national monuments in 1990 and 1976, respectively (Premoli *et al.* 2013). WWF declared the temperate forests a top 25 PCA out of all the world's G200*s* (Corcuera *et al.* 2002) due to environmental degradation and threats including exotic tree plantations and over-logging (Olson *et al.* 2000). Nahuelhual *et al.* (2012) believe "[t]he conversion to plantations in one of the greatest threats to native forest ecosystems, particularly temperate rainforests located in south-central and southern regions of the country" (p. 13). Hogan (2013) expressed concern the temperate forests will disappear within the next 20 years if current rates of deforestation continue.

15 - IUCN Red List permanent link: www.iucnredlist.org.

3.6.2 Historical Context: Economy and the Environment

Chile's economy has relied on natural resource extraction activities for hundreds of years. In the late 1680s, Chile temporarily produced wheat in the Coastal Range of Central Chile (Aronson *et al.* 1993; Aronson *et al.* 1998). Then in the mid-1800s the California and Australia gold rush created a global demand for wheat (Nahuelhual *et al.* 2012) and Chile began a second wave of production. Chile quickly became one of the highest global producers until the late 1880s when efforts to keep up with foreign competition failed, the gold rush ended, and Chile's wheat economy faded. As a result of unrestrained and poorly managed cultivation practices during both waves of wheat production, large tracts of land were cleared, overexploited, and ultimately abandoned because the soils were no longer productive (Aronson *et al.* 1993, 1998; Bahre 1979).

Mining also emerged in Chile in the 1800s. Since the mid 1800s, Chile has continued to be the world's number one copper producer (Aronson *et al.* 1998), currently accounting for more than 30% of global output. The original hub of copper production was in the Coquimbo Administrative Region (AR) north of Santiago (Fig. 3) in the matorral ecoregion. Smelters were introduced in the 1820s and required large amounts of wood and shrubs for fuel. Vegetation became so scarce in Coquimbo that coal had to be imported to keep the smelters running. Mine construction also required large amounts of timber for supports, but Chile's native species grew too slowly to meet needs. In the 1880s, mine operation in Coquimbo became unsustainable and, for the most part, came to an end (Bahre 1979). Today mining is concentrated in the Atacama Desert in the Antofagasta AR: the location of the world's largest copper mine, Chuquicamata. Chile excavated between 5.7 and 5.8 million tons of copper in 2013 and 2014 and is forecasted to excavate 6.2 million tons in 2015 (Cambero and O'Brien 2014). For comparison, the second highest producer of copper, China, excavated only 1.6 million tons in 2013.

As mining in Coquimbo depleted resources, concerns of dwindling forest supplies for smelters and mine construction grew (Clapp 1995). In response, German entrepreneur A. Junge experimented with exotic tree species as an alternate to slow-growing native tree species. Junge

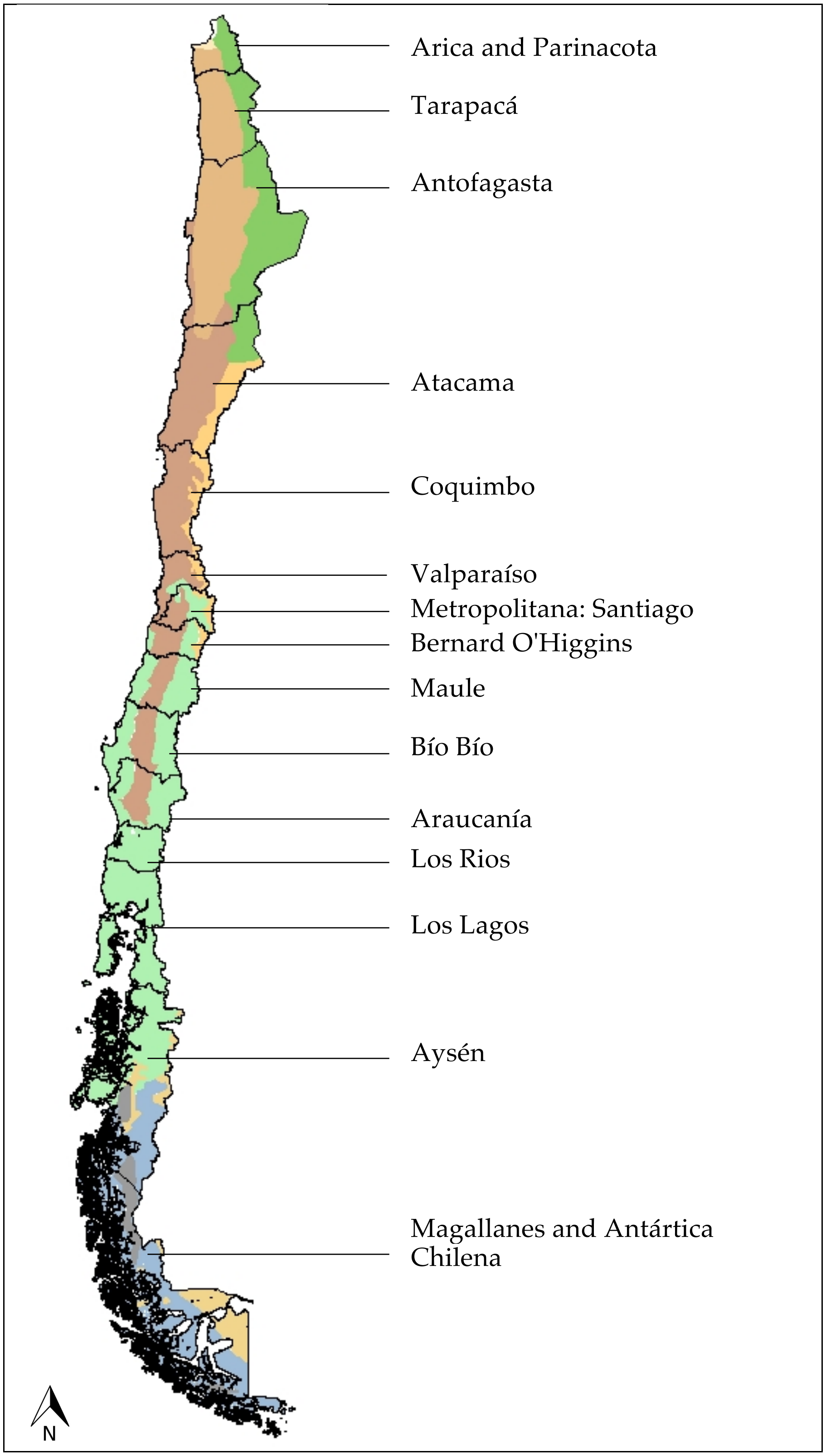


Figure 3: Map of Chile administrative regions

found pine (*Pinus radiata*) and eucalyptus (*Eucalyptus globulus and Eucalyptus nitens)* adapt well, have short 20–30 year rotation cycles, and are capable of growing in poor soils where native forest can no longer establish (Clapp 1995; Mead 2013; Toro and Gessel 1999). Eucalyptus was better suited for mineshaft construction because of its ability to hold under pressure whereas pine was better suited for lumber, paper, and other timber needs. In 1893, mine owner M. Cousiño took these findings and established the first pine and eucalyptus plantation (10 ha) near Concepción in the temperate forests (Clapp 1995; Mead 2013). In 1910 the Chilean government began a project to combat erosion resulting from agriculture and livestock activities (such as wheat production). Because of pine's proven ability to grow rapidly and establish deep root systems that stabilize soil, pine was planted on severely eroded abandoned lands along Central Chile's coastal range (Mead 2013; Toro and Gessel 1999).

Following the Great Depression, plantation expansion was seen as an industry that could stimulate economic recovery while combating erosion and increasing a diminishing wood supply (Clapp 1995; Patterson and Hoalst-Pullen 2011). The 1931 Forestry Law gave a 30-year tariff and inheritance tax exemption to landowners who reforested with plantations (Mead 2013). Though largely state dominated, the policy worked. The timber plantation industry expanded until it peaked in 1945 when land reform and a decrease in international demand slumped the market (Clapp 1995). Nevertheless, plantations continued to expand in Chile and by 1956 there were 200,000 ha of pine plantations (and a nominal amount of eucalyptus plantations) (Mead 2013) up from the original 10,000 ha 63 years earlier.

The Pinochet dictatorship came into power in 1973. Pinochet was influenced by the Chicago Boys neoliberal economic policies that promoted modernity and economic efficiency through commodification, privatization, and market deregulation (Clapp 1995; Patterson and Hoalst-Pullen 2011; Tecklin, Bauer, and Prieto 2011). The privatization of resource extraction sectors appeared to have the greatest potential to strengthen Chile's economy; but resource extraction requires intense production and efficiency to obtain maximum market value and sustain capital accumulation. The presence of existing pine and eucalyptus plantations coupled with their resilience, rapid growth, and contribution to the mining industry made commercial forestry an obvious solution to meeting production and efficiency needs. Pinochet's neoliberal philosophy effectively turned Chiles' natural resources into a commodity to be priced and freely exchanged and governed by market forces (Tecklin *et al.* 2011). Commercial forestry was incentivized through a strong recognition for private property rights, market deregulation, limited national governance, and a loosening of environmental laws (Clapp 1995; Patterson and Hoalst-Pullen 2011).

Within the first year Pinochet took power he promoted plantation development by enacting the 1974 Forestry Incentive Law 701. The Law encouraged private participation and expansion of plantations by creating economic incentives such as the elimination of some forms of property taxes and subsidies lowering the cost of plantation development and maintenance. The law also decreed Chile's forestry agency, the National Forestry Corporation of Chile[16] (Corporación Nacional Forestal de Chile, CONAF), subsidize maintenance costs and reimburse companies 75% of their reforestation costs (Aronson *et al.* 1998; Clapp 1995; Mead 2013; Nahuelhual *et al.* 2012; Patterson and Hoalst-Pullen 2011; Toro and Gessel 1999). Within a few years the timber industry dominated Chile's economy, a period known as the "green tide" (Aronson *et al.* 1998). Other forestry restrictions were lifted throughout the 1970s and new pro-industry, anti-regulation laws were passed in 1985 and 1986 to further stimulate plantation expansion and the exportation of nontraditional timber products, such as raw logs and wood chips (Clapp 1995). Pinochet's policies still influence the transformation of Chile's landscapes today (Patterson and Hoalst-Pullen 2011).

The most productive lands and therefore the core of Chile's plantation industry are in Central Chile's mid-latitudes where there is high species endemism and biodiversity (Armesto, Rozzi, Smith-Ramirez, and Arroyo 1998; Olson and Dinerstein 2002). Accordingly, plantation

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16 - CONAF oversees Chile's National System of State Protected Wildlife Areas (SNASPE) and is responsible for insuring forestry industry compliance with forestry laws and regulations. CONAF is a private corporation but acts as a public agency.

expansion has caused homogenization of the forests and extensive plant, habitat, and species loss (Nahuelhual *et al.* 2012). Nahuelhual *et al.* (2012) present some of the most detailed findings of plantation expansion in their report on land-cover change in the Coastal Range of the Maule and Bío Bío AR*s* where the matorral and temperate forests interlace in the Central Chile BH (Fig. 3). Nahuelhual *et al.* (2012) found plantations covered 5.5% (29,213 ha) of the Maule and Bío Bío AR*s* in 1975, 17.9% (95,049 ha) in 1990, and 42.4% (224,716 ha) in 2007. Between 1975 and 1990, 41.5% (29,213 ha) of plantations were established on cleared secondary native forests, 32% (27,418 ha) on arborous shrubland, and a mere 5.9% (9990 ha) on previously cleared agricultural lands. Furthermore, in 1990, eucalyptus made up 28% of Chile's total plantation coverage and pine made up 64% (1.5 Mha) (Raga 2009), matching New Zealand as the most pine plantation coverage in the world (Mead 2013). In 2011 the Global Forest Watch reported 27% of Chile's tree cover was native, 15% was plantations, and 58% was regenerated forest. Regenerated forests are native forests altered by human activities. Activities can include selective logging, human assisted regeneration such as seed sowing, or cleared areas left to fallow (Global Forest Watch 2011).[17]

3.6.3 Protected Areas and Biodiversity Representation Trends

Government Established Protected Areas: In 1925, Chile passed the Forest Law to formally recognize the existence of PA*s* in Chile (Oyarzún 2009). The first PA, Vincent Pérez Rosales National Park, was declared in 1926 in the temperate forests of the Los Lagos AR (MMA 2011).

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17 - Regenerated forests are often counted as native forests (Raga 2009). But regenerated forests will have reduced biodiversity and ecological process that have been transformed, weakened, or eliminated. Using the term "regenerated forests" is incorrect. Terms set by the FAO (2004) that should be used instead include: Secondary forests (regenerate on native forests, which have been cleared by natural or main causes); modified natural forests (naturally regenerated native species in places with indications of human activities); or semi-natural forests (forests of native tree species, established through planting, seeding, or assisted natural regeneration). Some studies distinguish between native forests and "original native forests". Therefore, based on the above statistics, this study argues that over 70% of Chile's tree cover has been altered by human activities (including conversion to plantations) and only 27% is native.

In the beginning, PA*s* were primarily established as forest reserves in Chile's "pristine" southern forests for their aesthetic and recreational value. In the 1960s, parks were established for their "wilderness value" (Pauchard and Villarroel 2002). These locations were typically under no threat of exploitation because they were in unproductive harsh environments with little or no economic value. Between 1960 and 1969, the government established 4.39 Mha of PA*s*; 3.98 Mha alone were in the most southern AR, Magallanes and Antártica Chilena (MMA 2011). In the 1970s, efforts were made to increase state PA*s* to combat environmental destruction; but PA development was slow to non-existent. Between 1970 to 1979 only 502,937 ha of public protection was designated (MMA 2011). The lack of action was a result of Pinochet's neoliberal philosophy that saw environmental protection as a barrier to economic prosperity; protected land could not be exploited for economic gain (Tecklin *et al.* 2011). In 1978 Chile adopted IUCN's four PA categories: National Parks (NP*s*), Nature Reserves (NR*s*), Pristine/Virgin Area Reserves (Chile has none), and Natural/National Monuments (NM*s*).[18] These PA categories, under national jurisdiction, were put under CONAF management. The Environmental Framework Law of 1994 established Chile's public PAN, the National System of State Protected Wildlife Areas (Sistema Nacional de Áreas Silvestres Protegidas del Estado, SNASPE), which put all NP*s*, NR*s*, and NM*s* in one framework under CONAF's authority within the Ministry of Agriculture (Oyarzún 2009; Pauchard and Villarroel 2002).

SNASPE currently has 36 NP*s*, 49 NR*s*, and 16 NM*s* (CONAF N.d.). In 2014 Stolton *et al.* reported 19% (14.5 Mha) of Chile is protected under one of these categories. Chile also has 42 Nature Sanctuaries (NS).[19] NS*s* are public or government designated PPA*s*.[20] In December

18 - In this study NP*s*, NM*s*, NR*s*, NS*s*, PPA*s*, and UNESCO and Ramsar site are each different PA classifications.

19 - In May of this year a new NS, Cajón del Achibueno, was created in the Maule AR. The 4,556 ha NS is composed of rivers, bodies of water, forests, and glaciers (Karmali 2015). It is not yet in the WDPA nor has it been included in this study due to its recent designation.

2014, the Committee on the Environment and National Resources of the Chilean Senate approved a bill creating the Department of Biodiversity and Protected Areas. The Department will assist the government in implementing Chile's international commitments such as the CBD Aichi Target 11 (El Economista América 2015).

The Chilean government has continued to vocalize the need for conservation but PA establishment remains a low priority (Corcuera *et al.* 2002; Pauchard and Villarroel 2002). In a country that relies heavily on natural resource extraction (Durán *et al.* 2013), this is probably a result of a Pinochet era mindset that PA*s* restrict access to natural resources, which in turn restricts economic growth (Corcuera *et al.* 2002; Durán *et al.* 2013; Squeo *et al.* 2012). Durán *et al.* (2013) state, "SNASPE is known to be inefficient in providing adequate coverage of the country's biodiversity and is underfunded, receiving only 0.03% of the national budget [in 2005]" (p. 2). SNASPE's inefficiency, lack of funding (MMA 2011), and a shortage of public lands (Holmes 2013, 2014; Núñez-Ávila and Corcuera 2014; Squeo *et al.* 2012) may also explain the country's PAN representation bias (Durán *et al.* 2013; Hogan 2013; Pauchard and Villarroel 2002; Pliscoff and Fuentes-Castillo 2011).

Articles and studies report SNASPE coverage in Chile is inversely proportional to species endemism and richness (Armesto *et al.* 1998; Durán *et al.* 2013; Holmes 2014; Núñez-Ávila and Corcuera 2014; Pauchard and Villarroel 2002; Tognelli *et al.* 2009). Scholars report SNASPE PAs are mostly in areas with low threat, low population density, and "little political opposition to conservation" (Holmes 2013:10). As a result, PA*s* are biased toward southern Chile, which is primarily composed of harsh habitats covered in glaciers, unvegetated terrain where biodiversity richness is low, investment potential is limited, and there is little to no threat from anthropogenic disturbances (Armesto *et al.* 1998; Corcuera *et al.* 2002; Durán *et al.* 2013;

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20 - A PPA-NS must be approved and designated by the Chilean government based on certain standards of biological importance, scientific value, and/or natural heritage interest. The site is subject to government regulation but the owners retain management and are responsible for protection in perpetuity (ELI 2003; Oyarzún 2009). See Appendix II for more information.

Pauchard and Villarroel 2002; Pliscoff and Fuentes-Castillo 2011). Armesto *et al.* (1998) report over half of Chile's state PA*s* are in the two most southern AR*s*.

The "rich, high, low" trend is reported to be particularly true of the G200 temperate forests (Armesto *et al.* 1998; Hoekstra *et al.* 2005; Hogan 2013), G200 Atacama Desert, and Mediterranean biome (Brooks *et al.* 2004; Hoekstra *et al.* 2005). The Atacama, though a G200, has probably lacked attention because it is not lush and the perception is there are no species of importance (Pauchard and Villarroel 2002). In the Mediterranean biome where the G200 Chilean matorral is located, land conversion exceeds protection by a factor of 22 (Underwood *et al.* 2008). Underwood *et al.* (2008) reported the matorral is one of the most endangered Mediterranean-type ecoregions in the world. Coad *et al.* (2008b) found only 1.4% of the matorral is protected making it one most significant bioregional gaps in PA coverage in the world (Brooks *et al.* 2004), the least protected ecoregion in Chile (Hogan 2013) and the second least protected G200 in the world (Coad *et al.* 2008b). Pauchard and Villarroel (2002) said, "Although central Chile . . . contains the most diverse types of ecosystems in the country . . . high land value and population concentration impaired the creation of protected areas in this region. Only high elevations and southern areas were available for conservation purposes" (p. 321).

In agreement with the CBD Aichi conservation target, Chile has agreed to at least 17% ecoregion representativeness by 2020 (MMA 2011). Because of Chile's previously reported PAN bias and a theoretical belief in the effectiveness of PPA*s*, the inclusion of PPA*s* in the state PAN is considered essential for meeting this goal. This idea has not been validated.

<u>Private Protected Areas</u>: In the 1990s, likely in response to the low priority the government was giving PA establishment, a growing awareness of the country's environmental issues, and Chile's free market philosophy, PPA*s* followed the global trend and emerged in Chile (Corcuera *et al.* 2002; Oyarzún 2009). The 1994 law establishing SNASPE also introduced PPA*s* for the first time in Chilean legislation and encouraged their establishment: The State shall foster and establish incentives for the creation of privately owned natural protected areas (Oyarzún 2009:6). However, the decree did not define PPA*s*, explain where they fall within SNASPE, or

provide any legal basis for their existence (ELI 2003). Over the years, subsequent frameworks and proposals were approved but none have become reality. Still today, there is no national or regional definition, legislation, database, regulation, or system of reporting PPA*s* in Chile unless it is a government designated PPA-NS; in which case it *is* included in the government PAN but not under SNASPE (Oyarzún 2009; Stolton *et al.* 2014).

A lack of government regulation has made assessment of Chile's private PAN difficult. Attempts have been made to compile a comprehensive database, but reliable data gathering is problematic. Reporting a PPA is voluntary and there are no tangible benefits to supplying information so many PPA*s* might not be reported. Conversely, PPA*s* may be reported where none actually exists. Furthermore, a reliable database requires reliable data. PPA landowners might supply, for example, information regarding size, location, and the types of activities permitted in the park and how much land those activities occupy. The accuracy of this information depends on the landowner's knowledge, fair assessment, and overall honesty. A database of PPA*s* will therefore only be as accurate as the willingness and reliability of the PPA landowner. Moreover, the process of data collection is costly, time consuming, and complicated. including information on ownership, motivation, size, management, and GIS spatial data. The

Chile's most reliable PPA database to date was compiled in 2013 in a census by Chile's Environmental Ministry (Ministerio de Medio Ambiente, MMA). The MMA commissioned Fundación Senda Darwin, a group of researchers dedicated to scientific research and the conservation of Chile's ecological systems, and ASI Conserva Chile, the Association of Conservation Initiatives on Private and Indigenous Lands, to implement the National Private Conservation Initiative (Iniciativas de Conservación Privada, ICP).[21] The purpose of the ICP Census was to create an accurate database of Chile's PPA*s* and develop a CNSPA that legally

21 - Fundación Senda Darwin (2013) is the principal report on the ICP Census background, methodology, and findings. The report is over 150 pages printed in Spanish. I could gather information from the report, but it was not within my ability to read all 150 pages or extrapolate details. The citations Núñez-Ávila *et al.* (2013) and Núñez-Ávila and Corcuera (2014) in this report refer to the original source, which should be consulted for more information.

recognizes the permanence of PPA*s*, promotes their effective conservation of biodiversity, and allows PPA*s* to be recognized by the IUCN and WDPA (Fundación Senda Darwin 2013). In a CNSPA, it is believed PPA*s* would fill state PAN representation gaps, connect existing PA, and enhance the overall conservation of Chile's PCA*s* (Núñez-Ávila *et al.* 2013). It is unclear though if PPA*s* are capable of meeting these expectations.

To define a PPA, ICP used Langholz and Krug's (2003) definition developed at the 2003 IUCN WPC (Núñez-Ávila and Corcuera 2014). A PPA is "a land parcel of any size that is: 1) predominantly managed for biodiversity conservation; 2) protected with or without formal government recognition; and 3) is owned or otherwise secured by individuals, communities, corporations or non-governmental organizations".[22] The census identified 308 PPA*s* with an estimated coverage of 1.67 Mha. Surveys asking about management, objectives, motivation, and general characteristics were sent to the 308 PPA*s*. ICP received 242 responses covering 1.25 Mha (Núñez-Ávila and Corcuera 2014). PPA recognition by ASI Conserva Chile "requires no more than the *intention* of protection in perpetuity from its members, expressed in a signed letter" (Núñez-Ávila and Corcuera 2014:66).

Previous studies on Chile's private PAN have used older, less comprehensive data. Some of these studies show PPA representation bias (Corcuera *et al.* 2002; Pliscoff and Fuentes-Castillo 2011). ICP census data has yet to be used to measure representativeness or to understand the contribution of Chilean PPA*s* to the country's greater PAN. It is important to conduct a timely study using ICP's most current data to determine the role of PPA*s* in Chile and if they show representation bias; are protecting Chile's most under-represented, threatened, and PCA*s*; and if a CNSPA will "fix" Chile's conservation shortcomings.

22 - Note that this definition of a PPA includes community PA*s*. But the IUCN makes a distinction between private and community PA*s*. (See Section 3.4.1.)

CHAPTER 4: METHODOLOGY

The purpose of this study is to measure the representativeness of Chile's terrestrial ecoregions under four PAN scenarios using GIS (Campbell and Shin 2013) to conduct a gap analysis. PA analyses often measure PA classifications as stand-alone systems. Looking at PA classifications individually and not as a collection of efforts allows for gap analysis mistakes such as double counting of PA coverage as well as improper conclusions on the contribution of each PA classification. The comparison of four scenarios in this study, however, is an approach similar to that done by Durán *et al.* (2013) and Pliscoff and Fuentes-Castillo (2011). This model integrates classifications to provide a complete picture of Chile's PAN and to determine to what degree PPA*s* impact state PAN ecoregion protection. An all-inclusive analysis is necessary to measure representativeness, engage in SCP, and assess the effectiveness belief of Chile's private PAN.

4.1 Summary of Gap Analysis Process

I collected GIS shapefiles[23] of Chile's PA classifications, WWF terrestrial ecoregions, and AR*s* from a variety of sources. I did some initial data processing to ensure compatibility and accuracy as well as to avoid common gap analysis mistakes such as double counting PA coverage. After data processing, I performed gap analyses in GIS by layering PA maps over ecoregion and AR maps. I entered representativeness (percentage) and coverage (hectares) data into an excel database. I then executed a number of calculations and comparisons to determine the representativeness of Chile's PAN under each scenario; if representation bias exists and to what degree, where, and by which PA classification; and if Chile's terrestrial ecoregions are inadequately, moderately, or adequately protected. The adequacy of protection was determined by measuring representativeness based on the following percentages: 0%–9.99% = inadequate

23 - A *shapefile* is a GIS file format containing geographic features represented as points, lines, and/or polygons. A *polygon* represents a *feature*, such as an individual ecoregion or PA. Features are displayed in *layers*, such as a map all of the PPA polygons, in a GIS data frame. A *data frame* is the GIS document where maps are created and analysis is conducted.

protection; 10%–16.99% = moderate protection (between previous CBD 10% target and current Aichi target); 17%–100% = sufficient protection (meets or exceeds 2020 Aichi target).

4.2 Data: GIS Layers

The following layers relevant to terrestrial Chile were used in analysis. Refer to the noted sections, figures, or appendices for more information:

WWF ecoregions (USGS 2004): Section 3.1 and 3.6.1, Figure 1
SNASPE (Ministerio de Agricultura 2010): Section 3.6.3
NS*s* (Ministerio de Agricultura 2010): Section 3.6.3 and Appendix II
UNESCO (WDPA 2014): Section 3.4.5.
Ramsar (WDPA 2014): Section 3.4.6
Chile's AR*s* (Biblioteca del Congreso Nacional de Chile 2008-2010): Figure 3
PPA*s* (ASI Conserva Chile 2013): Section 3.6.3

ICP mapped 292 PPA*s* covering 1.73 Mha (Núñez-Ávila *et al.* 2013).[24] This data was reduced to 271 PPA*s* covering 1.33 Mha during the 'data processing' phase of this study. The accuracy of the maps was confirmed by crosschecking the data with other sources. For instance, SNASPE and NS data was compared and confirmed with the WDPA. UNESCO and Ramsar data was also crosschecked and confirmed with the WDPA and UNESCO and Ramsar sources.

4.3 Data Processing

To ensure accurate results, several processes had to be completed before gap analysis could be conducted. First, I reprojected shapefiles into a common coordinate system (CS) so layers aligned properly. Second, I dissolved (i.e. condensed) duplicate PA data to make calculations easier and more accurate. Third, I screened and cleaned data to meet analysis needs and avoid common gap analysis mistakes. I assumed the spatial and attribute data of every shapefile is accurate. Any questionable data was verified through other sources.

24 - It is unclear why 292 PPA*s* were mapped and not the 308 identified, or the 242 surveyed, by ICP.

4.3.1 Coordinate Systems

A CS allows multiple shapefiles to be integrated into a data frame (Campbell and Shin 2013). There are two types of CS*s*, geographic and projected. A geographic coordinate system (GCS) defines locations on a 3-D sphere. Locations are identified by latitude and longitude. A projected coordinate system (PCS) (also known as a map projection such as Universal Transverse Mercator (UTM) or Robinson) enables maps to be projected on a 2-D surface. Locations are identified by x and y coordinates and measured in units such as meters or miles. If a layer does not have a GCS or is not in the same GCS as other layers, it must be "defined" and transformed into the correct GCS before it is projected in a PCS (ArcGIS N.d.). In this study, several shapefiles had to be defined and reprojected. I determined GCS WGS 84, and PCS UTM Zone 19s, to be the most suitable for Chile based on the length of the country and it's rough situation between 75°W in the south and 66°W in the north. WGS 84 UTM Zone 19s is best suited for southern hemisphere countries between 72°W and 66°W (Spatial Reference N.d.).

4.3.2 Attribute Data

Attribute data is all of the spatial (i.e. size and location) and non-spatial (i.e. ownership and year established) information related to the features displayed within a layer (ArcGIS N.d.; Campbell and Shin 2013). Attribute data is represented in a table. In this study, for example, rows list individual features (also known as a record) such as the name of a PA. Columns detail the attributes or characteristics of the PA feature, such as size, ownership, and governance type. Ideally one feature has one record but sometimes a feature is listed multiple times as multiple records. A reason may be multiple polygons were drawn to present a single record, such as the Hawaiian Islands. If the individual polygons were not "dissolved" into one record, there will be an equal number of records as there are polygons. Because this research is concerned with area, multiple rows for a single record would need to be manually added to calculate total area and conduct other calculations. I used GIS's dissolve tool to merge features (ArcGIS N.d.) thereby making calculation easier and accurate.

4.3.3 Data Screening

I screened PA shapefiles to meet the study's aims and correct common gap analysis mistakes.

KML to Layer Conversion: First, ICP data downloadable on the ASI Conserva Chile website is available only in KML format. KML allows users to view the data in an application other than ArcGIS, such as Google Earth (Campbell and Shin 2013). To view the data in ArcGIS, the file needed to be converted to ArcGIS format (ArcGIS N.d.).

Data Omission: I omitted data that met two requirements. First, this research measures PA terrestrial coverage so I deleted PA*s* located significantly offshore and/or located within a marine ecoregion (such as Rapa Nui and Juan Fernandez Islands). I retained PA*s* close to shore containing one of Chile's terrestrial ecoregions. Second, PA data projected as a polygon provides spatial information that shows the true size, shape, and location of the park. Sometimes though, a PA is depicted as a point if spatial data is unknown. Typically, to conduct analysis of point data, a buffer is drawn around the point in the PA's reported, approximate, or assumed size (Brooks *et al.* 2004; Chape *et al.* 2005; Underwood *et al.* 2008). This can lead to inaccurate conclusions of representativeness and coverage (Jenkins and Joppa 2009; Joppa *et al.* 2008). To avoid these inaccuracies, I screened data to find PA*s* depicted as points. Three points were found in the PPA layer and removed.

Intersect Analysis and Data Clipping: To avoid double counting of representativeness and coverage, I identified overlapping polygons using a GIS "intersect" operation and subsequently clipped one of the overlapping layers using a "clip" operation (ArcGIS N.d.; Campbell and Shin 2013). Overlap is a result of incorrectly or approximately drawn borders, one PA contained within another (such as NM*s* located in NP*s*), or parks with two classifications in two shapefiles (such as a PPA-NS). First, I clipped overlapping polygons within each PA classification to ensure PA classification totals were correct. Then, I clipped overlapping polygons between classifications. To determine which polygon classification to clip or retain, I created a hierarchy based on strength of legal recognition and environmental protection security (IUCN management categories) (Soutullo *et al.* 2008).

The first tier is NP*s*. NP*s* have the strongest legal standing and provide the strictest environmental protection out of all Chile's state PA*s*. The second tier is NM*s* and NR*s*, which have no overlap. The third tier is NS*s*, including PPA-NS*s* (See Appendix II). PPA*s* are the fourth tier because they have no legal recognition, regulation, or even guaranteed protection. The fifth tier is UNESCO and Ramsar sites. Even though UNESCO sites are subject to international legislation and are more strictly protected than PPA*s*, the focus of this research is on Chilean, not international, PA establishment.

Clipping data to avoid double counting is the most important step for an accurate gap analysis. It seems, however, to be a largely disregarded step (Chape *et al.* 2005; Soutullo *et al.* 2008). In a study on CPA*s*, Soutullo *et al.* (2008) said, "[O]ur estimates are likely to be inflated by double-counting overlapping reserves, suggesting that had double-counting been avoided the estimate of the total coverage of the global network of protected areas would have been even smaller" (p. 606). Chape *et al.* (2005) said in their global PA study that overlap error as a result of not clipping "was assumed to be smaller than the potential error of double counting" (p. 447). But Chape *et al.* (2005) admitted, "[F]urther work may be needed to address the scale of this problem" (p. 447). Therein lies the problem of not clipping: there is no way to know how small or great the margin of overlap error is. For instance, in this study I fully clipped six out of eight terrestrial UNESCO sites covering more than 7.37 Mha. The overlap was mostly with NP*s*. Had UNESCO sites not been clipped, the protection of several ecoregions would be incorrect, such as a G200 considered adequately protected when in reality it is only moderately protected. Even more severely, S4's total country coverage with UNESCO sites would be 33.50%. This study calculated coverage as 23.73%. In fact, total country coverage would be greater than 33.50% due to overlap between other classifications.

4.4 Limitations

Whenever calculating PA coverage there is a certain degree of inaccuracy. For instance, PA*s* may be recorded as points (Joppa *et al.* 2008), borders may be drawn incorrectly or misplaced in GIS, overlap may occur on maps where it does not or not occur where it does. PA data may also simply be missing (Boucher *et al.* 2013). These errors effect total PA coverage and representation calculations, especially when parks straddle or sit at the edge of ecoregion boundaries. In this study, state and international PA*s* will suffer less from these limitations than PPA*s* since there is no official system of recording PPA locations, borders, and, at times, authenticity. PPA findings in particular should be assessed with prudence and the overall results taken with the understanding there will be inaccuracies (Soutullo *et al.* 2008).

The greatest methodological limitation in this study was the impossibility of lining up the bottom third of the WWF Chile ecoregion layer with every other layer. The ecoregion layer was distorted due to either a data source digitization or datum transformation error. After exploring different possibilities to reproject the data, it was determined that it could not be without the source data. I contacted WWF several times to obtain this data but never received a response. As a result, PA and ecoregion overlap in the bottom half of Chile was manually calculated. In the end, it proved beneficial.

4.5 Data Analysis

After data processing, I layered PA and WWF ecoregion polygons to measure coverage and representativeness. Because of the WWF map alignment issues, calculations for the bottom third of Chile had to be done manually. Fortunately, by inspecting one park at a time (twice to avoid errors), I was able to ensure data was 100% clipped as well as calculate terrestrial coverage of coastal PA*s* with accidental ocean overlap. In the end, manual calculation was so valuable I did it for the top two-thirds of Chile as well. I recorded the data in an extensive Excel database. I performed various operations to calculate coverage and biodiversity representation of each PA classification in each scenario as well as determine Chile's progress toward the Aichi target.

CHAPTER 5: RESULTS

The first section of this chapter discusses the findings of the four scenarios. The second section discusses PA representation and coverage by ecoregion to provide more detail. The word "percent" or "percentage" refers to representativeness. "Coverage" refers to the amount of area protected in hectares.

5.1 Protected Area Network Representativeness and Coverage in Each Scenario

The following tables and figures should be referenced when reading the results:

Table 1: Ecoregion coverage and representation under each scenario.
Fig. 4: County-wide PA coverage under each scenario.
Table 2: Ecoregion coverage and representation by protected area classification.

5.1.1 Scenario 1 (S1): State protected area network

S1 is the baseline of state PA coverage in Chile. This scenario represents the coverage of all PA*s* legally recognized, designated, and regulated by the Chilean government. This includes SNASPE PA*s* and public and private NS*s*. In S1, 20.14% (15.19 Mha) of Chile's terrestrial land is protected. By percentage and coverage, NP*s* provide the most protection (12.33%, 9.3 Mha) and NR*s* the second most protection (7.17%, 5.41 Mha).

Only two ecoregions are adequately protected in S1: the subpolar and temperate forests. The subpolar forests have the highest percentage and coverage (55.62%, 7.65 Mha). In fact, half of Chile's total S1 terrestrial protection is in this ecoregion. The G200 temperate forests are the second most protected (19.69%, 4 Mha). The G200 Patagonian Steppe (13.13%, 371,958 ha) and the G200 Central Andean dry puna (11.66%, 963,148 ha) are both moderately protected. Meanwhile, the G200 Atacama Desert (1.35%, 142,009 ha) and the G200 Chilean matorral (1.80%, 267,154 ha) have the least representation and the second and third least coverage.

5.1.2 Scenario 2 (S2): Comprehensive National System of Protected Areas

S2 represents the coverage of S1 plus PPA*s*, thereby showing what a CNSPA in Chile would look like. S2 shows the contribution of PPA*s* to Chilean conservation. That is, it reveals if PPA*s* in Chile are 1) filling public PAN representation gaps, 2) as or more effective than the state PAN at protecting PCA*s*, and, ultimately, 3) living up to the PPA effectiveness belief.

S2, 21.91% (16.52 Mha) of Chile's terrestrial land is protected. PPA*s* add 1.33 Mha and cover 1.77% of terrestrial Chile. The only change in protection designation between S1 and S2 is the Southern Andean Steppe. Protection of the ecoregion more than triples from "inadequate" in S1 (3.23%, 96,461 ha) to "moderate" in S2 (10.17%, 303,644 ha). The increase is due to PPA*s*, which add 207,183 ha of protection and cover 6.94% of the ecoregion. There are no PPA*s* in the G200 Atacama or G200 Patagonian Steppe. PPA*s* raise protection in the G200 Central Andean Dry Puna by only .10% and the G200 matorral by .69%.

5.1.3 Scenario 3 (S3): Existing protected area network

S3 represents S1 plus UNESCO and Ramsar sites recognized by the IUCN. This scenario reflects what spatial data should look like in the WDPA and, therefore, what is globally recognized. In S3, 21.97% (16.57 Mha) of Chile's terrestrial land is protected. UNESCO adds an additional 1.28 Mha (1.70%) and Ramsar 98,566 ha (.13%). After data screening, UNESCO is only present in the G200 temperate forests (6.31%, 1.28 Mha). The addition of UNESCO raises representation of the ecoregion from 19.69% to 26%. Ramsar's contribution is insignificant. UNESCO and Ramsar do not contribute to the protection of the G200 Atacama or G200 matorral.

5.1.4 Scenario 4 (S4): Complete protected area network

S4 represents the combined coverage of Chile's state PA*s*, PPA*s*, and UNESCO and Ramsar sites. This scenario shows Chile's current *de jure* and *de facto* protection. If PPA*s* were legally recognized in Chile, the WDPA would (ideally) reflect this scenario and this data would be used in any Chile PA analysis. This is the data that would be used to determine Chile's progress toward the 2020 17% terrestrial ecoregion representation goal. In S4, 23.73% (17.9 Mha) of terrestrial Chile is protected.

Ecoregion protection designations, coverage, and percentage rankings are the same in S4 as they were in S2. That is, the subpolar forests remain the most protected (58.83%, 8.10 Mha)

Figure 4: Countrywide protected area coverage under each scenario

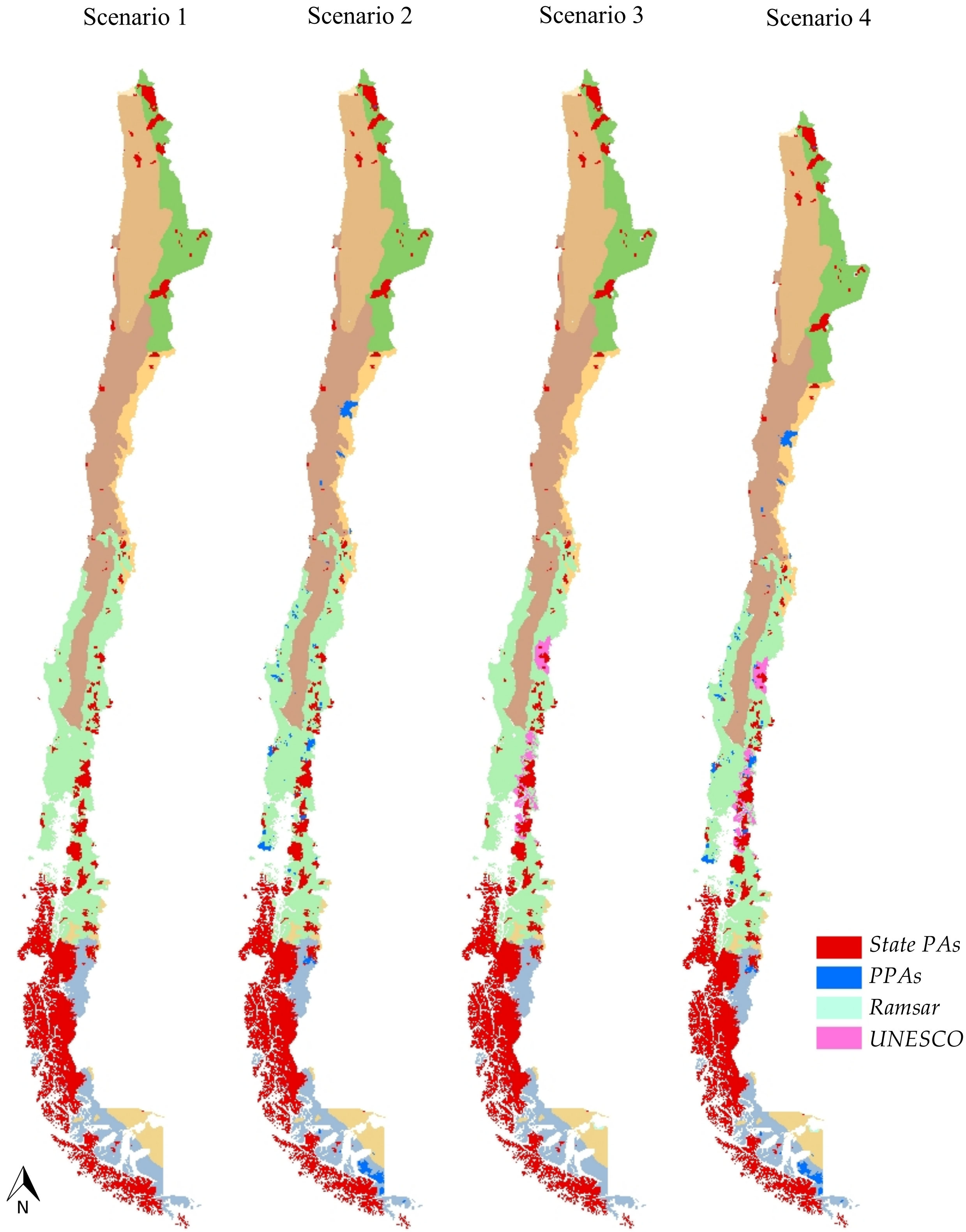

Table 1: Ecoregion coverage and representation under each scenario.

ECOREGION	SCENARIO 1		SCENARIO 2		SCENARIO 3		SCENARIO 4	
Atacama Desert (G200)	142,009	1.35%	142,009	1.35%	142,009	1.35%	142,009	1.35%
Central Andean Dry Puna (G200)	963,148	**11.66%**	971,480	**11.76%**	997,653	**12.07%**	1,005,986	**12.17%**
Chilean Matorral (G200)	267,154	1.80%	368,875	2.49%	267,633	1.80%	369,354	2.49%
Southern Andean Steppe	96,461	3.23%	303,644	**10.17%**	124,583	4.17%	331,766	**11.11%**
Valdivian Temperate Rainforests (G200)	3,995,018	**19.69%**	4,567,471	**22.51%**	5,274,304	**26.00%**	5,846,757	**28.82%**
Magellanic Subpolar Forests	7,653,578	**55.62%**	8,096,007	**58.83%**	7,653,578	**55.62%**	8,096,007	**58.83%**
Patagonian Steppe (G200)	371,958	**13.13%**	371,958	**13.13%**	407,418	**14.38%**	407,418	**14.38%**
Rock and Ice	1,697,827	97.17%	1,697,827	97.17%	1,697,827	97.17%	1,697,827	97.17%
Sechura Desert (G200)	4,717	3.34%	4,717	3.34%	4,717	3.34%	4,717	3.34%
TOTAL COUNTRY PROTECTION	**15,191,868**	**20.14%**	**16,523,988**	**21.91%**	**16,569,721**	**21.97%**	**17,901,840**	**23.73%**
G200 Protection	5,744,003	10.11%	6,426,510	11.31%	7,093,733	12.48%	7,776,241	13.68%

Notes: Column 1 is coverage in hectares. Column 2 is representation in percentages. Protection designation: 0%–9.99% = inadequate protection; 10%–16.99% = moderate protection (between previous 2010 CBD 10% representation target and current Aichi 17% target) highlighted in blue; and 17%–100% = sufficient protection (meets or exceeds Aichi Target) highlighted in green.

<u>Table 2:</u> Ecoregion coverage and representation by protected area classification.

ECOREGION	*SNASPE (NP, NM, NR) (n =137)*		NATIONAL PARK (n = 34)		NATIONAL MONUMENT (n = 16)		NATURAL RESERVE (n = 49)	
Atacama Desert (G200)	*125,602*	*1.20%*	16,408	0.16%	6,983	0.07%	102,212	0.98%
Central Andean Dry Puna (G200)	*955,038*	*11.56%*	665,981	8.06%	11,340	0.14%	277,717	3.36%
Chilean Matorral (G200)	*256,901*	*1.73%*	223,968	1.51%	7,789	0.05%	25,144	0.17%
Southern Andean Steppe	*76,315*	*2.56%*	64,390	2.16%	1,980	0.07%	9,944	0.33%
Temperate Rainforests (G200)	*3,604,317*	*17.77%*	1,854,452	9.14%	1,570	0.01%	1,748,295	8.62%
Magellanic Subpolar Forests	*7,653,389*	*55.61%*	4,574,999	33.25%	1,982	0.01%	3,076,408	22.36%
Patagonian Steppe (G200)	*371,958*	*13.13%*	238,321	8.41%	-	-	133,637	4.72%
Rock and Ice	*1,697,827*	*97.17%*	1,660,862	95.05%	-	-	36,965	2.12%
Sechura Desert (G200)	*4,686*	*3.32%*	-	-	4,686	3.32%	-	-
TOTAL PROTECTION	***14,746,033***	***19.55%***	**9,299,381**	**12.33%**	**36,330**	**0.05%**	**5,410,321**	**7.17%**
G200 Protection	*5,318,502*	*9.36%*	2,999,130	5.28%	32,368	0.06%	2,287,005	4.02%

ECOREGION	NATURE SANCTUARY (n = 38)		PPA*s* (n = 271)		UNESCO (n = 2)		RAMSAR (n = 7)	
Atacama Desert (G200)	16,407	0.16%	-	-	-	-	-	-
Central Andean Dry Puna (G200)	8,110	0.10%	8,332	0.10%	-	-	34,506	0.42%
Chilean Matorral (G200)	10,253	0.07%	101,721	0.69%	-	-	479	<.01%
Southern Andean Steppe	20,146	0.67%	207,183	6.94%	-	-	28,122	0.94%
Temperate Rainforests (G200)	390,700	1.93%	572,454	2.82%	1,279,286	6.31%	-	-
Magellanic Subpolar Forests	189	<.01%	442,430	3.22%	-	-	-	-
Patagonian Steppe (G200)	-	-	-	-	-	-	35,460	1.25%
Rock and Ice	-	-	-	-	-	-	-	-
Sechura Desert (G200)	30	0.02%	-	-	-	-	-	-
TOTAL PROTECTION	**445,835**	**0.59%**	**1,332,120**	**1.77%**	**1,279,286**	**1.70%**	**98,566**	**0.13%**
G200 Protection	425,501	0.75%	682,507	1.20%	1,279,286	2.25%	70,444	0.12%

Notes: Column 1 is coverage in hectares. Column 2 is representation in percentages.

and the G200 temperate forests the second most protected (28.82%, 5.85 Mha). The G200 Patagonian Steppe (14.38%, 407,418 ha), Andean Steppe (11.11%, 331,766 ha), and G200 dry puna (12.17%, 1 Mha) are all moderately protected. Finally, the G200 Atacama (1.35%, 142,009 ha) and G200 matorral (2.49%, 369,354 ha) still have the least representation. The Atacama's coverage is the same between S1 and S4 as only state PA*s* are present in this ecoregion.

5.2 Protected Area Ecoregion Coverage and Representation

Given Chile's shape and size, the following section breaks Chile into four regions, north to south, to most easily map and explain ecoregion protection. Northern Chile includes and G200 Sechura Desert, G200 Atacama Desert, and G200 Central Andean dry puna. Northern Central Chile includes the G200 Chilean matorral and Southern Andean Steppe. Southern Central Chile covers the G200 Valdivian temperate rainforests. Finally, Southern Chile includes the Magellanic subpolar forests, G200 Patagonian Steppe, and rock and ice.

5.2.1 Northern Chile

(Fig. 5)

Sechura Desert (G200): The Sechura is not ranked against other ecoregions but is included in calculations due to the presence of two PA*s*. The first is a NM covering 4,686 ha. The second is a NS covering 30 ha. There are no PPA*s* or UNESCO or Ramsar sites.

Atacama Desert (G200): The Atacama, one of the driest deserts in the world, is a G200 because it is scientifically important. The value of the Atacama "lies in the unique nature of [plant and animal community] composition, the high levels of endemism and remarkable species adaptations for survival in some of the Earth's most demanding abiotic conditions" (Hogan 2013). The Atacama is classified by WWF as "vulnerable". Threats include mining, pollution, livestock overgrazing, deforestation, commercial rare plant collection, and erosion (Hogan 2013; Olson *et al.* 2000). In all four scenarios the Atacama is inadequately protected and has the lowest representation (1.35%). The only PA*s* are state PA*s*. In S1 and S3, the Atacama has the second least coverage (after the Andean Steppe). In S2 and S4, the Andean Steppe's coverage increases and the Atacama becomes the least covered. The Atacama is the least protected ecoregion by NP*s* (.16%, 16,408 ha). The greatest contribution comes from NR*s* (.98%, 102,212 ha).

Central Andean Dry Puna (G200): The dry puna is composed of numerous microclimates that have allowed a rich diversity of plants and animals to adapt to the cold and dry, high-elevation climate (Hogan 2013). The puna is classified by WWF as "vulnerable". Threats include conversion of lands to agriculture or for grazing, livestock degradation, and firewood collection (Hogan 2013; Olson *et al*. 2000).

The dry puna is moderately protected in all four scenarios (ranging from 11.66% to 12.17%). The greatest contribution is from NP*s* (665,981 ha, 8.06%). After the subpolar and temperate forests, the dry puna is the third most protected ecoregion by NP*s*. PPA representation is.10% (8,332 ha) and Ramsar.42% (34,506 ha). There are no UNESCO sites.

5.2.2 Northern Central Chile

(Fig. 6)

Chilean Matorral (G200): The matorral is inadequately protected in all four scenarios (ranging from 1.80% in S1 and S3 to 2.49% in S2 and S4). In every scenario the matorral has the second least representation after the Atacama. Though the greatest contribution is from NP*s* (1.51%, 223,968 ha), only 2.4% of all NP*s* are in the matorral. This is the second lowest protection by NP*s* after the Atacama. PPA*s* add only 101,728 ha (.69%) and Ramsar sites less than 500 ha (<.01%) of protection to the matorral's 14.83 Mha. Forty-eight percent of PPA protection in the matorral can be attributed to one of Chile's five largest PPA*s.*

Southern Andean Steppe: The Andean Steppe is a non-threatened high altitude ecoregion unsuitable for agricultural activities (Hogan 2013). In S1 (3.23%, 96,461 ha) and S3 (4.17%, 124,583 ha) the Steppe is inadequately protected and has the least coverage of all ecoregions. In S2 (10.17%, 303,644 ha) and S4 (11.11%, 331,766 ha) the ecoregion is moderately protected but still has the second least coverage of all ecoregions. The designation change is due to PPA*s*.

PPA*s* have the most representation (6.94%) in the Andean Steppe and the greatest coverage (207,183 ha) of all PA classifications. Eighty-eight percent of PPA protection in the Andean Steppe can be attributed to two of Chile's five largest PPA*s*.

5.2.3 Southern Central Chile

(Fig. 7)

Valdivian Temperate Rainforests (G200): The temperate forests are adequately protected in all four scenarios (ranging from 19.69% to 28.82%). In every scenario the ecoregion has the greatest representation and coverage (ranging from 4 Mha to 5.85 Mha) of all the G200*s* and the second highest representation and coverage of all ecoregions after the subpolar forests. In total SNASPE covers 17.77% (3.6 Mha) of the ecoregion. NP*s* provide the most protection (9.14%, 1.85 Mha) followed closely by NR*s* (8.62%, 1.75 Mha). NP percentage and coverage is the second highest in the temperate forests (after the subpolar forests). The majority of PPA coverage is in this ecoregion (572,454 ha). The only UNESCO site included in this study is in the temperate forests (6.31%, 1.28 Mha). There are no Ramsar sites.

5.2.4 Southern Chile

(Fig. 8)

Magellanic Subpolar Forests: The subpolar forests is a high altitude ecoregion unsuitable for commercial activities or urbanization. The habitat is composed of mountains, ice fields, and glaciers and is climatically dominated by cold weather and strong winds (Hogan 2013). The subpolar forests are adequately protected in all four scenarios (ranging from 55.62% to 58.83%). In fact, the ecoregion has the highest representation and coverage (ranging from 7.65 Mha to 8.10 Mha) of every ecoregion in every scenario.

SNASPE covers 55.61% of all the subpolar forests in Chile (7.65 Mha). The greatest contribution to protection is from NP*s* (33.25%, 4.57 Mha). (NP coverage in the subpolar forests is nearly 2.5 times NP coverage in the temperate forests.) The second greatest contribution is from NR*s* (22.36%, 3.08 Mha). These NP and NR statistics are also the highest percentage and coverage by NP*s* and NR*s* in a single ecoregion. PPA*s* have the second highest percentage and coverage (3.22%, 442,430 ha) in the subpolar forests (after the Andean Steppe and temperate forests, respectively). Eighty-three percent of PPA protection in the subpolar forests is because of two of Chile's five largest PPA*s* (Table 4).

Patagonian Steppe (G200): The Patagonian Steppe has high levels of plant and animal species endemism and is classified by WWF as "critically endangered". Threats include overgrazing, desertification, land conversion for agriculture, invasive species, and government-sponsored predator control (Hogan 2013; Olson *et al.* 2000). The Steppe is moderately protected in all four scenarios (ranging from 13.13% in S1 and S2 to 14.38% in S3 and S4). The greatest contribution comes from NP*s* (8.41%, 238,321 ha). There are no PPA*s* or UNESCO sites but the Steppe does have the greatest representation and coverage of Ramsar sites (1.25%, 35,460 ha).

Rock and Ice: Though not a real ecoregion, in all four scenarios rock and ice is the most represented WWF land categorization (97.17%) and has the third highest coverage (1.7 Mha) after the subpolar and temperate forests. With the exception of one NS, rock and ice protection comes fully from NP*s* (95.05%, 1.66 Mha) and NR*s* (2.12%, 36,965 ha). NP*s* have the highest representation and third greatest coverage in this "ecoregion" after the subpolar and temperate forests.

5.3 Other Findings

This report has made several references to the AR distribution of Chile's PA*s*. During primary analysis it became important to compare my findings to these references and understand PPA AR distribution using the ICP data. The results (Table 3) are discussed in this section as PA AR representation is not a research objective so it should not be in the discussion chapter.

In 1998, Armesto *et al.* reported over half of SNASPE is in the two most southern AR*s* Aysén and Magallanes, which are dominated by subpolar forests and rock and ice. Thirteen years later, this study found 81.52% of total SNASPE coverage is in these two most southern regions: 34.53% in Aysén and 46.99% in Magallanes. The Magallanes AR covers less than 18% of the country. This study also found nearly 35% of total PPA coverage is in the two most southern regions. The majority of PPA*s* are in Magellanes AR (27.15%) primarily due Chile's largest PPA, Karukinka, and fourth largest PPA, Hacienda Chacabuco. A cross-reference between Table 3 and Table 4 reveals Chile's five largest PPA*s* coincide with the five AR*s* with the highest PPA coverage.

The lowest concentration of state PA*s* is in the Coquimbo AR (.09%, 14,317 ha), which is dominated by the matorral and is the birthplace of Chile's mining. The second lowest concentration of state PA*s* is in the Maule AR (.13%, 19,391 ha), the heart of Central Chile. (Section 3.6.2 discussed Maule in Nahuelhual *et al.*'s (2012) study on plantation expansion.) The lowest concentration of PPA*s* is in two of the top three most northern AR*s*. There are no PPA*s* in the Tarapacá AR, which mostly contains the Atacama ecoregion but also some of the Andean Steppe. The second least distribution of PPA*s* is in the Antofagasta AR, which has the same ecoregion composition as Tarapacá and is the heart of Chile's mining industry today.

The results presented in this chapter show measures of coverage and representation of state, private, and international PA*s* as both stand-alone systems and as integrated models under four scenarios. The representation of each ecoregion was detailed in turn to provide a better picture of the location of each PA classification. The following chapter will discuss the implications of these results to determine if Chile is meeting, or making progress toward meeting, global conservation goals and if PPA*s* are protecting PCA*s* and/or enhancing the state PAN. These results will also help determine if an IPPPAN is the correct approach, develop recommendations for improving Chile's PAN, and uncover questions for future research.

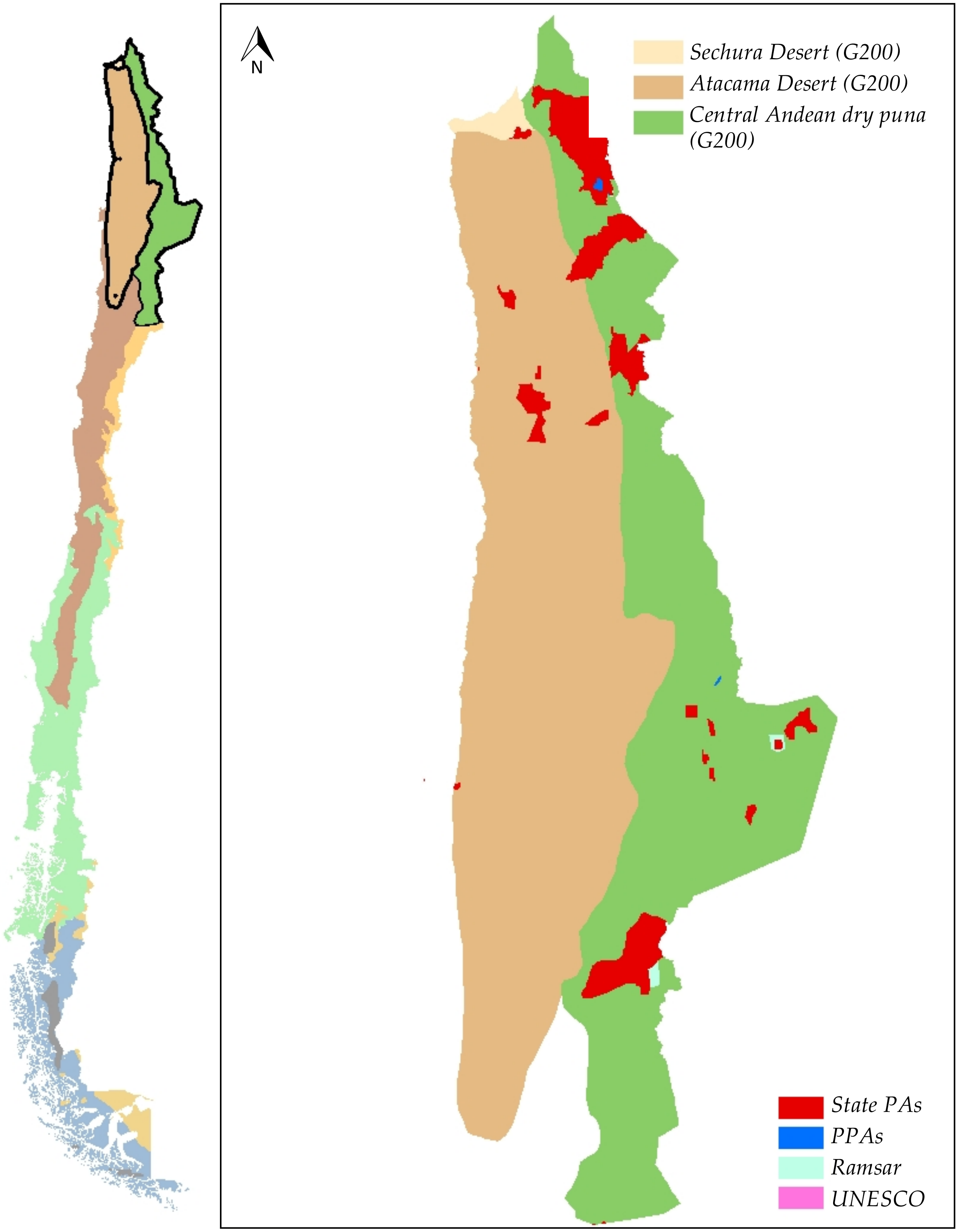

Figure 5: PAs in Northern Chile (Sechura-Atacama Desert and Central Andean dry puna)

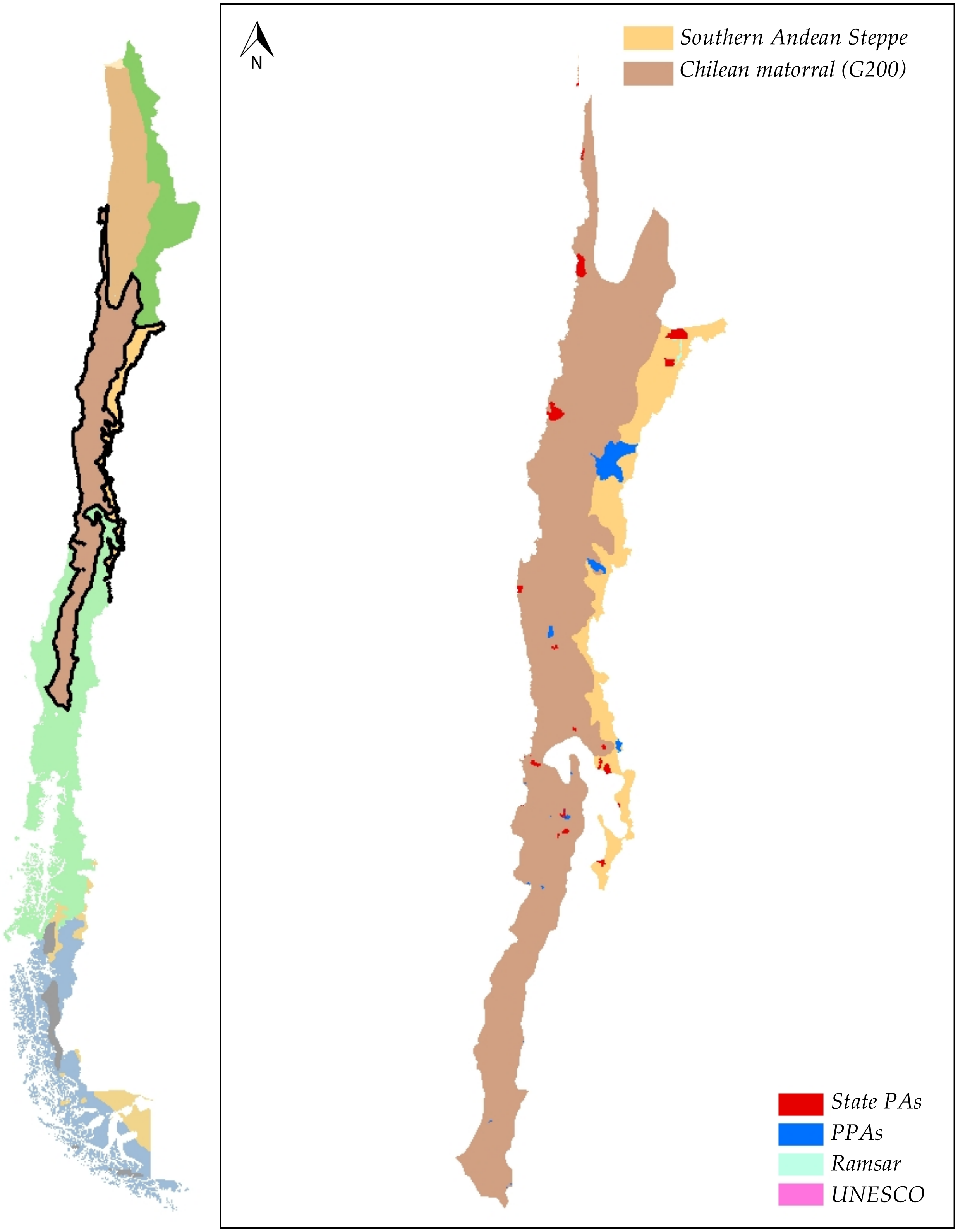

Figure 6: PAs in Northern Central Chile (Chilean matorral and Southern Andean Steppe)

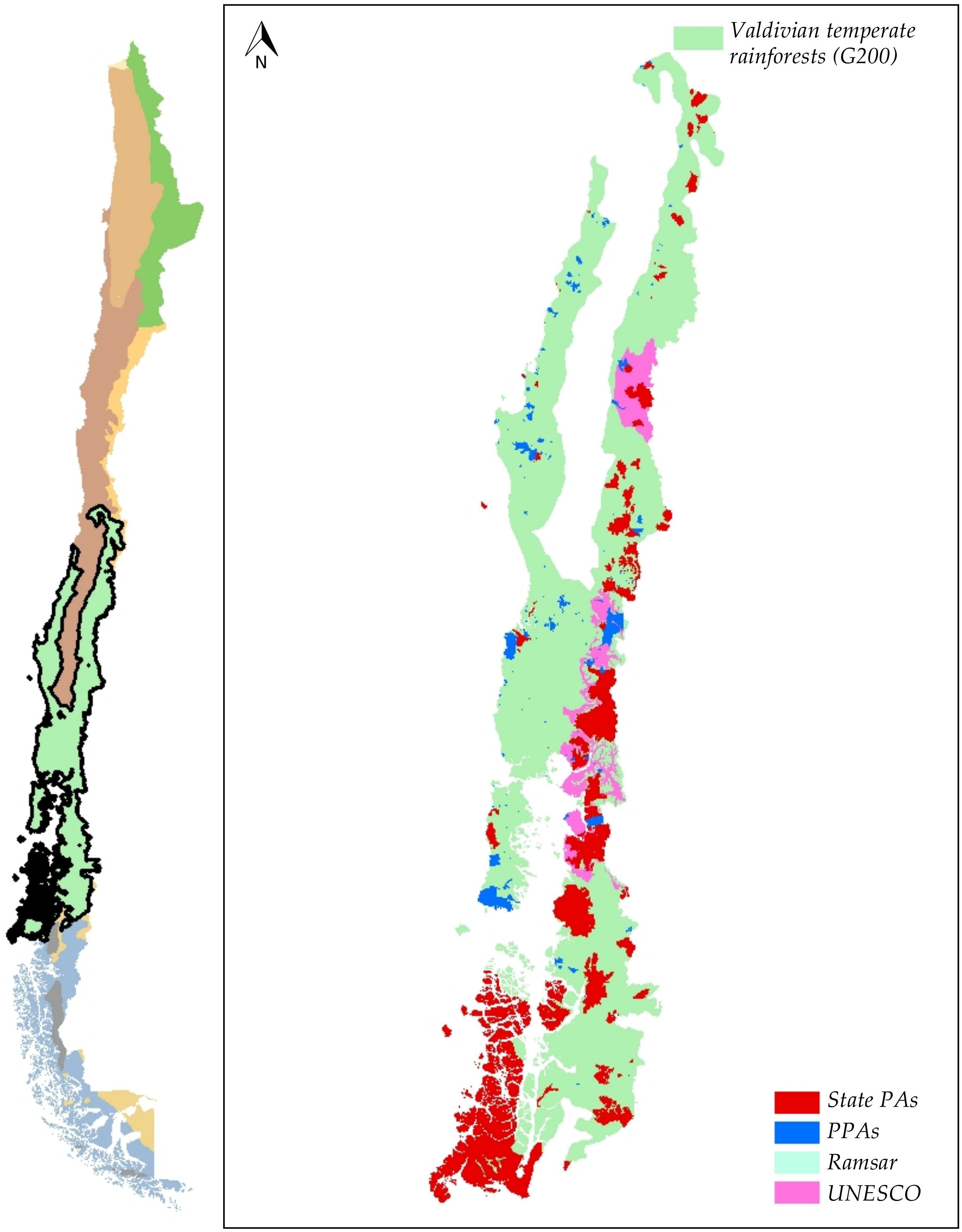

Figure 7: PA*s* in Southern Central Chile (Valdivian temperate rainforests)

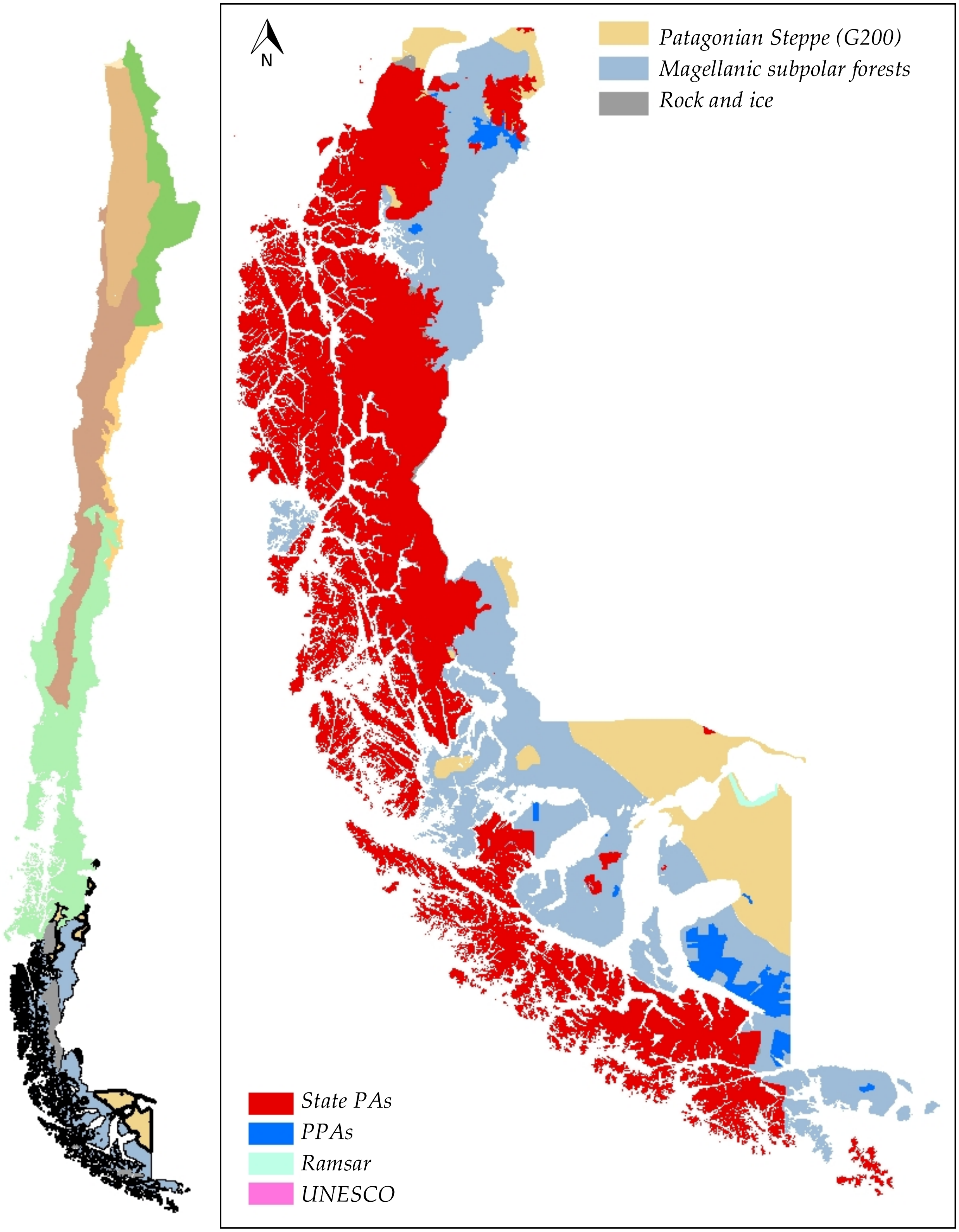

Figure 8: PAs in Southern Chile (Magellanic subpolar forests, Patagonian Steppe, rock and ice)

Table 3: Protected area coverage of Chile's administrative regions (north to south).

ADMINISTRATIVE REGION	STATE PAs (*SNASPE + NSs*)		SNASPE		NS		PPA		S4	
Arica & Parinacota	364,193	2.40%	364,162	2.47%	30	<.01%	6,168	0.46%	375,586	2.10%
Tarapacá	394,415	2.60%	376,846	2.56%	17,568	3.94%	-	-	394,415	2.21%
Antofagasta	379,152	2.50%	372,203	2.52%	6,948	1.56%	2,164	0.16%	410,596	2.30%
Atacama	139,933	0.92%	139,893	0.95%	40	<.01%	230,749	17.32%	383,941	2.15%
Coquimbo	14,317	0.09%	14,266	0.10%	51	<.01%	44,556	3.34%	58,873	0.33%
Valparaíso	25,987	0.17%	22,533	0.15%	4,025	0.90%	19,384	1.46%	45,371	0.25%
Santiago	101,443	0.67%	21,808	0.15%	79,636	17.86%	8,576	0.64%	110,019	0.62%
Bernard O'Higgins	58,674	0.39%	40,157	0.27%	18,517	4.15%	3,616	0.27%	62,289	0.35%
Maule	19,391	0.13%	17,887	0.12%	1,504	0.34%	44,266	3.32%	63,657	0.36%
Bío Bío	144,526	0.95%	141,938	0.96%	2,588	0.58%	93,852	7.05%	709,656	3.97%
Araucanía	296,948	1.95%	296,948	2.01%	-	-	30,581	2.30%	327,529	1.83%
Los Rios	103,262	0.68%	98,369	0.67%	4,892	1.10%	200,586	15.06%	563,425	3.15%
Los Lagos	1,112,197	7.32%	818,587	5.55%	293,611	65.86%	181,837	13.65%	1,842,465	10.30%
Aysén	5,108,101	33.62%	5,091,682	34.53%	16,419	3.68%	104,114	7.82%	5,212,215	29.14%
Magallanes y Antártica Chilena	6,929,325	45.61%	6,929,325	46.99%	-	-	361,671	27.15%	7,326,455	40.96%

Notes: Column 1 is coverage in hectares. Column 2 is the proportion of each PA classification within each AR. S4 is included because it is the comprehensive PAN. UNESCO and Ramsar are not included individually because of their minor contribution. The top two highest proportions are in green, the two lowest proportions are in blue. The five lowest proportions of NSs are highlighted because <.01% rounds to 0%.

Table 4: Protection of Chile's five largest PPA*s*.

PPA NAME	CHILEAN MATORRAL	S. ANDEAN STEPPE	TEMPERATE RAINFOREST	SUBPOLAR FORESTS	TOTAL PPA COVERAGE
Karukinka (Magallanes AR)	-	-	-	296,812	296,812
Comunidad Agrícola Diaguita Huascoaltinos (Atacama AR)	49,202	181,547	-	-	230,749
Parque Tantauco (Los Lagos AR)	-	-	108,548	-	108,548
Hacienda Chacabuco (Aysén AR)	-	1,513	-	73,014	74,527
Reserva Biológica Huilo Huilo (Los Rios AR)	-	-	53,601	-	53,601
TOTAL ECOREGION COVERAGE	**49,202**	**183,060**	**162,149**	**369,826**	**764,237**
PROPORTION OF PPA ECOREGION COVERAGE	**48.37%**	**88.36%**	**28.33%**	**83.59%**	**57.37%**

Notes: Coverage is in hectares. These five largest PPA*s* are those identified in this study. Other studies will include Parque Pumalín if PPA-NS*s* were included in the PPA shapefile. "Proportion of PPA ecoregion coverage" refers to how much the sum of the PPA*s* contributes to total PPA protection. The five PPA*s* account for 57.37% of Chile's total PPA coverage.

CHAPTER 6: DISCUSSION

The success and effectiveness of a PAN is based on the proportional representation of a range of biodiversity across biological scales and realms (Coad *et al.* 2008a; Hoekstra *et al.* 2005; Juffe-Bignoli *et al.* 2014; Margules and Pressey 2000; Pressey *et al.* 1993; Stewart *et al.* 2007). The most recent globally accepted "minimum standard" of proportional representation set by the IUCN and CBD was Aichi Biodiversity Target 11, which says at least 17% of each of the world's terrestrial ecoregions should be protected by 2020 (SCBD 2014). This study used the most up to date Chilean government, international, and PPA spatial data to assess Chile's terrestrial biodiversity representation and progress toward Target 11. Based on the results of the assessment, I conclude Chile's PAN under all four scenarios is biased, ineffective, and will not reach the 2020 target. Under all four scenarios protection across ecoregions is disproportional; some of the most threatened ecoregions are grossly under-represented and the least threatened ecoregions (and rock and ice) are tremendously protected. Only two out of seven terrestrial ecoregions (only one which is a G200) meet the Aichi target. PPA*s* are not effective at filling the gaps or enhancing the protection designation in PCA*s* either. Moving forward from these findings, PPA*s* need to find a best fit where they can contribute to Chile's conservation efforts within their ability and limited resources. Meanwhile, the Chilean government needs to reprioritize conservation efforts to enhance the representativeness of the most threatened and ill-conserved ecoregions, as well as engage in regular data collection, gap analysis, and SCP (Coad *et al.* 2008a; Durán *et al.* 2013; Langhammer *et al.* 2007; Tognelli *et al.*2009).

This chapter is broken into five sections. The first section summarizes the coverage and representativeness statistics presented in Chapter 5. The second section outlines the limitations of PPA*s*. These are possible reasons PPA*s* are not contributing to, and may not be able to contribute to, Chile's conservation in the manner they are expected to. Section three presents five recommendations for Chile to enhance their conservation efforts, with a focus on enhancing the contribution of PPA*s*. Section four lists questions for proposed future research. Section five is a conclusive summary of this study.

6.1 Coverage and Representativeness Trends of the State and Private PAN*s*

The following list ranks biodiversity representation and coverage from highest to lowest to clearly summarize the results of this study. The rankings hold true in all four scenarios unless otherwise noted. To clearly see PA distribution, rock and ice is inserted where it would rank if considered a true ecoregion. G200*s* are in italics. ADQ = adequate protection; MOD = moderate protection; blank = inadequate protection:

	Representativeness (percentage)		**Coverage (ha)**
--	Rock and Ice	1	Subpolar forests (ADQ)
1	Subpolar forests (ADQ)	2	*Temperate forests (ADQ)*
2	*Temperate forests (ADQ)*	--	Rock and Ice
3	*Patagonian Steppe (MOD)*	3	*Central Andean dry puna (MOD)*
4	*Central Andean dry puna (MOD)*	4	*Patagonian Steppe (MOD)*
5	Andean Steppe (MOD in S2 & S4)	5	*Chilean matorral*
6	*Chilean matorral*	6	Andean Steppe in S2 & S4 (MOD); *Atacama Desert in S1 & S3*
7	*Atacama Desert*	7	Andean Steppe in S1 & S3; *Atacama Desert in S2 & S4*

6.1.1 State Protected Area Network Trends

As discussed in Section 3.6.3, scholars report public PA coverage in Chile is inversely proportional to species endemism and richness and the current network is insufficient to achieve conservation targets or, at a minimum, adequate protection levels (Armesto *et al.* 1998; Durán *et al.* 2013; Pauchard and Villarroel 2002). This study confirms those findings. State PA*s* grossly over-represent rock and ice and subpolar forests where investment potential and threat is low to non-existent. Meanwhile, protection is almost nonexistent in the Atacama and the matorral, one of the most endangered Mediterranean-type ecoregions and one of the least protected G200*s* in the world (Coad *et al.* 2008b; Corcuera *et al.* 2002; Underwood *et al.* 2008). Neither the Atacama nor the matorral are even 2% represented. This is partially attributed to the fact 90% of the land in the Mediterranean region is privately owned (Núñez-Ávila and Corcuera 2014) and there is population pressure and a high concentration of production activities (MMA 2011).

The state PAN provides adequate representation of the temperate forests. WWF declared the temperate forests a top 25 conservation PCA out of all the G200*s* (Corcuera *et al.* 2002); Hogan (2013) expressed concern the temperate forests will disappear within the next 20 years if current rates of deforestation continue; and numerous scholars (Armesto *et al.* 1998; Hoekstra *et al.* 2005; Hogan 2013) say the "rich biodiversity, high threat, low representation" trend is especially true in this ecoregion (Hogan 2013). But this study found temperate forests no longer follow the "rich, high, low" trend. Rather, the forests are "rich biodiversity, high threat, high representation". The temperate forests are also disproportionately protected when compared to the rest of Chile's ecoregions, especially G200*s.* (In S1, temperate forest coverage is over four times that of the next most protected ecoregion, the G200 dry puna.) The temperate forests are also disproportionately protected when compared to the matorral. This reveals an immense imbalance in the protection of the Central Chile BH (Fig. 9). But this does not mean conservation efforts in the temperate forests should cease. Conservation efforts should be pursued when an opportunity arises, but the temperate forests should not be viewed as a top PCA. Chile's state PAN efforts need to be reprioritized toward truly "rich, high, low", grossly under-represented, and high threat ecoregions, such as the G200 Atacama Desert and G200 Chilean matorral, the two most under-represented ecoregions in Chile.

6.1.2 Private Protected Area Network Trends

Chile's PPA*s* show representation bias similar to the state PAN and do not fill PCA gaps (Corcuera *et al.* 2002). In fact, in 2011 the MMA had already acknowledged most PPA*s* are in areas already extensively represented by SNASPE (MMA 2011) such as the over-represented subpolar forests and adequately protected temperate forests. The temperate forests are a G200 so PPA coverage is valuable and future parks should not be discouraged. But PPA*s* disproportionately protect the temperate forests and are not filling state PAN gaps (Holmes

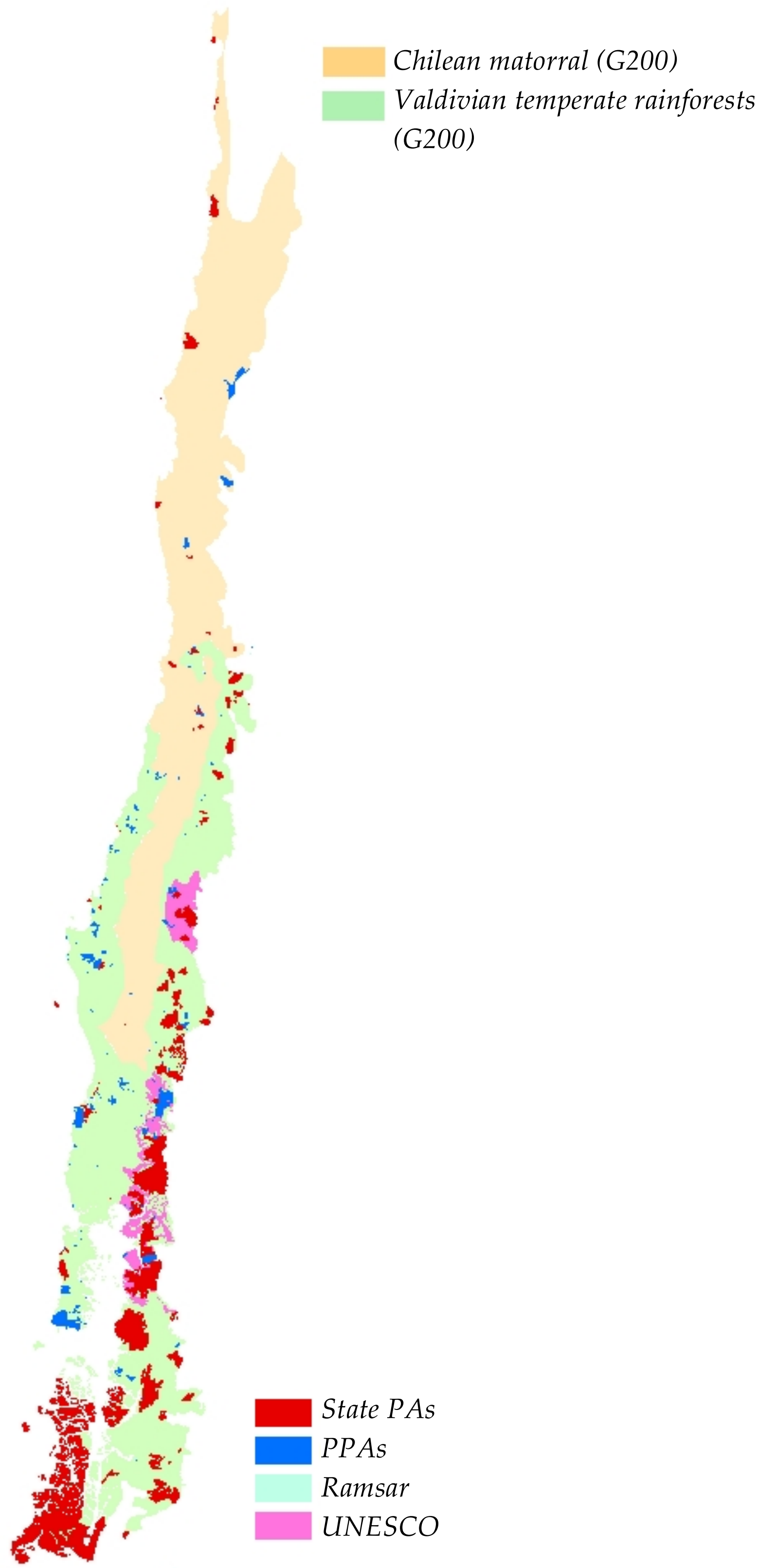

Figure 9: PA coverage in Central Chile.

2013). Neither are PPA*s* filling gaps in the Atacama or matorral where protection is needed most. In fact there are no PPA*s* in the Atacama and PPA representation in the matorral is only .69%. Forty-eight percent of PPA coverage in the matorral can be attributed to Chile's largest community PPA, Comunidad Agrícola Diaguita Huascoaltinos.

The only ecoregion where PPA*s* have an appreciable impact on ecoregion designation is in the Andean Steppe where PPA*s* have the highest representation. The addition of PPA*s* changes the protection designation from inadequate to moderate. This input is meaningful as all ecoregions need protection, but the Steppe is not a PCA. It should be noted too Diaguita Huascoaltinos accounts for nearly 79% of PPA protection in the Steppe.

6.1.3 UNESCO and Ramsar Trends

Ramsar site coverage is insignificant, covering only .13% (<100,000 ha) of Chile. UNESCO sites (before data processing) have extensive distribution across Chile, but over 85% overlaps with state PA*s*. After clipping, UNESCO covers only 1.70% of terrestrial Chile and only the temperate forests. UNESCO and Ramsar sites did not significantly change S3 or S4 from S1 or S2 so they will not be discussed further. The rest of this chapter will focus on state and private PA*s*.

6.2 Private Protected Area Limitations

Theoretically, PPA*s* are a great way of expanding total PA coverage, filling in state PAN gaps, and helping to meet global conservation goals. But in reality, using the most recent data on Chile's private PAN, this study has shown that despite the reported growth of PPA*s* in Chile[25] (Pauchard and Villarroel 2002; Tecklin and Sepúlveda 2014) these expectations are unrealistic. PPA*s* are not enhancing protection in PCA*s* and have hardly begun to fill state PAN gaps. I believe this can be explained by at least three PPA site limitations: total PPA coverage, PPA size, and ad hoc site-selection. I also believe there are PPA functional limitations that put the rationality of establishing a CNSPA into question. This includes land value and a lack of

25 - There is evidence PPA*s* in Chile are growing, but because PPA*s* are not recorded, the growth rate is unknown. This is a global phenomenon (Juffe-Bignoli *et al.* 2014; Stolton *et al.* 2014).

funding, management capability, and other resources necessary for meaningful conservation.

6.2.1 Site Limitations

First, the total coverage and size of PPA*s* in Chile is too small. PPA*s* cover only 1.77% of Chile's terrestrial area, which is a fraction, less than 9%, of total state PA terrestrial coverage (20.14%). Second, the overwhelming majority of PPA*s* are small in size. This study found 202 (74%) are less than 1,000 ha. Small parks may not be able to sustain viable species populations, may lack the connectivity necessary for species migration or to avoid fragmentation and isolation, and may suffer from the encroachment of surrounding habitat-destruction, invasive species, or poaching (Carmen Sabatini *et al.* 2007; Corcuera *et al.* 2002; Dudley 2008; Dudley and Pressey 2001; Joppa *et al.* 2008; Matteucci and Camino 2012; SCBD 2014; Stolton *et al.* 2014). A WWF study[26] cited in Corcuera *et al.* (2002) said it is estimated adequate species ranges are between 10,000 ha and 25,000 ha. Only 20 PPA*s* in this study are greater than 10,000 ha.

Third, in the ICP census, the most commonly reported motivation for site-selection is scenic value of the landscape (Núñez-Ávila and Corcuera 2014), not because the site is threatened, contains valuable species or habitats, or is insufficiently protected by the state PAN. (Establishing a park for scenic value does not mean it does not contain important biodiversity; it just wasn't the reason for site-selection.) Scenic value is a suggested reason for the high concentration of PPA*s* in Southern Chile (Corcuera *et al.* 2002; Núñez-Ávila and Corcuera 2014). If PPA*s* are truly going to contribute to the protection of Chile's PCA*s*, reserves cannot be established in this ad hoc manner. Sites must be systematically and carefully selected so "limited resources are deployed most effectively. More importantly, reserve selection must do more than react to threats: Land must be allocated to conservation at least as assertively as to competing

26 - This WWF study is referenced in multiple pieces of literature, but all say the WWF study is "forthcoming" or "in print". I could not locate the original source, which was cited as follows: WWF. 2002. Evaluación Ecológica de la Ecorregión Valdiviana: Amenazas y Prioridades para la Conservación de la Biodiversidad. Valdivia, Chile: WWF.

uses, and conflicts must be resolved explicitly" (Pressey *et al.* 1993:124).

6.2.2 Functional Limitations

It is suggested the value in PPA*s* is they can protect areas the government cannot because 65% of land in Chile is privately owned (Corcuera *et al.* 2002; Pauchard and Villarroel 2002; Squeo *et al.* 2012; Stolton *et al.* 2014). This makes it difficult to establish public PA*s* in currently unprotected areas such as the priority Mediterranean region (MMA 2011; Squeo *et al.* 2012) where 90% of the land is in private hands (Núñez-Ávila and Corcuera 2014). Though the lack of publicly available land suggests a CNSPA is necessary, the soundness of the idea is questionable. PPA*s* in a CNSPA would still depend on voluntary establishment, which, as this study has shown, is ad hoc and does not enhance representativeness. Using the matorral as an example, Holmes (2013, 2014) suggests there is not only a limited amount of land for sale that can be used for conservation, but land prices are high, which may explain why PPAs are already unevenly distributed and biased to the south where land is cheaper and the scenic value is higher (Corcuera *et al.* 2002). One has to ask why a small landowner in the matorral would sacrifice agricultural land to private conservation as opposed to profiting from its production or resale value. If a strict PPA is established, this puts the ecological significance of the PPA into question: Is there habitat? Is the site polluted? Is the site being abandoned because of an encroaching outside element? And if the site is a multi-use PPA, we must ask: Are the land use activities compatible with conservation? Are there systems in place to reduce the impact of such land use activities? But the big question is: If landowners in high value PCA*s* are not voluntarily putting their land under protected status now, why would the establishment of a CNSPA prompt them to do so in the future? Incentives may be offered as an answer, but the implications and potential unknowns should be heavily considered first. Section 6.3.2 explores incentives further.

Financial stability is a critical element for effective PA establishment and management (Juffe-Bignoli *et al.* 2014). A PA requires sufficient upfront and long-term financial capital and technical resources, such as GIS, to conduct assessments, engage in SCP, implement the results of the assessments, and ensure lasting effectiveness through continuous management and evaluation of efforts (SCBD 2014; Stolton *et al.* 2014). The ICP census reports 83% of the 242 surveyed PPA*s* rely on the management ability and monetary resources of the landowner (Núñez-Ávila and Corcuera 2014). Many PPA*s* in Chile have insufficient funds to hire staff, guards, or invest in conservation and restoration activities to meet their reported objectives (Núñez-Ávila and Corcuera 2014; Núñez-Ávila *et al.* 2013). A lack of landowner finances also translates to an inability to purchase a larger tract of land less susceptible to the threats faced by smaller PA*s*, or in PCA*s* where land costs more. Anyway, there is nothing to indicate PPA*s* are principally established on land purchased *specifically* for conservation. In fact, it can be deduced PPA*s* are typically declared on already owned lands that were (or still are) being used for other non-conservation purposes. This deduction can be made based on the ad hoc establishment of PPA*s* and Corcuera *et al.*'s (2002) report that "activities such as grazing or logging frequently continue within unilaterally declared 'protected' areas" (p. 139). Future research should assess trends in privately purchasing land for strict conservation and if there is a relationship between PPA designation and land abandonment.

PPA*s* in Chile face numerous other limitations as well. The ICP census also reports 63% of the 242 respondents have no work or management plan (Núñez-Ávila and Corcuera 2014), no instruments to help them develop effective conservation and monitoring programs (Fundación Senda Darwin 2013), and no minimum standards (Tecklin and Sepúlveda 2014). This is not uncommon for PPA*s* (Corcuera *et al.* 2002). Poor management is one of the single largest problems facing regional, national, and the global PAN (Juffe-Bignoli *et al.* 2014; SCBD 2014). PPA landowners also have difficulty committing to conservation in perpetuity, or at least the long-term (Stolton *et al.* 2014). This can be due to changing interests or changing fortunes of the landowners, the economy, or laws (Pasquini *et al.* 2011; Tecklin and Sepúlveda 2014).

So, if not small PPA*s*, what about large PPA*s*? Large PPA*s* (mostly referring to those operated by large NGO*s* or organizations) have more rules and financial and technical resources than smaller PPA*s*, and a better understanding of representativeness, site-selection, the role of PA*s*, and conservation in general. But large PPA*s* in Chile cannot be counted on as a solution to Chile's conservation problem either. The few large PPA*s* that do exist in Chile are anomalies that were either purchased by wealthy individuals (Parque Pumalín and Hacienda Chacabuco established by the Tompkins family, and Parque Tantauco owned by former president Sebastian Piñera), are family legacy lands (Reserva Biológica Huilo Huilo owned by the Petermann family), are indigenous lands (Comunidad Agrícola Diaguita Huascoaltinos owned by the indigenous Diaguita community), or were donated to NGO*s* by failed natural resource extraction companies (Karukinka is run by the Wildlife Conservation Society and the Valdivian Coastal Reserve is run by The Nature Conservancy) (Holmes 2014; Stolton *et al.* 2014; Tecklin and Sepúlveda 2014).

The costs to purchase and maintain large tracts of land are very high and can only be done with an endowment fund ensuring conservation is effective in perpetuity (Corcuera *et al.* 2014). But even large, global NGO*s* such as WWF have trouble obtaining grants or funding from donors in the long-term or perpetuity (Bouchard 2013). Moreover, because most land is in private hands, unless large landowners turn their properties over to conservation or failing businesses donate their land to NGO*s*, the establishment of large PPA*s* is as likely to happen as the establishment of large public PA*s*.

6.3 Recommendations

A fear evolving from this study's findings is that the theoretical potential of PPA*s* on which so many hopes for saving Chile's biodiversity are based will override the findings of this report. This will not only divert attention and resources away from a more reliable and realistic solution to Chile's conservation problem, but potentially cause PPA*s* to contribute to, as opposed to prevent, habitat and species loss. Creating a CNSPA will allow PPA*s* to be recognized by the Chilean government and IUCN, but it may also create a false sense of security. Holmes (2013b) elucidates, "A rising profile for PPA*s* may lead to states reducing their investment in PA*s*, with the expectation the private sector will replace it . . . [But] PPA*s* may only protect certain kinds of places and certain forms of biodiversity, and, moves towards greater roles for PPA*s* may leave other areas unprotected" (p. 20).

Establishing a CNSPA in Chile will take time, money, and resources. Conservation is an imperative and it will take many years to create a legal system that integrates PPA*s* into the state PAN. Plans will need to be made, amended, negotiated, and approved for funding, management, monitoring, IUCN recognition, and the like. Money is another issue as SNASPE is already underfunded. Available finances need to be judiciously spent on activities with the greatest chance of success. Is putting these resources into creating a CNSPA, as opposed to actual on the ground conservation, really the most judicious and successful decision? A CNSPA will give PPA*s* legal recognition, which means they will be recognized by the IUCN, included in the WDPA, calculated in global gap analysis, and included in Chile's progress toward conservation goals. PPA contribution is rather inconsequential though. Is PPA recognition really worth the effort?

After considering the findings and implications of this research, I suggest gambling time and limited resources on creating a CNSPA, which this study has shown will not be as effective as hoped, a more reliable solution would be systematically reprioritizing and improving the already established state PAN. I recommend this be done by 1) finding a best fit for PPA*s*; 2) enhancing the state PAN by expanding the PPA-NS network in accordance with these best fits; 3) creating a PPA institute using ICP resources and data to facilitate the establishment of PPA-NS*s*; 4) foster stronger relationships between NGO*s*, small PPA*s*, and the government to aid in PPA-NS designation, landowner environmental education, and the sharing of information and resources; and 5) engaging in regular PPA data collection, gap analysis, monitoring, and SCP.

6.3.1 Finding a "Best Fit" for Private Protected Areas

This report's determination that PPA*s* in Chile cannot mend the state PAN in the way they are purported to should not be taken as an insult or dissuade PPA establishment. There is an obvious benefit to the additional coverage provided by PPA*s* no matter where they are. But hectares do not equal effectiveness (Mitchell 2007). Rather than disregard for PPA potential, the findings of this research should be an important step toward discovering their best fit in Chile's conservation in a way that focuses on PPA*s* complementing, not fixing, the state PAN within the boundaries of their true ability (Holmes 2013; IUCN 2005). Given the Chilean PPA limitations of size, finances, and technical resources described above, PPA*s* might be better suited for small-scale conservation, not state PAN enhancement (Stolton *et al.* 2014), which is inherently a large scale undertaking. Small-scale conservation includes protecting a historic tree, nesting sight, or breeding ground, or other activities that do not require intense capital, space, financial, or human resources (Fundación Senda Darwin 2013; Heinen 2012; IUCN 2005; Langholz and Lassoie 2001).

It is reported that adjacent land use is the greatest threat facing PA*s* (Pauchard and Villarroel 2002) and it is widely suggested PPA*s* can serve as buffer zones, biological corridors, or connectors that reduce PA fragmentation and enhance ecological processes such as genetic flow (Boucher *et al.* 2013; Carmen Sabatini *et al.* 2007; Corcuera *et al.* 2002; Dudley 2008; Juffe-Bignoli *et al.* 2014; Núñez-Ávila *et al.* 2013; Pauchard and Villarroel 2002; Stolton *et al.* 2014). An example of a PPA connecting existing PA*s* in Chile is Hacienda Chacabuco, Chile's fourth largest PPA owned by the Tompkins family's organization Conservación Patagonica. (See Section 5.3). Chacabuco is between the SNASPE NR*s* Lago Cochrane and Lago Jeinimeni, Chile's fifth largest NR. The Tompkins family has gradually purchased lands between the two NR*s* to create a connected landscape that in the future will be Patagonia National Park.

PPA*s* serving as corridors, connectors, and buffer zones are roles PPA*s* in Chile are assumed to play (Corcuera *et al.* 2002) and roles cited as a benefit of establishing a CNSPA (Fundación Senda Darwin 2013). But, save for a Hacienda Chacabuco and maybe a handful more (research needs to be conducted to determine correct numbers), Corcuera *et al.* (2002) reports Chile's PPA*s* are isolated from larger PA*s*, few are near or adjacent, which has made them ineffective as buffer zones or corridors (Corcuera *et al.* 2002). This does not mean PPA*s* are not capable of enhancing connectivity in the future. It only demonstrates PPA in Chile*s* have historically been sited in an ad hoc manner and without landowners understanding how to best engage in effective conservation. Studies need to be conducted to find the best fit for PPA*s* in Chile's existing PAN and how to make those best fits both implementable and resilient. I suggest enhancing the state PAN and expanding the PPA-NS network to achieve this.

6.3.2 Enhance the State Protected Area Network and Expand the PPA-NS Network

Enhancing the state PAN can be done by the Chilean government developing and adopting new conservation instruments and policies and updating their NBSAP using the most recent gap analysis findings of this study (SCBD 2014). The state PAN is certainly not perfect. Limits to all PA classifications, state and private alike, include political boundaries, poor enforcement of prohibited activities, lack of ecological considerations, or a failure to address border threats (Boucher *et al.* 2013). But the state PAN, unlike a CNSPA, is already a well-established system with methods of regulation, management, and setting and working toward objectives; legal protection and penalties for violators; scientific and technical capacity to conduct planning and monitoring assessments; more human, communication, and financial resources than all but the very largest of existing PPA*s;* and some degree of security as PA designation can be burdensome to change (Corcuera *et al.* 2002). Most, if not all, of these characteristics are missing in PPA*s.* These characteristics would also need to be considered in the development of a CNSPA, which will take a lot of time, negotiation, and money for what is essentially a duplication of efforts.

The lack of public land available for protection is a legitimate rebuttal to the recommendation to increase the role of the Chilean government. But the Chilean government, being the government, can do things Chilean citizens cannot. For example, the government has secure property rights over land, water and natural resources. Landowners in Chile don't have land tenure (Pasquini *et al.* 2011), do not hold rights to the natural resources within their land boundaries, and private land rights can be overridden by eminent domain (Tecklin and

Sepúlveda 2014). The government can also limit or prohibit development near existing PA*s* (thereby reducing border threats). Furthermore, the government can use the NBSAP to guide the expansion of the PPA-NS network to meet Aichi targets and achieve adequate protection of all of Chile's ecoregions. PPA-NS*s* are only designated based on certain minimum requirements and standards that serve to maintain the integrity of a site (see Appendix II), thereby making Chile's PAN more successful at protecting PCA*s* and using limited resources responsibly. A CNSPA, however, would probably grandfather in PPA*s*, which would reduce the integrity of a comprehensive PAN. (See Section 6.2: Limitations of PPA*s*.) Of course, this is a speculation. How a CNSPA in Chile would responsibly incorporate existing PPA*s* needs further exploration.

It is said obtaining PPA-NS status in Chile is not common because it is costly. There are also are no incentives to be a PPA-NS, only restrictions (Corcuera *et al.* 2002; Núñez-Ávila and Corcuera 2014). A lot is written on the need (or even requirement) for incentives to increase the number of PPA*s*, such as conservation easements, tax breaks, or subsidies (Chacon 2005; Corcuera *et al.* 2002; MMA 2011; SCBD 2014). I am hesitant to recommend incentives for voluntary park establishment though because voluntary establishment is not systematic. Incentives will not solve the PPA problems addressed in this study, such as poor distribution, lack of connectivity, and site and functional limitations. Incentives in other countries have also led to system abuse and unintended negative consequences (Chacon 2005; Mitchell 2007; SCBD 2014). That being said, I believe incentivizing PPA-NS*s* should be explored.

Turning private land into a PPA-NS could be incentivized, but the sites should only be those deliberately chosen, nominated, and sought out by the government through gap analysis and SCP. A committee of experts and scientists would determine where PPA*s* are needed, how much land is required, and what restrictions and ongoing management and monitoring systems need to be implemented. Sites would be chosen for their ability to serve as a corridor or buffer zone, reduce fragmentation, protect vital breeding grounds, or other conservation activities considered PPA best fits. This would put conservation in the hands of experts, scientists, and the government, not landowners with limited knowledge, skill, and resources or ulterior motives to take advantage of a system for economic gain.

For example, to better illustrate this recommendation, a committee determines a corridor is needed between two existing state PA*s*. An endangered species cannot migrate between feeding grounds in one PA and breeding grounds in the other PA because two fenced private lands are in between. PPA-NS "mediators" would educate the landowners on the situation, offer incentives in accordance with landowner needs, and provide assistance to get the lands declared PPA-NS*s* with the agreement a migration path will be opened seasonally. In this example, the mediators facilitated landowner cooperation to open a migration route between *both* land parcels, which was a requirement. One parcel would not solve the problem. Voluntary PPA establishment is chance PPA establishment and the chances of both parcels being voluntarily declared are slim to none.

I theorize if PPA landowners are able to get support to cover or subsidize the costs of designating a NS, there are few reasons landowners would not go this route if "protecting biodiversity" (Núñez-Ávila and Corcuera 2014), not finances, is truly their motive, as PPA landowners have reported. Funding for expanding the PPA-NS network would be diverted from that which would be spent developing a CNSPA, or money that would be lost implementing incentives for voluntary PPA establishment (such as loss of tax revenue). Ultimately, this recommendation is based on theory and speculation so research should be conducted to understand the trade offs, pros, and cons of offering incentives as well as the trade offs, pros, and cons of either enhancing the NS network or developing a CNSPA. Whatever is decided, the Chilean government's role needs to ensure PPA*s* are placed systematically, limited resources are used most efficiently, parks are maintained in perpetuity, external and internal threats are minimized, and the overall protection of the site is effective with the ultimate goal of increasing conservation in PCA*s* and meeting conservation goals.

6.3.3 Chilean Private Protected Areas Institute

In congruence with the previous recommendations, the ICP census data should be seen as more than statistics justifying the establishment of a CNSPA. Rather, the identification of 242+ parks is a unique opportunity to create a PPA institute. The primary difference between an institute and a CNSPA is the institute would be a non-governmental middle man that would serve as an independent third part to facilitate activities between the government and landowners to create PPA-NS*s*. Chileans have a historical distrust of the government as a result of a 17-year brutal dictatorship, over a hundred years of indigenous land right disputes, social inequality (i.e. education and health care costs), and government corruption (Dube 2015; Quiroga 2015). An independent institute might increase landowner interest and cooperation in a government program. This theory should be further explored in social research.

The institute, with ICP and supporting organization resources, would have access to state, private, and international PA databases, scientists, and GIS to assist in gap analysis, SCP, helping PPA*s* find and serve their best fit, and PPA-NS site-selection (Boucher *et al.* 2013; Pasquini *et al.* 2011). The data collected in the Census is a good starting point to determine if any current PPA*s* have the potential to be PPA-NS. Other institute activities could include teaching owners how to set realistic objectives, identify funding sources, manage their lands with limited resources, and balance conservation with other land-use activities (Pasquini *et al.* 2011). The institute would give PPA landowners access to other PPA landowners and organizations for the free exchange of ideas and advice, as well as possible collaboration or pooling of resources (Corcuera *et al.* 2002; Gordon *et al.* 2013; SCBD 2014). (Sharing information and knowledge is Aichi Biodiversity Target number 19 (SCBD 2014).) Corcuera *et al.* (2002) said, "[I]t is crucially important for the private sector to create opportunities for mutual learning such as conferences and seminars, field visits, publications, and training materials" (p. 145).

6.3.4 Foster Relationships Between the Government, NGO*s* and Private Protected Areas

The fourth recommendation is fostering stronger relationships between conservation NGO*s*, the government, and PPA landowners. It is said partnerships at all levels are required to meet conservation goals and make planning and implementation more efficient (Gordon *et al.* 2013). Conservation NGO*s* could enhance their relationship with the government by helping find the best fit for PPA*s*, providing support for a PPA institute, and facilitating in the expansion of the PPA-NS system. NGO*s* could enhance their relationship with PPA*s* by providing environmental education, assisting in all facets of maintaining a PPA, and serving as PPA-NS mediators.

<u>6.3.5 Regular Data Collection, Gap Analysis, Monitoring, and Systematic Conservation Planning</u>

Lastly, gap analysis and SCP are iterative and adaptive processes (Langhammer *et al.* 2007). Assessments need to be conducted as new PAs are designated; new knowledge of species threats, numbers, and needs come to light; and as site threats change, among other unforeseen circumstances. The process of site-selection and PAN design will change based on the findings of these assessments. Pressey *et al.* (1993) explain priorities have to be adjusted at the regional, national, and global scale "in response to threats and differences in the most appropriate form of protection. The success of reserve location, design and management will have to be measured by monitoring of the features and qualities for which the reserves are initially dedicated" (p. 128). Maintaining the ICP census database is particularly important.

Finding a best way forward for PPA*s* necessitates data is accurate and up to date. This has traditionally been a problem in Chile, but the ICP census has changed that. The ICP census is far superior to previous PPA databases, many of which were just lists (such as the Privately Protected Areas Network established in the late 1990s (Corcuera *et al.* 2002; Oyarzún 2009). To maintain the quality of ICP data and the accuracy of future studies, the census must be updated regularly so new gap analysis can be conducted and the results distributed to key parties.

<u>6.4 Proposed Research</u>

Interpreting the results of PA assessment is difficult. Measuring the number of PA*s*, coverage, and representativeness is not enough to conclude if a PAN is effective or complete (Boucher *et al.* 2013). There are many more factors to consider than this study has, such as management effectiveness (and what counts as effective) (Juffe-Bignoli *et al.* 2014), habitat fragmentation

(Carmen Sabatini *et al.* 2007), the protection of ecosystem services (Durán *et al.* 2013; SCBD 2014), and if a site is susceptible to external threats (Stolton *et al.* 2014). Future research should address these issues using the most up to date data. Many questions about Chile's PAN*s* need to be addressed as well. Some include:

- What is the extent of PPA site and functional limitations? How can they be overcome?
- What is the current state of PA fragmentation under the four scenarios?
- How many PPA*s* are purchased and established strictly for conservation?
- Is there a relationship between conservation and land abandonment?
- What is the best fit for PPA*s*?
- Are incentives a viable and secure option for enhancing voluntary PPA establishment or promoting PPA-NS designation?
- What are the constraints and opportunities for expanding the PPA-NS network?
- What do NGO*s*, the Chilean government, and PPA*s* want from collaboration?
- How much public land is available for conservation? Where? What are the opportunities or limitations for PA establishment?
- Are existing PPA*s* doing what they claim to do in the manner they claim to do it?
- What is limiting protection in the Atacama and matorral? How can it be overcome?

Answers to these and other questions will strengthen Chile's ability to protect PCA*s*, fill representation gaps, and meet global conservation goals.

GIS PA distribution data could, and should, be used to conduct studies on the representation of species, ecosystem services, and the like to further understand the role of PA*s* and the contribution of PA classifications. Ecoregions do not consider, for instance, the societal and human benefits provided by PA*s*, such as promoting a culture of conservation, and protecting watersheds, plants that limit erosion or mudslides, or keystone species. All of these are important to consider when assessing how well a PAN is distributed. The PPA data could also be used to look at trends in PPA site-selection over time to understand what historically influenced protection in particular locations to predict where PPA*s* might be established in the future. This would help with SCP.

6.5 Conclusion

This study has assessed the representativeness of Chile's PAN under four scenarios and revealed the contribution of various PA classifications and the ability of PPA*s* to fill in state PAN gaps. This study has determined, in spite of efforts made by the Chilean government, international organizations, and private landowners, Chile's existing PAN, in any scenario, is inadequately representing PCA*s* and will not meet the 2020 Aichi biodiversity target. As a by-product of these primary findings, this study has identified PCA*s* for conservation expansion.

This study has concluded that: 1) the state PAN shows representation bias and is not effective at protecting PCA*s*; 2) UNESCO and Ramsar sites contribution is negligible and not worthy of further exploration; and 3) PPA*s* are not filling representation gaps, show representation bias similar to the state PAN, and are not effective at protecting PCA*s*. Drawing from literature, PPA*s* also suffer from various site and functional limitations compromising their long-term effectiveness. Increasing the role of PPA*s* may cause the Chilean government and other conservation organizations to reduce their role in establishing PA*s* because they believe PPA*s* will effectively replace their efforts (Holmes 2013). But this study has shown PPA*s* are not, and probably cannot, meet those expectations.

That being said, PPA*s* *are* an important conservation tool. PPA*s* not only add to the total area under protection, but they have the ability to provide recreation and education opportunities; protect historical, spiritual, and cultural sites; provide ecosystem services important for humanity such as and air and water purification, flood control, and carbon sequestration; and support healthy soil and nutrient recycling. However, in regards to proportional representation of ecoregions in Chile, this study has shown that PPA establishment must be strongly guided. A CNSPA is a theoretical solution to guiding PPA establishment but establishing a new method of PA designation and regulation, and getting such a system incorporated into Chilean law, will require considerable time and resources. Furthermore a CNSPA will not stop ad-hoc site-selection. Instead of a CNSPA, I believe creating a complementary PPA institute, expanding the existing PPA-NS network, developing a new NBSAP based on the gap analysis findings of this report, and strengthening ties with NGO*s* may prove more effective. PPA*s* also need to find a new best fit to contribute to Chile's conservation within their abilities, the ICP database needs to be maintained, and gap analysis assessing state and private PA*s* must continue.

The findings of this research are not limited to Chile and therefore have implications for private PAN*s* and the development of IPPPAN*s* around the world. Other countries can utilize the four-scenario model presented in this study to assess the contribution and ecoregion representation of the country's various PA classifications. (The four-scenario model may also be used to assess and compare protection of ecosystem services and other societal benefits provided by PA*s* discussed above.) Some countries may determine UNESCO sites are providing representative protection and, rather than an IPPPAN, PPA*s* may be better suited as UNESCO buffer zones. In the coming years, it will be increasingly crucial to expand the representation of ecosystems, species, and habitats in regional, national, and global conservation efforts. Effective PA establishment requires conducting timely analyses using relevant data to set and adjust conservation priorities and establish new models of conservation governance and policy.

The results of this assessment show how complex assessing PAN effectiveness can be and how difficult it can be to determine the best way forward to meet conservation goals and ensure adequate representativeness of ecosystems, species, and habitats. But only by continuously assessing PA classifications and PAN*s* from the regional to global level and engaging in SCP, will countries and the world be able to protect PCA*s* and proportionally represent the world's biodiversity in perpetuity.

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APPENDIX I

IUCN Protected Area Management Categories

Ia Strict nature reserve: Strictly protected for biodiversity and also possibly geological/ geomorphological features, where human visitation, use and impacts are controlled and limited to ensure protection of the conservation values.

Ib Wilderness area: Usually large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, protected and managed to preserve their natural condition.

II National park: Large natural or near-natural areas protecting large-scale ecological processes with characteristic species and ecosystems, which also have environmentally and culturally compatible spiritual, scientific, educational, and recreational and visitor opportunities.

III Natural monument or feature: Areas set aside to protect a specific natural monument, which can be a landform, sea mount, marine cavern, geological feature such as a cave, or a living feature such as an ancient grove.

IV Habitat/species management area: Areas to protect particular species or habitats, where management reflects this priority. Many will need regular, active interventions to meet the needs of particular species or habitats, but this is not a requirement of the category.

V Protected landscape or seascape: Where the interaction of people and nature over time has produced a distinct character with significant ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.

VI Protected areas with sustainable use of natural resources: Areas that conserve ecosystems, together with associated cultural values and traditional natural resource management systems. Generally large, mainly in a natural condition, with a proportion under sustainable natural resource management and where low-level non-industrial natural resource use compatible with nature conservation is seen as one of the main aims.

(Dudley 2008)

APPENDIX II

Reconciling PPA and NS Overlap and Clipping

Possibly the largest difference between this and other studies measuring PPA coverage in Chile is that PPA-NS*s* were retained in the NS shapefile and not the PPA shapefile. (Durán *et al.* 2013; Pliscoff and Fuentes-Castillo 2011; Squeo *et al.* 2012). In most studies, PPA-NS*s* are retained in the PPA shapefile. I feel it is inappropriate to treat PPA-NS*s* as PPA*s* for the following reasons:

1) **NS*s* are established in a deliberate and systematic manner.** Sites are designated only if they meet standards of biological importance, scientific value, and/or natural heritage interest. Sites must also possess important characteristics such as serving as a buffer zone or conserving under-represented biodiversity (ELI 2003). PPA-NS recognition requires the landowner to go through a government application process. The Marine Conservation Agreement (N.d.) online Practitioner's Toolkit provides an explanation:

> The process [of obtaining NS status] always involve[s] consultation with several local and national agencies and a proposal. Proposals need to identify a clear [management and] enforcement plan and compile biological information emphasizing the main reasons to establish a [PPA-NS]. . . based on the habitats, hot spots of biodiversity, presence of flag species, or unique ecosystem processes. . . the project needs to be approved not only by the agency that deals with each specific conservation tool, but also by other [environmental] agencies.

2) **PPA-NS*s* are legally recognized in Chilean law and by the IUCN, and are recorded in the WDPA.** PPA-NS*s* are recognized under the National Monuments Law under the authority of the National Monuments Council that is part of the Ministry of Education (Tecklin and Sepúlveda 2014).

3) **PPA-NS*s* are subject to government regulation and land-use restrictions**. If the landowner wishes to engage in extraction activities or make land-use changes such as the development of

roads, an environmental impact statement must be completed and permission granted from a committee (Corcuera et. al. 2002). The landowners also cannot engage in activities that may alter the natural state of the PPA-NS, such as fishing or farming. Natural resources within the PPA-NS are also subject to legislation (Oyarzún 2009).

4) **NS*s* emphasize the protection of specific flag species** that are of interest to conservation and science, not tourism. The compatibility of tourism and conservation is questionable due to pressures tourism puts on resources and the environmental wear tourists put on the site (González-Roglich, Southworth, and Branch 2012; Holmes 2013; Langholz and Lassoie 2001)

In this study, when the area of a PPA that did *not* overlap with a NS was *less* than 100 ha, the PPA-NS was fully clipped from the PPA shapefile and retained in the NS shapefile. In total, 14 PPA-NS polygons were fully clipped (Table 5).[27] One example is Parque Pumalín, which one of the largest PPA*s* in Chile and one of the most highly discussed PPA*s* in the world (Oyarzún 2009; Tecklin and Sepúlveda 2014). When the area of a PPA that did *not* overlap with a NS was *more* than 100 ha, the PPA was partially clipped to the extent of the NS. The remaining 100+ ha of the PPA were retained in the PPA shapefile. In total, four PPA-NS polygons were partially clipped. An extreme case was PPA-NS Reserva Natural Protegida Altos de Cantillana. Over 5,500 ha of the PPA polygon did not overlap with the NS polygon of the same name. A reason for the large difference may be that Altos de Cantillana was inaccurately placed in GIS or only a portion of the PPA is a NS.

The difference between PPA coverage and representation before and after clipping is not enough to change the results of this study (Table 6). In fact, PPA bias is slightly strengthened before clipping; though not immensely because PPA coverage is minor.

27 - To ensure PPA-NS*s* were clipped accurately, I compared NS shapefiles against the WDPA. Only one PPA-NS, Santuario Naturaleza Dunas de Concón, is not in the WDPA. Polygon overlap of this PA between the NS and PPA shapefiles was exact, so I retained the polygon as a NS. The fact this PA is not in the WDPA shows the limitations of the WDPA.

Table 5: Private protected area and nature sanctuary polygon overlap: area clipped and retained in PPA shapefile.

PPA SHAPEFILE NAME	NS SHAPEFILE NAME	AREA CLIPPED	AREA RETAINED
VALDIVIAN TEMPERATE RAINFORESTS			
Cascada Las Ánimas	Predio Cascada de las Ánimas	2,717	-
Comunidad Alto Huemul (Fundo Rayenlemu)	Alto Huemul	18,508	-
Huemules del Nuble	Predio Los Huemules del Niblinto	7,186	-
Parque Pumalín	Parque Pumalín	292,645	-
Predios San Francisco de Lagunilla y Quillayal	Predios San Francisco de Lagunilla y Quillayal	14,407	-
S.N.* El Morrillo	Predio El Morrillo	1,060	-
S.N. Las Torcazas de Pirque	Las Torcazas de Pirque	826	-
S.N. los Nogales	Los Nogales	10,895	-
Santuario Laguna Reloca Forestal	Humedal de Reloca	293	-
S.N. el Roble	Sector del Cerro El Roble	753	436
Santuario Parque Pedro del Río Zañartu	Península de Hualpén	374	326
Total Ecoregion Coverage Clipped/Retained		**349,664**	**762**
CHILEAN MATORRAL			
S.N. Dunas de Concón	Campo dunar de la punta de Concón	20	-
S.N. Palmar el Salto	Palmar El Salto	329	-
S.N. y sitio Ramsar Laguna Conchalí	Laguna Conchalí	51	-
Santuario Serranía El Ciprés Comunidad El Asiento	Serranía el Ciprés	1,761	-
Reserva Natural Protegida Altos de Cantillana	Predio Sector Altos de Cantillana; Horcón de Piedra y Roblería Cajón de Lisboa; San Juan de Piche	4,106	5,534
S.N. San Juan de Pichi	Predio Sector Altos de Cantillana; Horcón de Piedra y Roblería Cajón de Lisboa; San Juan de Piche	590	1,061
Total Ecoregion Coverage Clipped/Retained		**6,856**	**6,595**
SOUTHERN ANDEAN STEPPE			
S.N. los Nogales	Los Nogales	10,895	-
Total Ecoregion Coverage Clipped/Retained		**10,895**	**-**
TOTAL AREA CLIPPED/RETAINED IN PPA SHAPEFILE		**361,592**	**7,357**

***Notes*:** Area clipped or retained is in hectares. Data is organized by ecoregion.
*S.N. = sanctuario natural, nature sanctuary.

Table 6: Comparison of private protected area ecoregion protection before and after nature sanctuary shapefile overlap clipping.

ECOREGION	AFTER NS CLIPPING (used in current analysis)		BEFORE NS CLIPPING	
Atacama Desert (G200)	-	-	-	-
Central Andean Dry Puna (G200)	8,332	0.10%	8,332	0.10%
Chilean Matorral (G200)	101,721	0.69%	108,578	0.73%
Southern Andean Steppe	207,183	6.94%	218,078	7.30%
Valdivian Temperate Rainforests (G200)	572,454	2.82%	922,117	4.55%
Magellanic Subpolar Forests	442,430	3.22%	442,430	3.22%
Patagonian Steppe (G200)	-	-	-	-
Rock and Ice	-	-	-	-
Sechura Desert (G200)	-	-	-	-
Total Country Protection	**1,332,120**	**1.77%**	**1,699,535**	**2.25%**
G200 Protection	682,507	1.20%	1,039,028	1.83%

***Notes*:** Area is in hectares. Percentages refer to PPA ecoregion representation. For example, before clipping PPA*s* covered 4.55% of the temperate forests. After clipping PPA*s* cover 2.82% of the temperate forests. Data is organized by ecoregion. Only the highlighted ecoregions were affected.