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Using benefits and costs estimations to manage conservation: Chile's protected areas

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Using benefits and costs estimations to manage conservation: Chile's protected areas

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Abstract

Despite the relevance of protected areas as biodiversity conservation tools, indicators of cost-benefit analysis of both public and private protected areas has been scarce in the literature. In this paper, we estimate and evaluate the ecosystem benefits and the management and opportunity costs of the protected areas of Chile´s National System of Protected Areas (SNASPE). We found that annual social benefits provided by SNASPE, of almost USD 2 billion, outweigh by far its annual management and opportunity costs, of USD 177 million. However, a large heterogeneity of costs and benefits is observed across the different categories of protected areas as well as among the protected areas within each category located in different geographical zones. Most of the benefits are concentrated in the South and Austral zones of Chile, zones that also exhibit the largest extension of land in SNASPE. Moreover, benefit-cost ratios vary extensively across protected areas; but, on average, the benefit-cost ratio is 11.3:1 for the entire SNASPE, which provides large opportunities to increase public investment in protected areas in Chile. Our results also shed lights on how detailed studies of benefits and costs indicators of SNASPE can improve conservation planning and conservation efficiency.

Keywords:
Ecosystems Valuation, Protected Areas, Cost-benefit Analysis, Biodiversity Conservation

1. Introduction

Despite the crucial role of biodiversity in supporting human life, the large and rapid decline of biodiversity remains a rampant phenomenon on a global scale (PNUMA 2012, TEEB 2010, PBL 2010, CBD 2010, Bradshaw et al. 2009, MEA 2005, Novacek and Cleland, 2001). This undesired trend is the result of an inadequate appraisal of ecosystems' contribution to human wellbeing, which provokes their undervaluation and, therefore, the assignment of a much lesser priority to their care and conservation than the one they deserve given their relevance for human current welfare and future survival (Figueroa and Pastén 2014). As a result, the benefits that biodiversity provides to the population have yet not been adequately reflected in the policies and management of ecosystems, so that the current rate of biodiversity loss is higher than it would be if they had been taken into account (MEA 2005). Moreover, society demands ecosystem services in terms of risk reduction, preferences and values, direct use and consumption of goods and services (Wolff et al., 2015), encouraging the protection of natural ecosystems under growing pressure from a globalized world.

The establishment of protected areas (PAs) is one of the tools most used to restrict access to and to protect ecosystems, natural habitats and species by countries around the world. Moreover, given concerns about the practicalities of exploiting natural resources sustainably, the maintenance of world remaining habitats in PAs is one of the most important strategies to safeguard relatively impacted ecosystems (Balmford et al., 2002) and is currently the best option to protect flora and wildlife under threat because in situ conservation of natural ecosystems is recognized as essential to maintain biodiversity (Rodrigues et al., 2004). The global recognition of the importance of protected natural areas has meant that most countries of the world have set large areas for protection through a National System of Protected Areas (SNASPE). Moreover, the absence of private protection of biodiversity in many countries has implied that PAs are the main mechanism by which governments can afford biodiversity conservation (Naidoo and Ricketts, 2006).

Although there has been growing concern about the alarming deterioration of biodiversity worldwide, and consensus about the need for national systems of protected areas to be adequately funded, in recent decades the budgets of national agencies in charge of these systems have been severely reduced (Darvey, 1998). This phenomenon has been especially acute in the developing world (Bruner et al. 2001) and in the last years (Watson et al., 2014). Public funding will be always necessary, because species, ecosystems, ecosystems' functions, and environmental and ecosystem services are 'public' or 'common' goods in an economic sense and, therefore, it is unfeasible in practice to attain their socially optimal provisions through only private market mechanisms. In this context, a better estimation of the benefits and costs of conservation can serve to allocate limited public resources more efficiently and, when it is needed, to provide arguments to adequately funding conservation (Naidoo and Ricketts, 2006; Figueroa and Pastén, 2014). In the last decades, the conservation literature has emphasized the importance of incorporating both conservation benefits and costs in conservation planning to improve the effectiveness as well as the efficiency of conservation efforts (Naidoo et al. 2006) and several studies have estimated the benefits and costs of the protection and conservation of different ecosystems and protected areas (Costanza 1997 and 2014; Kremen et al. 2000, Kniivilä et al.

2002, Balmford et al. 2003, MacMillan et al. 2006; Messer 2006, Berentsena et al. 2007, Figueroa 2010 and 2012; Sutton and Armsworth 2014). These trends has pushed conservation planning to move, in the last fifteen years, from relying extensively on expert assessment to determine conservation targets, towards using more quantitative, data intensive methods[1] (Boyd et al. 2015). There is no doubt that further developments of these quantitative methods using ever more precise and accurate measures of conservation benefits and costs in PAs could significantly improve planning conservation measures and program as well as planning SNASPE that maximize conservation achievements for a given budget, or minimize the cost of attaining predetermined conservation targets.

This paper contributes to the literature on economics of conservation planning. We provide empirical evidence on the benefits from and the costs of nature and biodiversity conservation using a novel empirical approach that combines two methods already used in the literature: on the one hand, a systemic analysis with a focus on the macro (or systemic) costs and benefits of Chile's National System of State Wild Protected Areas (SNASPE, for its Spanish acronym); and, on the other hand, a specific analysis with a focus on the costs and benefits at the micro (or unit specific) and geographical zone levels. To our knowledge this is the first study that estimates and evaluates a wide range of benefits from a SNASPE's ecosystem services, as well as the management and opportunity costs of the SNASPE in a developing country. The results allow us to show the heterogeneity of costs and benefits in the SNASPE in Chile, and to highlight the need for more studies to improve and advance economic micro level planning of protected areas. At the aggregate level, for Chile's SNASPE, the benefits of ecosystem services far exceed the sum of operating costs and opportunity costs of land use. Nevertheless, there is great heterogeneity in the distribution of such benefits and costs according to the type of protected areas and their geographical locations. The outcomes shed some lights not only on how to improve conservation planning using strategies and management measures from a macro (SNASPE) level but also from a micro (protected area) level, which offers new opportunities to take advantage of newly realized complementarities, scale effects, synergies, transferences, etc. The paper is structured as follow. In the section 2, we introduce the object of analysis. Section 3 presents the method. Section 3 presents the results. In section 4 we discuss the results. Section 5 provides the conclusions of the paper.

2. Methods

We estimate the ecosystem benefits annually provided by 84 of the 98 protected areas of the SNASPE and we also estimate the annual costs for the country to run and maintain these protected areas. The 14 remaining PAs were not evaluated due to the lack of information, especially geographical data. The 84 PAs analyzed are located in 4 different geographical zones of Chile: 1) North zone; it comprises 5 administrative regions in the extreme north of the country (Arica and Parinacota; Tarapaca; Antofagasta; Atacama; Coquimbo); 2) Central zone: it considers 5 regions (Valparaíso; Metropolitan Region; Bernardo O'Higgins; Maule and Bio-Bio); 3) South zone: it comprises 3 administrative regions (Araucanía, Los Ríos and Los Lagos); and, 4) Austral zone: it includes the 2 extremes regions of the country (Aysen and Magallanes). The

[1] See, for example Williams et al. (2004), Underwood et al. (2008). Newbold and Siikamäki (2009 and 2015) and Epanchin-Niell and Wilen (2012).

sample of 84 PAs studied here represents 99.7% of the total area of SNASPE and 95.6 of the annual total number of visitors to the system. Inside the sample, the most numerous category of protected area is national reserves (48%) which contain 37.3% of the SNASPE area. National parks account for 62.3% of the total area of SNASPE. The 13 National monuments analyzed comprise only 0.1%. Most of the extension of public protected areas is located in the Austral zone, with almost 85%; followed by the North and South zones, with 8% and 5.7%, respectively.

2.1 Estimation of Ecosystem Benefits

To address the challenging task of economically valuing the benefits of ecosystem services provided by the set of 84 public PAs considered here we operationalize the conceptual framework developed by the Millennium Ecosystem Assessment (MEA 2005b) employing the concept of total economic value (TEV). To implement this concept empirically we use the TEV Calculating Matrix (TEVCM) developed by Figueroa and Pastén (2014) which calculates the total economic value (TEV) of a natural area. The TEVCM integrates three key aspects of the economic value estimation of ecosystem benefits: (i) it typifies ecosystem good and services in three explicit categories following the MEA (2003, 2005b) nomenclature (regulating, provision and cultural); (ii) it homologizes these three categories of ecosystem goods and services with the two main categories (or sources) of value considered in economic science (direct use value and indirect use value); and (iii) it systematizes the procedure used to calculate the economic value of ecosystem goods and services by type of ecosystem present in the natural area that is being economically valuated (as proposed by Costanza et al. 1997), by type of ecosystem services (as proposed by the Millennium Ecosystem Assessment, MEA 2003, 2005b) and by the economic categories of the TEV approach.

To calculate the area of different ecosystems in the 84 PAs of SNASPE studied, a number of methodological steps were followed. The first step involved the collection of information about the area of the ecosystems of Chile, obtained from the cartographic coverage of current land use (CONAF-CONAMA-IBRD, 1997) and plant formations identified in Pliscoff and Luebert (2009). The second step was determining land use and vegetation in the PAs by using a Geographic Information System (GIS) to overlying the digital mapping of protected areas on the mapping of land use and vegetation. Finally, the total area of ecosystems in selected protected areas was obtained from the spatial analysis of the second step plus information provided by the government institutions where protected areas did not have digital map. The estimation of flows of ecosystem services of protected areas requires the classification of its ecosystems and the calculation of their areas. The classification of the ecosystems was obtained from the plant formations of Luebert and Pliscoff (2009).

A set of economic valuation techniques was implemented to produce reliable estimates of the benefits provided by Chile's SNASPE. Moreover, the economic values of benefits estimated here represent conservative figures (floor values) due to two reasons: 1. the lack of information precluded the estimation of economic values for several ecosystem goods and services (benefits); and 2. the estimation approach implemented here was always to avoid any possibility of an overvaluing bias. The unit values of ecosystem services used in the estimation of benefits are shown in Table 1.

Table 1. Unit Value of Ecosystem Benefits

ECOSYSTEM SERVICE	VALUATION METHOD	SOURCE	UNIT VALUE (USD/HA)
Water purification + wetland	Benefit transfer	Brander et. al (2006)	81,1
Biological control	Benefit transfer	Costanza et. al (1997)	1,47
Pollination	Productivity loss	Gallai *et al.* (2008),	19,02
Regulation of environmental disturbances	Benefit transfer	Brander et. al (2006)	128,06
Waste treatment			
+ Cental Chile	Opportunity cost	Calculation of market value of the dilution rate	0,0125 US$/m3/s
+ South	Opportunity cost		0,00264 US$/m3/s
Regulation of the climate	Revealed preferences	Calculation from value of reduction insurance premium	0,0463
Regulation of the water	Opportunity cost	Calculation from the cost of building equivalent regulatory capacity	0,45 US$/m3
Regulation of the atmosphere			
+ Forest	Market value	CantorCO2e	4,98-126,97
+ Shrubbery	Market value	CantorCO2e	49,02
+ Steppes and grasslands	Market value	CantorCO2e	35,24
+ Altitude grasslands	Market value	CantorCO2e	35,24
+ Glacier	Market value	CantorCO2e	0,23
+ Wetland	Market value	CantorCO2e	3,6-175,42
Erosion control and soil formation			
+ Forest	Replacement cost	Calculation from subsidy value of reforestation	10,83
+ Shrubbery	Replacement cost		11,15
Nutrient regulation			
+ Forest	Replacement cost	Calculation from market value of nutrients	46,2
+ Shrubbery	Replacement cost		46,2
Provision of habitat			
+ Forest	Market value	Calculation based on market value land for conservation	9,12
+ Shrubbery	Market value		9,12
+ Steppes and grasslands	Market value	idem.	9,12
+ Wetland	Market value	idem.	9,12
+ Marine/Coastal	Market value	idem.	9,12
+ Rivers			
• Metropolitan, V and VI Regions	Opportunity cost	Calculation based on market value of ecological flow water	0,0125 US$/m3
• VII, VIII and IX Regions	Opportunity cost		0,00264 US$/m3
Inheritance value	Opportunity cost	Calculation from market value of food, fiber and fuel extraction.	16,95
Fiber and food supply		Calculation from exported PFNM	5,92
+ Non Timber Forest Products	Market value	Calculation based on market value of projected future marine products	233,33
+ Marine reserves	Market value		
Water supply			
+ Forest	Factor market	Calculation based on econometric model of production water flow as input	78,99
+ Shrubbery	Factor market		78,99
+ Steppes and grasslands	Factor market		78,99
+ Altitude grasslands	Factor market		78,99
Fuel supply	Market value	Calculation based on market price of electricity	US$ 0,099/kwh
Tourism and recreation			
+ Domestic tourists	Market value	Calculation from tourism and recreation expenses	1,52
+ Foreign tourists	Market value		9,63
Genetic resources			
+ Chilean Shrubbery	Benefit transfer	Calculation of the genetic prospecting value based on Simpson & Craft 1996	0,0336
+ Temperate forests	Benefit transfer		0,002
+ Juan Fernandez Archipelago	Benefit transfer		9,771
Cultural and spiritual	Benefit transfer	Costanza et. al (1997)	0,59

Source: Own elaboration with data from Figueroa (2011)

Our estimations of ecosystem benefits do not take into account the existence value of ecosystems for several reasons: lack of information, presence of endangered species, lack of time and resources, among others. The relevance of existence value in the model of economic management of protected areas is discussed below after presenting the results.

2.2 Estimation of Management and Opportunity Costs

To estimate the annual cost of the PAs in Chile's SNASPE we defined two types of relevant costs: management (operational or direct) costs and opportunity (land) costs. Management costs comprise infrastructure and operational costs related to the implementation of the management plan for each protected area. Data of management plans for protected areas were collected during 2011. They cover a period of 28 years, from 1981, the oldest, until 2009, the newest. It is worth mentioning that given the heterogeneity of protected areas in Chile, some management plans, even though long-standing, continue to be representative of the current optimal management conditions due to its remoteness, sparse population living nearby and small number of visitors. On the other hand, the opportunity cost of a protected area is a money measure of unrealized potential profits from land uses that compete with conservation use (Squeo, 2012).

2.2.1 Management Cost: Infrastructure Costs

To estimate the investment costs in the management plans of PAs it was necessary to project current physical investment needs for those protected areas either lacking information or with too old management plans. In the case the projection obtained was lower than investment requirements specified in the management plan we kept the value of the latter. Data on management plans were obtained for 70 out of 98 public protected areas in Chile, consisting of 25 national parks, 26 national reserves and 2 natural monuments.

We elaborated a model of infrastructure costs validated through consultations with national experts on protected areas. The model was built using two steps. First, an econometric model predicting the optimal number of park guards was elaborated using information from the management plans of the PAs. The estimates of this model were used to project the required number of park guards in those protected areas without information. Second, the optimal level of physical capital for each protected area was predicted using per-guard coefficients obtained from the information in the PAs management plans. These coefficients were calculated as an average for each type of protected area (national park, national reserve and natural monument) in each geographical area (North, Centre, South and Austral). The choice of these two block models was made because of the better available information on the optimal number of park guards (70 plans) in comparison to the information on physical requirements (only 50 plans).

We related the optimal number of park guards to the following explanatory variables: land area of the protected area; number of visitors; population living around the protected area, distance from the protected area to the regional capital; distance from the protected area to the national capital; a dummy variable if the protected area is an island; and other dummy variable if the protected area main objective was protection. Land area, distance to regional capital and distance to national capital were measured in natural logarithms. Conceptually and intuitively, one would expect that, ceteris paribus, the optimal number of guards is:

- Increasing in the land area
- Increasing in the number of visitors
- Increasing in the population living around the protected area
- Decreasing in the distance to regional capital
- Decreasing in the distance to the national capital
- Increases if the protected area is in an island
- Decreases if the protected area is intended only for protection

A number of regressions with different specifications and explanatory variables were run with the chosen econometric model explaining the optimal number of park guards by: land area of the protected area; number of visitors; population living around the protected area, distance from the protected area to the regional capital; distance from the protected area to the national capital; a dummy variable if the protected area is an island; and other dummy variable if the protected area main objective was protection. Regarding the population living around protected areas, we consider those populations living in a10 kilometers-buffer zone around the borders of each PA under study. However, the inclusion of this explanatory variable was not significant in any model and the models in which it was included exhibited lower predictable power than the preferred one.

We conducted initial estimates by ordinary least squares (OLS), but the presence of outliers and leverage variables were detected. The OLS model tends to attach an excessive importance to observations with very large residuals, distorting the estimation of the parameters. In addition, bad leverage points significantly affect the OLS estimation of both the intercept and the slope (Yohai, 1987; Maronna and Yohai, 2000). Following Verardi and Croux (2009), our preferred approach to deal with outliers and leverage points was to implement an MS-estimator that minimizes the collinearity of subsamples. Table 2 presents the results of the preferred model.

Table 2. Econometric models for the optimal number of park guards

Variables	OLS	MS-estimator
Constant	7.4462	21.5049***
	(5.8871)	(3.8748)
Ln (area)	1.2646***	1.0868***
	(0.2937)	(0.2163)
Visitors	0.00008***	0.00005***
	(0.00001)	(0.0000)
Ln (distance nat, capital)	-0.7876	-2.6425***
	(0.7879)	(0.5396)
Ln (distance reg. Capital)	-0.9485	-1.3871***
	(0.7055)	(0.3853)
Protection	-5.0133***	-2.1816***
	(1.8891)	(0.7871)
Island	8.981***	5.6706***
	(3.3333)	(0.7348)
Number of Observations	70	70

Standard errors in parenthesis
**: significant at the 5% level
***: significant at the 1% level

OLS only provides significant estimates for land area (logarithm), number of visitors, and the dummies for protection and island. Correcting for the outlier and the bad leverage problems by using the MS-estimator increased the number of variables being significant, adding two variables to the model: distance to national capital (logarithm), and distance to regional capital (logarithm).

In order to estimate the physical capital per guard, we considered basic infrastructure for optimal and sustainable public use in protected areas. We carried out a survey on these items in the PAs of the SNASPE, and supplemented the data gathered with information obtained from management plans and expert consultations. The monetary costs by type of infrastructure were obtained from the data provided by the PAs management plans, the public purchases of CONAF (recorded in www.mercadopublico.cl) and the National Fund for Regional Development (FNDR, for its Spanish acronym). The estimated costs were annualized using an interest rate of 7%, which is a compromise between the social rate of discount (6%) and the private discount rate (8%) in Chile, and considering also the lifespan for different infrastructure, machinery and equipment.

2.2.2 Management Costs: Operational Costs

Operational costs consisted of two types of spending: (a) operating expenditures for the well-functioning of protected areas; (b) monitoring expenditures on critical species in each protected area. Regarding operating expenses, information from the annual reports of some PAs and surveys from other PAs provided data from a sample of 24 PAs on salaries and other expenses for different years. In this sample, operating expenses represent, on average, 30% of the salary bill of protected areas (with the exception of few PAs, like Torres del Paine that exhibits a higher percentage due to its international importance). The 30% rate was assumed for most of protected areas. Monitoring costs of species were calculated considering those species listed as critical in the UICN classification and are under control by the governmental park agency (Corporación Nacional Forestal, CONAF). Species satisfying these criteria should be monitored in each protected area. There were different costs of monitoring species according to the extension of the protected areas. In particular, those protected areas greater than 1,000 hectares hire external monitoring services with a cost of US$ 30,000 per specie. These external monitoring services identify impact generators and consist of 2 site visits of 3 days by a team of 3 professionals. Protected areas of small size, mainly natural monuments, considered a less expensive monitoring system based on an improved version of the current species censuses implemented by park guards with a cost of US$ 8,000 per specie.

2.2.3 Opportunity Cost of Land

The estimates of opportunity cost of land for each protected area required information about the area of potential alternative uses and the prices of the land for these different uses. Land was classified according to their land use capability: agriculture, livestock, forestry and conservation. Data for each protected area was obtained from several sources, mainly management plans, municipality development plans, studies and maps on land use capabilities from the Natural Resource Information Center (CIREN).

The alternative cost of land under protection was calculated using market prices which, in a perfectly competitive market for land, represent the present value of all the net benefits from the future exploitation of land. Annual opportunity cost was estimated using the already mentioned discount rate of 7%. Market prices for land were obtained from a hedonic pricing model of land developed by Donoso (2009), which considers a number of statistically significant variables predicting the land value per hectare depending on distance from the national capital, distance to the regional capital, among others. To check the accuracy of these estimates, per-hectare opportunity costs were compared to actual property values obtained from Vasquez et al. (2012).

3. Results

Table 3 shows that five out of the eighteen ecosystem services account for almost three quarters of total ecosystem benefits: erosion control and soil formation (26.5%), provision of habitat (15.2%), regulation of the atmosphere (12.2%), water regulation (10%) and water supply (9.7%). Other interesting information emerges from Table 3. First, most of ecosystem benefits correspond to those that provide an indirect economic value (83%), which highlights the importance of ecosystem benefits not traded in markets. This type of benefits is difficult to be captured to finance the implementation and proper management of public protected areas in Chile; however, some of them could be captured through payments for environmental services (PES). Second, ecosystem benefits are concentrated in the Austral zone (57%), even though the Central and South zones exhibit ecosystem benefits which are, relative to their areas, higher than in the Austral zone. In fact, protected areas of the Central zone contain 1.2% of the SNASPE´s area but generate 3.7% of its total ecosystem benefits. More relevant still, protected areas of the South zone produce 30.5% of the ecosystem benefits and represent only 5.7% of the SNASPE´s area.

Table 3. Ecosystem benefits by type of ecosystem service and geographical zone (Million USD/Year)

Ecosystem benefit	North	Centre	South	Austral	Total
Water purification	8.74	0.26	3.35	25.42	37.76
Biological control	0.00	0.10	1.14	0.73	1.97
Pollination	12.61	4.30	33.66	90.39	140.96
Regulation of environmental disturbances	3.56	0.40	5.24	39.78	48.99
Waste treatment	0.00	0.08	0.12	0.00	0.20
Climate Regulation	0.00	0.00	0.04	0.00	0.04
Water regulation	0.00	21.69	177.65	0.00	199.34
Regulation of the atmosphere	28.16	6.30	59.18	150.42	244.06
Erosion control and soil formation	89.97	18.19	137.29	285.13	530.59
Nutrient regulation	0.07	3.93	35.89	44.08	83.97
Provision of habitat	4.51	0.43	7.12	291.19	303.25
Inheritance value	0.07	0.88	41.94	34.01	76.91
Indirect Economic Value	**147.69**	**56.56**	**502.62**	**961.15**	**1,668.03**
Fiber and food supply	0.00	0.43	1.22	2.91	4.57
Water supply	0.36	7.80	61.99	123.90	194.04
Fuel supply	0.04	4.94	13.97	33.25	52.20
Tourism and recreation	23.36	4.47	30.01	21.35	79.19
Genetic resources	0.02	0.00	0.00	0.00	0.03
Cultural and spiritual	0.00	0.04	0.46	0.29	0.79
Direct Economic Value	**23.78**	**17.69**	**107.65**	**181.69**	**330.82**
Total Economic Value	**171.47**	**74.25**	**610.27**	**1,142.85**	**1,998.84**

Source: Own estimates using unitary values from Table1 and SNASPE's geographic zoning.

Table 4, in turn, shows the important fact that the benefits of each category of protected area in Chile's SNASPE substantially outweigh their total (management plus opportunity) costs. The protected category of national parks accounts for 61% of the total area under protection studied here, and it generates a very similar proportion of total ecosystem benefits (60.7%), USD 1,213.1 million; the protection category of national reserves , on the other hand, provides USD 774.5 million (38.7%) in ecosystem benefits. Obviously, natural monuments represent a very small portion of those benefits (0.6%) in concordance with their small area. These proportions are not altered significantly regarding the participation of these protection categories in the total costs of the SNASPE.

Table 4. Total annual benefits and costs of Chile's SNASPE, by geographic location of the different categories of PAs (Million USD/year)

Type of Protected Area	Benefits				Costs			Total Net Benefits
	N°	Indirect Value	Direct Value	Total Economic Value	Management Cost	Opportunity (land) Cost	Total Costs	
National Parks	**32**	**1042.0**	**171.1**	**1213.1**	**19.4**	**89.0**	**108.4**	**1104.8**
North zone	7	83.3	1.7	85.1	2.9	2.4	5.3	79.8
Central zone	3	5.2	3.0	8.1	1.8	1.2	3.0	5.1
South zone	13	390.8	79.0	469.8	9.1	42.6	51.7	418.1
Austral zone	9	562.7	87.4	650.1	5.6	42.8	48.3	601.8
National Reserves	**41**	**622.6**	**151.8**	**774.5**	**15.8**	**50.8**	**66.6**	**707.9**
North zone	5	62.3	19.8	82.0	1.8	1.8	3.7	78.3
Central zone	13	50.9	14.3	65.2	5.2	5.7	10.9	54.3
South zone	9	111.6	27.5	139.1	3.6	24.7	28.3	110.8
Austral zone	14	397.8	90.3	488.2	5.3	18.5	23.7	464.5
Natural Monuments	**11**	**3.4**	**7.9**	**11.2**	**2.1**	**0.2**	**2.4**	**8.9**
North zone	3	2.1	2.3	4.3	0.7	0.1	0.8	3.5
Central zone	1	0.5	0.5	1.0	0.3	0.1	0.3	0.7
South zone	4	0.2	1.1	1.4	0.6	0.1	0.7	0.7
Austral zone	3	0.6	4.0	4.6	0.5	0.0	0.5	4.1
Total	**84**	**1,668.0**	**330.8**	**1,998.8**	**37.3**	**140.0**	**177.3**	**1,821.5**
North zone	15	147.7	23.8	171.5	5.5	4.3	9.8	161.7
Central zone	17	56.6	17.7	74.3	7.2	7.0	14.2	60.1
South zone	26	502.6	107.7	610.3	13.4	67.3	80.7	529.6
Austral zone	26	961.2	181.7	1,142.8	11.3	61.4	72.6	1,070.2

Source: Own elaboration

The analysis of the geographic distribution of benefits and costs for each category of protected areas allowed us to identify significant heterogeneities between PAs throughout Chile. This is consistent with global-scale analyses that have shown that the costs needed to establish and manage protected areas vary enormously among countries (Naidoo and Ricketts, 2006). Our results regarding management costs are interesting, since the costs of managing PAs in the North, Central and South zones of the country are not substantially lower than those of the Austral zone (Table 4). Indeed, while management costs for the three categories of protected areas in the Austral zone are 11.3 million USD/year, in the South zone they amount to 13.4 million USD/year, while in the Central and North zones of the country they reach 7.2 USD million/year and 5.5 USD million/year, respectively. In particular, all national parks in the South zone represent annual management costs that are 62.5% higher than the costs of those national parks located in the Austral zone (9.1 USD million/year vs. 5.6 USD million/year, respectively) which is consistent with the higher number of parks in the South than in the Austral zone (13 to 9). Regarding the opportunity cost of land, protected areas of the South and Austral zones have the highest total opportunity costs, USD 67.3 USD million/year and 61.4 USD million/year, respectively. This is remarkable considering that SNASPE protected areas in the Austral zone are 15 times larger in terms of area extension that those in the South zone. The importance of glacier ecosystems in the austral zone of Chile and the ruggedness of its terrain explain that a relatively minor proportion of the land of the PAs in this geographical zone is suitable for commercial purposes (agriculture, livestock or forestry).

Figures per hectare and per year are shown in Table 5. In the last row of the table it is possible to observe that, for all the 84 PAs analyzed here, the benefit-cost ratio is 1.12:1. This is a very relevant figure from the point of view of public policy because it implies that Chile's SNASPE is an environmental management tool highly profitable for the Chilean society as a whole. Moreover, it is worth to reiterate here that, because we were unable to valuate some additional benefits associated to existence values, option values or quasi-option values, our economic valuation of total ecosystem services (total benefits) provided by SNASPE are only a lower bound (a 'floor value') of their true economic value and they might be significantly higher after a more complete valuation of the services provided by the PAs in Chile´s SNASPEs.

Table 5. Benefits and costs per hectare in the SNASPE, by type of Protected Area (USD/ha/year)

Type of Protected Area	Benefits			Costs			Total Net Benefits	Benefit/ Cost ratio
	Indirect Value	Direct Value	Total Economic Value	Management Cost	Opportunity (land) Cost	Total Costs		
National Parks	**116.8**	**19.2**	**136.0**	**2.2**	**10.0**	**12.1**	**123.6**	**11.2**
North zone	112.8	2.4	115.2	3.9	3.3	7.2	106.1	15.4
Central zone	207.1	118.5	325.6	71.6	48.5	120.0	199.7	2.7
South zone	442.8	89.5	532.3	10.3	48.2	58.6	473.5	9.1
Austral zone	77.4	12.0	89.4	0.8	5.9	6.6	82.7	13.5
National Reserves	**116.6**	**28.4**	**145.0**	**3.0**	**9.5**	**12.5**	**132.5**	**11.6**
North zone	159.5	50.6	210.1	4.7	4.7	9.4	200.6	22.3
Central zone	335.6	93.9	429.6	34.1	37.7	71.8	391.5	6.0
South zone	476.1	117.2	593.3	15.4	105.4	120.8	446.0	4.9
Austral zone	87.2	19.8	107.0	1.1	4.1	5.2	101.8	20.6
Natural Monuments	**173.9**	**508.8**	**682.7**	**138.1**	**12.2**	**150.3**	**532.4**	**4.5**
North zone	180.9	198.2	379.1	64.3	0.0	68.8	316.9	5.5
Central zone	158.4	161.1	319.5	91.1	26.6	117.7	201.8	2.7
South zone	582.1	3012.6	3594.7	1671.8	193.4	1865.2	1279.2	1.9
Austral zone	1023.3	6684.4	7707.7	846.3	58.8	905.2	6295.7	8.5
Total	**116.8**	**23.2**	**140.0**	**2.6**	**9.8**	**12.4**	**127.6**	**11.3**
North zone	129.5	20.8	150.3	4.8	3.8	8.6	104.5	17.5
Central zone	314.8	98.5	413.3	40.2	39.0	79.2	332.0	5.2
South zone	449.8	96.3	546.1	12.0	60.3	72.2	473.8	7.6
Austral zone	81.2	15.3	96.5	1.0	5.2	6.1	90.4	15.8

Source: Own elaboration

Regarding benefits generated, indirect value generated per hectare seems to be pretty similar among the three types of protected areas, ranging from USD 116.6/ha – USD 116.8/ha in national reserves and national parks, respectively, to USD 173.9/ha in natural monuments according to

Table 5. However, while direct benefits generated by national parks and national reserves are not so different (US 19.2/ha and USD 28.4/ha, respectively), those generated by natural monuments are substantially higher: USD 508.8/ha. The average national benefits per hectare are closer to those of national parks and national reserves as these two categories of PAs represent the largest proportion of SNASPE's total area. At the national level, the similarity between average benefits per hectare for national parks and national reserves is also replicated in the case of both, unit management costs and unit opportunity costs per hectare. Natural monuments face similar opportunity costs, on average, to those of the national parks and national reserves, but their unit management costs are substantially higher. Therefore, it can be concluded that there is not a linear relation between the average benefits or the average (management) costs and the size of the protected area.

Table 5 also shows that the heterogeneity of total benefits and total costs that exists among the SNASPE PAs of different protection categories and geographic zones also exists for unit benefits and unit costs, i.e. for benefits/ha and costs/ha (expressed in USD/ha), which are the usual indicators used in the literature to assessing the relative efficiency of PAs, as it was mentioned above. Total economic value per hectare is extremely high for natural monuments located in the southern region. However, in the categories of national parks and national reserves, it must be noted that the TEV of PAs in the South zone is much higher than in the Austral zone. In addition, for any of these two categories management costs turn out to be greater in the Central zone of the country than in the other zones, which can be explained by the much higher anthropogenic pressures existing in the central part of the country due to the presence on the largest urban areas of Chile, to which the SNASPE responds assigning larger budget resources. The opportunity cost of land per hectare per year is the highest for PAs located in the South zone of Chile. This reflects the fact that a large proportion of these PAs is located in a geographic zone with high agricultural, livestock and especially forestry potential. In contradistinction, the PAs of the central zone have a higher proportion of their area with only conservation alternatives because they are in high altitude localities which have no alternative uses such as agriculture or livestock production, because the lands with these uses were occupied long ago by cities and other uses.

In terms of efficiency, at the aggregate level of protection category and geographical area, each of the pairs category-zone presents a benefit to cost ratio greater than 1 (see Table 5). The most efficient protected areas correspond to national reserves in the North zone (benefit: cost ratio = 22.3), the national reserves of the Austral zone (ratio = 20.6) and national parks in the North zone (ratio = 15.5). In contradistinction, the protected areas with less benefit to cost ratio correspond to natural monuments in the South (ratio = 1.9) and the Central (2.7) zones, in addition to national parks in the Central zone (ratio = 2.7).

Estimates of benefit-cost ratios for each protected area are available upon request to the authors. Table 6 highlights the 15 PAs with the highest and the 15 with lowest benefits-cost ratios in Chile´s SNASPE.

Table 6. Ranking Top 15 most and 15 least efficient protected areas in the SNASPE sample

Protected Area	Benefit Cost Ratio	Area (Has)	Visitation (Number)	Total Benefits (USD/Year)	Opportunity Cost of Land (USD/Year)	Total Cost (USD/Year)	Threatened Species (Number)
Most Efficient Protected Areas							
NP Bernardo O´Higgins (Austral)	334	3500000	13315	155,716,630	0	466,566	1
NR Alacalufes (Austral)	309	2313138	682	137,389,960	0	444,470	2
NP Alberto Agostini (Austral)	276	1400000	0	86,347,731	0	312,398	2
NP Hornopiren (South)	260	48232	479	136,767,992	90,072	525,480	5
NP Isla Magdalena (Austral)	223	157616	0	70,761,688	0	316,713	4
NR Las Vicunas (North)	187	209131	448	44,407,877	0	236,912	2
NP Volcan Isluga (North)	131	174144	361	31,472,336	0	239,819	2
NR Katalalixar (Austral)	127	674500	0	47,002,230	0	371,508	2
NP Lauca (North)	94	137883	13340	29,697,267	0	317,129	2
NR Los Cipreses (Centre)	57	36883	10647	26,935,940	0	473,023	2
NR Nuble (Centre)	50	55948	1076	17,484,992	0	346,956	2
NR Los Flamencos (North)	48	73986	208579	27,362,766	0	570,145	2
NR Alto BioBio (South)	47	33525	20	14,642,126	0	309,677	2
NP Llanos de Challe	37	45078	2010	11,86,0754	1,321	319,135	2
NR Guamblin Island (Austral)	35	10625	0	3,699,700	0	105,1.38	2
Least Efficient Protected Areas							
Protected Area	**Benefit Cost Ratio**	**Area (Has)**	**Visitation (Number)**	**Total Benefits (USD/Year)**	**Opportunity Cost of Land (USD/Year)**	**Total Cost (USD/Year)**	**Threatened Species (Number)**
NR Trapanada	1.17	1305	192	629,227	326,214	539,953	1
NR Lago Peñuelas	1.15	9260	41989	3,336,099	2,031,383	2,902,942	1
NR Las Nalcas (South)	1.11	17530	0	5,633,726	4,741,133	5,092,546	4
NP Bosque Fray Jorge (North)	0.96	9940	15767	2,996,062	2,443,471	3,135,681	1
NM Lahuen Nadi (South)	0.95	200	0	104,723	32,800	118,920	1
NR Huemules Niblinto (Centre)	0.76	2020	290	667,552	627,476	872,720	2
NR Bellotos Melado (Centre)	0.69	417	283	117,164	78,548	167,798	2
NR Los Queules (Centre)	0.69	147	327	72,676	44,780	105,432	1
NR La Chimba (North)	0.62	2583	2800	136,711	0	220,217	1
NR Las Chinchillas (North)	0.56	4229	3540	1,181,664	1,849,232	2,128,083	1
NM Pichasca (North)	0.52	128	4446	132,873	51,469	255,286	0
NM Contulmo (South)	0.52	82	1339	59,947	17,062	115,475	3
NR Laguna Torca (Centre)	0.40	604	7723	176,756	148,259	445,161	2
NM Dos Lagunas (Austral)	0.35	181	1019	81,271	26,941	233,609	1
NR El Yali (Centre)	0.08	520	1747	34,969	137,187	453,102	1

Source: Own elaboration.

Each constructed indicator shows a large heterogeneity among protected areas. For example, our estimates of ecosystem benefits are low for the natural monuments of Dos Lagunas, Contulmo, as well as for the national reserves Los Queules, Bellotos del Melado, El Yali, Pichasca, La Chimba and Laguna Torca. In the other extreme, ecosystem benefits are the highest for some of the biggest protected areas in the country: national parks Bernardo O'Higgins, Hornopiren and Alberto Agostini, and national reserves Los Alacalufes, Katalalixar and Las Vicunas. This should not be surprising as benefits are linked to the potential area providing ecosystem benefits. The pattern of management costs is somewhat similar, smaller protected areas generally have the smallest management costs while the most popular areas face the largest total costs generally, as they require more park guards and more infrastructures. Our estimates show the existence of economies of scale for management costs; greater protected areas have lower average management costs. On the other hand, the opportunity costs were also heterogeneous across protected areas, varying almost three orders of magnitude, from US$0/ha to US$193.3/ha, which is explained by a number of factors determining the suitability of the soil for different uses, such as slope, erosion risk, salinity, and texture, among others. It is worth noting that some of the least efficient PAs exhibit relatively high opportunity costs in comparison with other protected areas: national park Bosque Fray Jorge and national reserves Lago Penuelas, Las Nalcas and las Chinchillas, which explains partially its low benefits to cost ratios. The comparison of benefits and costs across protected areas replicates more or less the same results for the least "efficient" protected areas, mostly natural monuments (Dos Lagunas, Contulmo, Pichasca and Lahuen Nadi) and some national reserves (La Chimba, Las Chinchillas, El Yali, Laguna Torca, Los Queules, Huemules de Niblinto and Bellotos del Melado, among others).

4. Discussion

The results in the previous section highlight the heterogeneity of the benefits and costs across public protected areas in Chile. Our estimates show that the national average management costs per hectare (USD 2.6/ha/year) is consistent with the existing global estimates of these costs (Balmford et al. 2003; Brunner et al. 2004). Moreover, significant variation across type and geographical location of protected areas is observed which should preclude the use of global estimates of conservation costs per hectare for the economic analysis of an individual protected area in other geographical area/country with similar ecosystems to be protected. Nonetheless, our cost estimates could be helpful for economic management and planning purposes in developing countries in the South hemisphere after a detailed analysis of the eventual similarities and differences across regions. On the other hand, opportunity cost of land in protected areas is a significant part of the total cost of conservation. This implies that a desirable expansion of the SNASPE in the Central zone of Chile, the more underrepresented zone in terms of conservation, would imply relevant land acquisition costs for the State.

A direct question from the results presented above is what to do with those least efficient protected areas whose estimated ecosystem benefits do not cover their management and opportunity costs. From our analysis it is possible to argue that they should be maintained by the public SNASPE due to two reasons. First, Table 6 shows that least efficient protected areas in our sample of the SNASPE are the habitat of several threatened species of Chile. For example, natural reserve La Chinchilla currently holds the only wild colonies of chinchilla (*Chinchilla laniger, Chinchillidae*), making this protected area crucial for the conservation and recovery of existing populations of chinchillas (Molhis, 1983). Natural monuments Dos Lagunas together with national reserve Laguna Torca contain important populations of Chilean black-necked swans, one of the main species protected by the Chilean government. Economic valuation of this species has not been carried out; however, the episode of death and emigration of black-necked swans from the Natural Sanctuaries Rio Cruces and Chorocomayo near Valdivia due to water and/or food problems was the most iconic ecological problem of Chile in 2004 (Fischer, 2013). Natural monument Contulmo is among the few places where is still possible to find the Southern Darwin´s Frog (*Rhinoderma darwinii*) whose population has sharply declined in Chile with remaining populations being small and severely fragmented (Soto-Azat et al. 2013). In particular, from Table 6, it is clear that the Central zone is the one with least efficient management of protected areas because many of their protected areas are small and have few visitors per year[2]. Central zone ecosystems are among the hot-spot at world level, where the country has implemented one of the more extensive systems of public protected areas in Latin America (Squeo et al., 2012). Second, we must stress the fact that measured total economic value of benefits for any individual PA has not accounted for no-use values, it could be expected that including these non-measured benefits would result in imply high benefits-costs ratios for these protected areas.

In terms of public policy, heterogeneity among protected areas in Chile's SNASPE provide elements for the design of management and financing strategies that allow a more efficient and sustainable system of protected areas. Ecosystem benefits and cost can be included as relevant information regarding decision making to finance protected areas. Moreover, the figures produced here highlight the need of closing the funding gap currently existing between the optimal management costs estimated in this paper and the current provision of resources to the SNASPE. Three main steps can be implemented according the information obtained here. First, for many protected areas the ecosystem benefits are far larger than their costs (opportunity costs + management costs), which provides a good argument to the Chilean government to increase its current spending on public protected areas based on the social profitability of public resource use. Second, it is possible that some of the SNASPE land that has high opportunity costs could be sold or exploited for productive initiatives, under the restriction of not affecting the habitat of relevant species, in order to buy new land to extending existing protected areas or creating new ones in those geographical locations with insufficient biodiversity representation. For this, future studies should focus on analyzing overlaps between productive lands inside protected areas and the habitat of vulnerable species. Third, the significant ecosystem benefits estimated for the SNASPE highlight the opportunities to implement sources of financing related to ecosystem services. The State should study the way of implementing economic instruments that allow the SNASPE to capture part of the ecosystem benefits of water supply; erosion control and soil formation; and water regulation, among the principal services. Similarly, there is a potential for sustainable tourism development in several PAs. Tourism ecosystem benefits have not being fully realized and they could provide part of the funding for improving the management of SNASPE protected areas, especially in those PAs unable to enjoying economies of scale in terms of area.

[2] The same can be stressed for most of the natural monuments which are small, have few visitors and contain relevant animal species.

5. Conclusions

In this paper, we have estimated that the benefits from the ecosystem services provided by public protected areas in Chile clearly outweigh the management and opportunity costs of the country's SNASPE. Nevertheless, there exists a large heterogeneity among the different types of protected area (parks, reserves and monuments) and among their geographical locations.

This heterogeneity is relevant from the point of view of biodiversity public policy. On the one hand, there is a potential to incorporate these ecosystem benefits as relevant information regarding decision making for the financing of protected areas. On the other hand, there is a need to close the funding gap between the optimal management costs estimated in this paper and the current spending on Chile´s SNASPE (SNASPE). Today, the Chilean state allocates USD 0.95 per hectare to finance the current management of public protected areas, an amount that should be increased to at least USD 2.6 per hectare to cover the costs of optimal management. In other words, the Chilean government would need to produce a threefold increase in its current spending on public protected areas. However, this investment would be highly profitably from a social point of view since the benefit/cost ratio estimated here for Chile's SNASPE is quite high (11.2). Another alternative to close the financial gap could be allowing productive initiatives within the PAs of the SNASPE. Finally, implementing initiatives to increase the number of visitors, respecting carrying capacity limits of PAs, could provide funding for a more efficient management the SNASPE as a whole, and especially of those PAs considered least efficient.

Moreover, further analyzing and understanding in detail the benefit as well as the cost heterogeneities we have found in this study across different types of PAs in the Chilean SNASPE could be critical to improve the management planning of this system in the future. For example, it can be paramount to better deciding on cross subsidies between PAs that are socially justified and which could allow to increase the overall conservation efficiency of the entire SNASPE. Our estimations show that the economic benefits provided by most of the small protected areas of the SNASPE, notably natural monuments and some national reserves, are not able to cover their management costs. However, non-use values of protected areas are not incorporated in our estimations of their economic benefits and these protected areas are rich in endangered species, some of them endemic to Chile. At the end, it must be stressed that many protected areas are not large enough to maintain viable wild populations of some species (Pauchard and Villarroel 2002; Acosta-Jamett et al. 2003), especially those located in the Central zone of the country. As Squeo et al. (2012) has pointed out, although protected areas have proved to be an effective instrument to protect ecosystems. Further analysis on benefits and costs in the SNASPE as well as in private protected areas could shed lights on future conservation planning and on specific measures and policies to improve the effectiveness and efficient of biodiversity conservation in the country.

References

Balmford, A., Gaston, K. J., Blyth, S., James, A. and Kapos, V. (2003). "Global variation in terrestrial conservation costs, conservation benefits, and unmet conservation needs". *PNAS* 100(3): 1046–1050.

Balmford, A., Bruner, A., Cooper, P., Costanza, R., Farber, S., Green, R.E., Jenkins, M., Jefferiss, P., Jessamy, V., Madden, J., Munro, K., Myers, N., Naeem, S., Paavola, J., Rayment, M., Rosendo, S., Roughgarden, J., Trumper, K. and Turner, R. K. (2002). Economic Reasons for Conserving Wild Nature. Nature 297: 950-953.

Benoit, I. (1989). Libro Rojo de la Flora Terrestre de Chile. CONAF, Ministerio de Agricultura. Santiago.

Berentsena, P.B.M., Hendriksenb, A., Heijmanc, W.J.M. and van Vlokhovenb, H.A. (2007). Costs and benefits of on-farm nature conservation. Ecological Economics 62(3–4): 571–579.

Boyd, J., Epanchin-Niell, R. and Siikamäki, J. (2015) Conservation Planning: A review of Return on Investment Analysis. Review of Environmental Economics and Policy 9 (1): 23-42

Bruner, A. G., Gullison, R. E., Rice, R. E. and da Fonseca, G. A. B. (2001). Effectiveness of parks in protecting tropical biodiversity. *Science* 291**,** 125–128.

Bruner A.G, Gullison R.E, Balmford A. (2004). Financial costs and shortfalls of managing and expanding protected-area systems in developing countries. BioScience. 54: 1119-1126.

CBD. (2011). *COP 10 Decision X/2: Strategic Plan for Biodiversity 2011–*2020. Convention on Biological Diversity. http://www.cbd.int/decision/cop/?id=12268

CDB (2010). Perspectiva Mundial sobre la Diversidad Biológica 3. Secretaría del Convenio sobre la Diversidad Biológica. Montreal, 2010.

Coria, J. and Calfucura, E. (2012): Ecotourism and the development of indigenous communities: the good, the bad and the ugly. Ecological Economics, vol. 73: 47–55.

Cunningham, A. B. (2001). Applied ethnobotany: People, wild plant use and conservation. London: Earthscan.ersity and sustaining local livelihood. Annu. Rev. Environ. Resour. 30:219–52

Davey, A.G. (1998). National System Planning for Protected Areas. IUCN, Gland, Switzerland and Cambridge, UK. pp. 71.

Deguignet M., Juffe-Bignoli D., Harrison J., MacSharry B., Burgess N., Kingston N. (2014). 2014 United Nations List of Protected Areas. UNEP-WCMC: Cambridge, UK. RUL: http://wdpa.s3. amazonaws.com/WPC2014/2014_UN_LIST_REPORT_EN.pdf

Donoso, G. (2009): Valor de la tierra Agricola y sus determinantes. Report for the Agricultural Planning Office (ODEPA). Santiago, Chile.

Dudley, N. (ed.) (2008). Directrices para la aplicación de las categorías de gestión de áreas protegidas. UICN. Gland, Suiza. pp. 96. Disponible en: http://data.iucn.org/dbtw-wpd/edocs/PAPS-016-Es.pdf

Emerton, L. (1999). The nature of benefits and the benefits of nature: Why wildlife conservation has not economically benefited communities in Africa. Report No. 9. Community Conservation Research in Africa: Principles and Comparative Practice. Global Environmental Change Programme, Economic and Social Research Council, U.K.

Emerton, L. and Mfunda, I. (1999). Making Wildlife Economically Viable for Communities Living Around the Western Serengeti, Tanzania. IUCN – The World Conservation Union, Eastern Africa Regional Office: Nairobi.

Epanchin-Niel, R. S. and Wilen, J. E. (2012). Optimal spatial control of biological invasuions. Journal of Environmental Economiics and Management (63) 2): 260-270.)

Figueroa, E. (2011). Economic and political economy considerations for social decision making to protect biodiversity- In E. Figueroa (ed.), Biodiversity Conservation in the Americas: Lessons and Policy Recommendations; pags. 31-46. Editorial FEN-Universidad de Chile. Santiago, Chile. ISBN: 978-956-19-0756-0.

Figueroa, E. and Pasten, R. (2014). Economically valuing nature resources to promote conservation: An empirical application to Chile's national system of protected areas. *Papers in Regional Science*, 93: 865–888.

Fischer, K. (2013): Modelo conceptual para la restauración ecológica de humedales, caso de estudio del humedal Rio Cruces. B.A Thesis Biology, Universidad Austral de Chile.

Fuentes, E. and Domínguez, R. (2011). Consultoría de aplicación y análisis de resultados del Management Effectiveness Tracking Tool (METT) a las principales áreas protegidas en Chile. Informe Final, PNUD-GEF-CONAMA.

Kniivilää, M., Ovaskainenb, V. and Saastamoinena, O. (2002). Costs and benefits of forest conservation: regional and local comparisons in Eastern Finland. *J. Forest Economics* 8, 131–150.

Kontogianni, A., Tourkolias, C., Machleras, A. and Skourtos, M. (2012). Service providing units, existence values and the valuation of endangered species: A methodological test. *Ecological Economics* 79: 97–104.

Kremen, C., Niles, J.O., Dalton, M.G., Daily, G. C., Ehrlich, P. R., Fay, J. P., Grewal, D. and Guillery, R. P. (2000). Economic Incentives for Rain Forest Conservation Across Scales. *Science* 288 (5472): 1828-1832.

Galaz, J. Plan Nacional de Conservación de la Chinchilla Chilena, Chinchilla laniger (Molina, 1782), en Chile.

Glade, A. (ed.). (1988). Libro Rojo de los Vertebrados Terrestres de Chile. CONAF. Santiago.

Hannah, L., Midgley, G., Andelman, S., Araújo, M., Hughes, G., Martinez-Meyer5, E., R. Pearson6 and Williams. (2007). Protected area needs in a changing climate. *Front Ecol Environ*, 5(3): 131–138

Jofré, C. and Méndez, M. A. (2011). The preservation of evolutionary value of Chilean amphibians in protected areas. In E. Figueroa B. (ed.), Biodiversity Conservation in the Americas: Lessons and Policy Recommendations; Editorial FEN-Universidad de Chile. Besegraf Ltda.; Santiago, Chile. pp. 81-112.

Laurila-Panta, M., Lehikoinenb, A., Uusitaloc, L. and Venesjärvib, R. (2015). Review How to value biodiversity in environmental management?, Ecological Indicators 55, 1–11

MacMillan, D., Hanley, N. and Daw, M. (2004). Costs and benefits of wild goose conservation in Scotland. Biological Conservation 119: 475–485.

Manzur, M. I. (2005). Situación de la Biodiversidad en Chile: Desafíos para la Sustentabilidad. Programa Chile Sustentable. Santiago, Chile. pp. 208.

Margules, C.R., Pressey, R.L. and William, P.H. (2002). Representing biodiversity: Data and procedures for identifying priority areas for conservation. Journal of Biosciences, 27 (4): 309-326.

MEA. (2005). Ecosystem and Human Well-Being: Biodiversity Systesis. World Resources Institute, Washington, DC.

Messer, K. D. (2006). The conservation benefits of cost-effective land acquisition: A case study in Maryland. Journal of Environmental Management 79 (3): 305–315.

Myers, N. (2003). Biodiversity Hotspots Revisited. Bioscience 53(1): 916-917.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B. and Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, 403: 853-858.

Naidoo, R., Balmford, A., Ferraro, P. J., Polasky, S., Ricketts, T. H., and Rouget, M. (2006). Integrating economic costs into conservation planning. *Trends in Ecology and Evolution*, 21(12): 681-687.

Naidoo R. and T. Ricketts (2006): Mapping the economic costs and benefits of conservation. PLoS Biol 4(11): e360. DOI: 10.1371/journal.pbio.0040360

Naughton-Treves, L., Buck Holland, M. and Brandon, K. (2005). The role of protected areas in conserving biodiversity and sustaining local livelihood. Annu. Rev. Environ. Resour. 30:219–52

Newbold, S. and Siikamäki, J. (2015). Conservation prioritization using reserve site selection methods. In R. Halvorsen and D. Layton (eds), *Handbook on the economics of natural resources*; Northampton, MA: Edgar Elgar.

Newbold, S. and Siikamäki, J. (2015). Cost-effective prioritization of watershed protection measures for Pacific salmon in stochastic and heterogeneous environments. *Ecological Applications* 19 (7): 1774- 1790.

Novacek M. J. and Cleland, E. (2001). The current biodiversity extinction event: Scenarios for mitigation and recovery. PNAS vol 98(10): 5466-5470. RUL: www.pnas.orgycgiydoiy10. 1073ypnas.091093698

PBL. (2010). Rethinking Global Biodiversity Strategies: Exploring structural changes in production and consumption to reduce biodiversity loss. Netherlands Environmental Assessment Agency (PBL); The Hague/Bilthoven.

PNUMA. (2012). *GEO5 Global Environmental Outlook*. Programa de Naciones Unidas para el Medio Ambiente. Nairobi. Kenia. 20 pp. Disponible en: http://www.unep.org/geo/pdfs/geo5/GEO5_report_full_es.pdf

Pauchard, A. and Villarroel, P. (2002). Remove from marked Records Protected areas in Chile: history, current status, and challenges. *Natural Areas Journal*, 22(4): 318-330

Powel, G.V.N., Barborak, J., Rodriguez S., M. (2000). Assessing representativeness of protected natural areas in Costa Rica for conserving biodiversity: a preliminary gap analysis. Biological Conservation 93:35-41

Rouget, M, Richardson, D. M., Cowling, R. M. (2003). The current configuration of protected areas in the Cape Floristic Region, South Africa—reservation bias and representation of biodiversity patterns and processes. *Biological Conservation*, 112:129–145.

Soto-Azat C, Valenzuela-Sánchez A, Collen B, Rowcliffe JM, Veloso A, et al. (2013): The Population Decline and Extinction of Darwin's Frogs. *PLoS ONE* 8(6): e66957. doi:10.1371/journal.pone.0066957.

Squeo, F.A., G. Arancio y J.R. Gutierrez. (2001). Libro rojo de la flora nativa y de los sitios prioritarios para su conservación: Región de Coquimbo. Ediciones Universidad de La Serena. La Serena.

Squeo, F., Estévez, R., Stolla, A., Gaymer, C., Letelier, L. and Sierralta, L. (2012): Towards the creation of an integrated system of protected areas in Chile: achievements and challenges. Plant Ecology & Diversity, vol. 5, No. 2, June 2012, 233–243.

Sutton, N. J. and Armsworth, P. R. (2014). Biodiversity Benefit Data and the Effectiveness of a Cost Targeting Strategy. *Conservation Biology*, 28(6): 1451–1461.

Stevens, T., Glass, R., More, T. and Echeverria, J. (1991): Wildlife recovery: is benefit-cost analysis appropriate?, *Journal of Environmental Management*, 3(4): 327-334.

Underwood, E.C., Shaw M.R., Wilson K.A., Kareiva P., Klausmeyer K.R., McBride M.F., Bode, M., Morrison, S. A. and Hoekstra, J. M. (2008) Protecting Biodiversity when Money Matters: Maximizing Return on Investment. *PLoS ONE* 3(1): e1515. doi:10.1371/journal.pone.0001515

UNEP-WCMC 2014). *World Database on Protected Areas.* http://www.wdpa.org (accessed April 2014).

Walter, H. E. (2011). Protecting Cacti: A Pending and Urgent Task in Chile's Biodiversity Conservation. In E. Figueroa B. (ed.), Biodiversity Conservation in the Americas: Lessons and Policy Recommendations; Editorial FEN-Universidad de Chile. Besegraf Ltda.; Santiago, Chile. pp. 47-80.

Williams, J.W., ReVelle, C.S. and Levin, S.A. (2004). Using mathematical optimization models to design nature reserves. *Frontiers in Ecology and the Environment* 2 (2): 98-105.

Wolff, S., Schulp, C. and Verbug, P. (2015). Mapping ecosystem services demand: A review of current research and future perspectives. *Ecological Indicators* 55 (August): 159.