UNIVERSIDAD DE CHILE - FACULTAD DE CIENCIAS - ESCUELA DE PREGRADO

OPORTUNIDADES DE CONSERVACIÓN EN PLANTACIONES AGROFORESTALES: EL CASO DE LOS MAMÍFEROS

Seminario de Título entregado a la Universidad de Chile en cumplimiento parcial de los requisitos para optar al Título de Biólogo con mención en Medio Ambiente

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Se informa a la Escuela de Pregrado, Facultad de Ciencias, Universidad de Chile que el Seminario de Título, presentado por la Srta. Patricia Alejandra Ramírez Saavedra

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ha sido aprobado por la Comisión de Evaluación, en cumplimiento parcial de los requisitos para optar al Título de Biólogo con mención en Medio Ambiente.

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RESUMEN BIOGRÁFICO

Nací en Santiago en el año 1984. No siempre me interesó la conservación biológica, cuando era niña quise estudiar medicina, pero la vida me llevó por otros caminos. Ahora descubrí lo bello de la naturaleza y, con esta Memoria, espero estar colaborando con un granito de arena en lo que espero sea mi destino profesional.

El ayer es historia,
El mañana es un misterio,
Pero el hoy es un obsequio,
Por eso se llama 'presente'.

Eleanor Roosesevelt

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RESUMEN

La complejidad estructural de las plantaciones podría enriquecer la presencia de mamíferos dentro de ellas. Probé esta hipótesis a través de un meta análisis para poder determinar si las plantaciones estructuralmente más complejas pueden sostener más diversidad de mamíferos y si éstos responden de manera diferente dependiendo de su afiliación taxonómica, tamaño corporal y dieta. Analicé 71 casos de comparaciones bosque-plantación y diez casos de comparaciones plantación-plantación. Tanto la riqueza como la abundancia de mamíferos nativos fue menor en plantaciones que en bosques nativos, sin embargo, no hubo diferencia en los tamaños corporales, dieta y filiación entre estos dos ambientes. Una mayor riqueza y abundancia de mamíferos nativos se encontró en plantaciones complejas, independientemente del tipo de plantación. La filiación taxonómica, dieta y tamaño corporal no difirieron entre plantaciones simples y complejas. La complejidad estructural de las plantaciones aumenta la diversidad de mamíferos dentro de las mismas permitiendo, de esta forma, enriquecer el valor auxiliar de las plantaciones forestales para la conservación biológica.

Palabras clave: Biodiversidad, meta-análisis, complejidad estructural, sotobosque, land sparing, wildlife-friendly farming

ABSTRACT

The structural complexity of plantations could enrich the presence of mammals within them. I tested this hypothesis through a meta-analysis in order to determine whether more complex plantations can sustain more mammal diversity and if mammals respond differently pending on its taxonomic affiliation, body size and diet group. I recorded 71 cases of comparisons forest-plantations and ten cases of plantation-plantation. Both richness and abundance of native mammals were lower in plantations than in native forest, although there was no difference in body size, dietary group and taxonomic affiliation between those two habitats. A higher richness and abundance of native mammals was found in complex plantations, independently of the plantation type. Taxonomic affiliation, body size and diet did not differ between complex and simple plantations. The structural complexity of plantations increases the diversity of mammals, thus, enriching the auxiliary value of forestry plantations for biological conservation.

Keywords: Biodiversity, meta-analysis, structural complexity, understory, land sparing, wildlife-friendly farming

INTRODUCTION

The establishment of protected areas is the most common strategy for the biodiversity conservation worldwide (Naughton-Treves et al. 2005). Setting aside lands or "land sparing" for nature conservation assumes that wildlife survival is unlikely in lands used for commodity production (Fischer et al. 2008). However, these protected but isolated areas are not able to sustain all species from the original landscape (Pimentel et al. 1992; Simonetti 1998). Further, a significant number of species survives and populations thrives outside parks and reserves (Western 1989; Pimentel et al. 1992). To conserve biodiversity in semi-natural and productive landscapes is both an increasing need and an opportunity (Daily 2001). In fact, to promote the "wildlife-friendly farming" approach aims to increase the possibility of conserving biodiversity in areas devoted to commodity production while maintaining similar levels of production (Fischer et al. 2008).

Both strategies, "land sparing" and "wildlife-friendly farming", are complementary strategies that can enhance biodiversity conservation, especially when the demand for land is increasing (Fischer et al. 2008) due to the growth of the human population and the consequently need for more goods and services (Vitousek et al. 1997; Musters et al. 2000). The demand for wood products, for instance, has resulted in an increase of global plantations (Lindenmayer et al. 2003). By the year 2005 forest plantations covered 271 million hectares worldwide or 2.1% of the total land area (FAO 2009). Although the primary goal of these plantations is the production of goods such as wood and fiber, increasing evidence suggests that there may be opportunities for biological conservation in commercial plantations (Lindenmayer & Hobbs 2004; Nájera & Simonetti 2010).

The presence of biodiversity in forestry plantations is presumably associated with structural characteristics, particularly their structural complexity, such as the presence of understory vegetation, remnants of native vegetation or multiple vegetation strata (Hartley 2002; Lindenmayer & Hobbs 2004; Nájera & Simonetti 2010). Structurally complex plantations hold more native species than simple ones serving as temporary habitat for numerous species of fauna, including birds, small mammals and invertebrates (Hartley 2002; Lindenmayer et al. 2003; Grez et al. 2003; Lindenmayer & Hobbs 2004). Recently, Nájera and Simonetti (2010) tested through a meta-analysis if structural complexity within agro-forestry systems could enhance avian diversity. They show that, independently of the plantation type, structurally complex plantations with multiple vegetation strata or a well developed understory hold a greater species richness and abundance than simple ones, turning plantations environmentally "friendlier".

If the improvement of biodiversity is related to the structural complexity of plantations, it would be expected that structurally complex plantations would hold greater richness and abundance of taxa other than birds, such as mammals. After Nájera and Simonetti (2010), I test this hypothesis using a meta-analysis of the available information on the response of mammals to the complexity of plantations. First, I assess if structural simplification from native forests to plantations leads to a decrease in richness and abundance of native mammals and if species are differentially affected regarding their taxonomic affiliation. Second, I assess if structurally complex plantations can enhance native mammal's richness and abundance and if species are differentially affected regarding their taxonomic affiliation. Large bodied species and carnivorous are usually more affected by habitat loss than small bodied species or diet generalists (Beier 1993; Andrén 1994; Maehr & Cox

1995). Therefore, I also analyze if structural simplification and complexity affect mammals species differentially regarding their body size and diet. Finally, I analyze the conservation impact of structural simplification and complexity by establishing species conservation status and endemism.

To identify the variables that determine the presence and abundance of biodiversity within plantations will allow the design of appropriate management policies to increase conservation in productive lands promoting "wildlife-friendly farming". This is urgent for 36% of mammal species which greatest threat globally is habitat loss (IUCN 2008). This will be a win-win approach where wildlife and biodiversity in general will benefit (Norton 1998) and where producers will be able to get environmental certifications to compete in international markets which are increasingly interested in sustainable products (FAO 2009; Norton 1998).

METHODS

I reviewed the ISI Web of Knowledge database for articles published between 1988 and 2009 dealing with mammalian diversity and abundance in plantations, using the search terms "mammal*" and "plantation*". These articles were then collated into those who compared mammal richness and/or abundance between natural habitats and plantations and those who compared plantations with different structural complexity. I also included relevant publications cited in these works in case they were not captured in the ISI database, increasing our sample size.

Each comparison was considered an independent case; more than one case was obtained from publications that performed more than one comparison. Structural complexity of plantations was classified as simple or complex depending on the development of the vertical strata within the plantation (August 1983). Simple plantations are those with single vegetation strata, single or multiple species canopy cover with thinned or cleared undergrowth, scarce or no shrub cover. Structurally complex plantations are those with multiple vegetation strata, single or multiple species canopy cover with dense undergrowth or abundant shrub development (modified from Nájera & Simonetti 2010).

First, I determined the response of mammals to changes from forest to plantations, regardless of the plantation type, and secondly, the response of mammals to structural complexity within plantations of the same commodity, in terms of decrease or increase in total or mean abundance or richness. Significance of changes was tested with the Sign test, considering only the direction but not the magnitude of the differences between the samples (Zar 1996). An increase of abundance or richness in plantations was considered as a positive response, meanwhile, for comparisons plantation-plantation an increase of abundance or richness in complex plantations was considered as a positive response. Finally, I analyzed if structural simplification, from forests to plantations, and complexity within plantations affected mammals species differentially. To do so, I recorded taxonomic affiliation (order), body size (kg), diet (carnivores, herbivores or omnivores), threat categories (IUCN 2008) and endemism (at country level) (Wund & Myers 2005).

RESULTS

A total of 245 papers were retrieved for the 1988 – 2009 period. From these, only 43 (17.6%) gave quantitative data on mammal richness and/or abundance suitable for analyses. Comparisons of forest-plantations comprised the bulk of the screened literature (39 articles), while plantation-plantation comparisons accounted only for 6 articles. Two studies had both forest-plantation and plantation-plantation comparisons. We recorded 71 cases involving comparisons between forest and plantations in 19 countries, being the most studied plantations Eucalyptus (19.7%), timber (18.3%) and pines (12.7%) (Table 1). Studies were carried out in South America (11 studies), Africa (8), Asia (7), Australia (5), Central America (4), North America (3) and Oceania (1), and the main focus were the tropical forest, the rainforest and the temperate forest. Concerning comparisons between different levels of structural complexity in a given plantation, we recorded ten cases in five countries. Three articles were from Central America, two from South America and one from Asia. The most studied plantation was coffee comprising 40% of the cases (Table 1). Only 24 out of 43 publications were suitable for taxonomic, body size endemism and dietary analyses. This resulted in 20 articles for forest-plantation comparisons and four for plantation-plantation comparisons.

Table 1. Number of publications and cases per plantation type used for comparisons between native forest and plantations and between plantations with different structural complexity.

Publications used for comparisons forest-plantation		
Type of plantation	Publications	Cases
Eucalypts	10	14
Timber (other species)	9	13
Pines	9	9
Coffee	5	8
Cacao	5	6
Rubber	2	4
Teak	2	4
Oil palm	2	3
Others	8	10
Total	39	71

Publications used for comparisons plantation-plantation		
Type of plantation	Publications	Cases
Coffee	2	4
Cryptomeria japonica	1	3
Eucalypts	1	1
Pine	1	1
Populus sp	1	1
Total	6	10

Richness and abundance of native mammals were significantly higher in native forests than in plantations. Plantations held fewer species than forests in 81% of the cases, and lower abundance in 75%, regardless of plantation type (Sign test $p < 0.001$ for both cases; Table 2). However, some cases exhibited an increase in species richness and abundance in plantations (10 and 15 cases, respectively). These plantations were 70% and 60%, respectively, structurally complex (Table 3). In number of species, 66% experienced a decrease in their abundance in plantations (Sign test $p < 0.001$; Table 4).

Table 2. Changes in native mammal richness and abundance as a response to structural simplification from forests to plantations and to structural complexity within plantations (shown in number of cases).

	Response to structural simplification			Response to structural complexity		
	Increases	Decreases	*p*	Increases	Decreases	*p*
Richness	10	44	<0.001	9	1	0.01
Abundance	15	46	< 0.001	5	4	0.5

Table 3. Level of structural complexity within plantations that exhibited an increase in native mammals richness or abundance in comparisons between forests and plantations.

	Structural complexity		
	Simple	Complex	Undescribed
Richness	1	7	2
Abundance	2	9	4

Table 4. Changes in richness and abundance of native mammals species as a response to structural simplification from forests to plantations and to structural complexity within plantations (shown in number of species).

	Response to structural simplification			Response to structural complexity		
	Increases	Decreases	*p*	Increases	Decreases	*p*
Abundance	58	111	<0.001	15	5	0.02

In 90% of the cases complex plantations held higher species richness than simple plantations, but no differences were found in native mammal abundance (Sign test $p = 0.01$ and $p = 0.5$, respectively; Table 2). This absence of differences could be due to a lack of statistical power (0.70[1]) given the reduced sample size (Zar 1996). However, when assessed species by species rather than case by case, 75% of the species were more abundant in complex plantations than in simple ones (Sign test $p = 0.02$; Table 4).

Although Tubulidentata and Prosboscidea were absent from plantations, there was no significant difference in the taxonomic representation between forests and plantations ($\chi^2 = 9.02$, df = 4, $p = 0.60$; Table 5). Pilosa was only found in plantations accounting for only 3% of the species. The proportions of species in each dietary group did not differ significantly among habitats ($\chi^2 = 4.07$, df = 2, $p = 0.13$; Table 5). Mammal´s body size showed no significant difference between forest habitats and plantations (Table 6). 62.5% fewer endemic species were found in plantations than in forest; on the contrary, introduced mammals were twice as often in plantations than in forest. Still, these last ones accounted for only 2% and 0.82% of the mammal species, respectively (Table 7). On the other hand, 46.2% and 75% fewer vulnerable and endangered species, respectively, where found in plantations than in forests (Table 7). All vulnerable and endangered species found in plantations (7 and 1 species, respectively) were also found in forest, except for one vulnerable primate species that was found only in plantations.

[1] According to Cohen (1988), a desired power test would be one greater than 0.90.

Table 5. Percentage of mammal species per orders and dietary groups found in plantations and native forests.

	N[a]	% In forests	% In plantations
Orders			
Rodentia	54	79.6	68.5
Carnívora	24	87.5	83.3
Marsupial[b]	17	94.1	76.5
Primate	16	87.5	37.5
Ungulate[c]	14	92.9	78.6
Scandentia	7	85.7	28.6
Soricomorpha	3	100.0	100.0
Pilosa	3	0.0	100.0
Lagomorpha	2	100.0	100.0
Insectivora	2	50.0	100.0
Cingulata	2	50.0	50.0
Tubulidentata	1	100.0	0.0
Proboscidea	1	100.0	0.0
Diet			
Omnivores	80	81.2	68.8
Herbivores	22	84.1	65.9
Carnivores	44	90.9	72.7

[a]Total of species reported by publications.
[b]Infraclass.
[c]Superorder.

Table 6. Mean body size (kg) of mammals per orders present in forests and plantations

	Mean weight (SE)					
Orders	N[a]	Forests	N[a]	Plantations	U	*p*
Rodentia	43	0.8(0.4)	37	0.7(0.4)	3137	0.45
Carnivora	21	12.9(4.6)	20	12.3(4.9)	615.5	0.32
Marsupial[b]	16	5.4(3.7)	13	7.0(4.6)	389.5	0.49
Primate	14	8.4(3.7)	6	13.1(8.4)	139	0.41
Ungulate[c]	13	166.8(65.3)	11	165.1(77.5)	138	0.35
Scadentia	6	0.1(0.02)	2	0.2(0.008)	24.5	0.48
Insectivora	1	0.01(--)	2	0.5(0.5)	4.5	0.40

[a]Total of species reported by publications.
[b]Infraclass.
[c]Superorder.

Table 7. Conservation status and endemism of mammal in response to structural simplification from forests to plantations and to structural complexity within plantations (shown in number of species).

	Response to structural simplification		Response to structural complexity	
	Forests	Plantations	Simple plantations	Complex plantations
Category				
Native	113	95	16	19
Endemic	8	3	4	5
Introduced	1	2	0	1
Status				
Least Concern	93	83	12	15
Vulnerable	13	7	3	3
Near Threatened	9	6	3	5
Endangered	4	1	0	0
Data deficient	3	3	2	2

There were no taxonomic changes in response to structural complexity within plantations (Wilcoxon p = 0.42; Table 8). The order Insectivora was present in both types of plantations but was left out from this analysis because there was no quantitative data on their abundance. Likewise, no statistical differences were found in species dietary groups (Wilcoxon p = 0.11; Table 8). Body size of mammals did not differed between simple and complex plantations (Table 9). Regarding body size of Insectivora and Soricomorpha, there were no changes as the same species were present in both kinds of plantations. Complex plantations hosted only one more endemic species than simple plantations and, unlike the last ones, hosted one introduced rodent species, but it only accounted for the 4% of the mammal species (Table 7). Finally, no endangered species were found in either type of plantation; however, complex plantations hosted 40% more near threatened species than simple plantations (Table 7). All three near threatened species found in simple plantations were also found in complex plantations.

Table 8. Changes in mammal´s abundance in response to the increment of structural complexity within plantations

	Increasing (%)	Decreasing (%)
Orders		
Primate	100.0	0.0
Rodentia	87.5	12.5
Ungulate*	75.0	25.0
Carnivora	66.7	33.3
Soricomorpha	0.0	100.0
Diet		
Omnivores	100.0	0.0
Herbivores	60.0	40.0
Carnivores	50.0	25.0

*Superorder.

Table 9: Mean body size (kg) of mammals per orders present in simple and complex plantations

	Mean weight (SE)					
Orders	N[a]	Simple plantations	N[a]	Complex plantations	U	*p*
Rodentia	8	1.5(1.1)	11	1.1(0.8)	13.0	0.50
Carnivora	5	20.3(13.8)	6	16.1(11.8)	220	0.26
Ungulate[b]	4	89.4(60.2)	4	87.9(60.8)	162.5	0.50

[a]Total of species reported by publications.
[b]Superorder

DISCUSSION

The rapid growth of the human population has led to a major land transformation (Vitousek et al. 1997) converting native forests into other land uses, such as commercial plantations, in order to fulfill the demands for goods and services (FAO 2009). As forests shelter a major part of all terrestrial species, the impacts of land transformation on biodiversity is a matter of concern (Carnus et al. 2003).

In comparison to forest, plantations did not affected large bodied or carnivorous mammals, nonetheless, plantations held fewer richness and abundance of native mammals, and a diminished proportion of species with conservation concern, which reflects changes in species composition. This is due mainly because mammalian assemblages in plantations usually comprise habitat generalist, common and widespread species that have ample habitat elsewhere (Christian et al. 1994, 1998). However, in some cases plantations exhibited greater species richness and abundance than native forest; those were mainly structurally complex plantations with a well developed understory or a heterogeneous interior with remains of native forest or a multiple vegetation strata.

In this regard, structural complexity increased the presence of mammals in plantations, independently of the plantation type. Higher richness and abundance of native mammals were found in complex plantations than in simple plantations and, although there was a slight increase, a larger proportion of species with a conservation concern was also found. Even though plantations are often more simple than forests, structurally complex plantations implies a greater habitat heterogeneity, therefore, allowing the existence of a greater number of species (MacArthur 1972) and increasing mammal diversity by acting as "friendlier" plantations.

In general, there were few available studies regarding structural complexity within plantations. The support of any decision making for conservation must be based in the systematic appraisal of the evidence, so, this lack of studies highlights the need for more research in order to increase the evidence upon conservation decisions should rely on (Sutherland et al. 2004; Pullin & Stewart 2006).

Although it has been recognize that the maintenance of the understory vegetation can improve within plantation habitat quality by providing services for mammals (Bellows et al. 2001; Hartley 2002; Lindenmayer & Hobbs 2004), no experimental studies have addressed this issue at the time. Experimental studies have demonstrated that the removal of the understory vegetation reduces bird diversity and abundance in oil palm plantations (Nájera & Simonetti, in press), but this kind of research is absent in the case of mammals. Thus, more experimental studies should take place in plantations in order to study and monitor the variables that improve mammal occurrence in plantations.

Human-managed ecosystems can play a key role for conservation purposes (Ceballos et al. 2005). To do so, plantations quality must be improved so they can shelter more species. In this sense, promoting structural complexity within plantations enhances not only mammal but also native birds and insects diversity (Nájera & Simonetti 2010; Grez et al. 2003) and brings out the possibility of contributing to biodiversity conservation. This could bring benefits not only to biodiversity itself, but also to plantations managers who can be benefit by the presence of potential pest controllers (Moguel & Toledo 1999) and by the expedition of green certifications (Norton 1998) that will give them access to the international markets that are interested on meeting today´s environmental needs. In conclusion, complex plantations offers an opportunity to conserve mammals and to sustainable development.

REFERENCES

Andrén, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. Oikos **71**: 355-366.

August, P.V. 1983. The role of habitat complexity and heterogeneity in structuring tropical mammal communities. Ecology **64**: 1495-1507.

Beier, P. 1993. Determining minimum habitat areas and habitat corridors for cougars. Conservation Biology **7**: 94-108.

Bellows, A.S., J.F. Pagels and J.C. Mitchell. 2001. Macrohabitat and microhabitat affinities of small mammals in a fragmented landscape on the upper coastal plain of Virginia. The American Midland Naturalist **146**: 345-360.

Carnus, J., Parrotta, J., Brockerhoff, E., Arbez, M., Jactel, H., Kremer, A., Lamb, D., O'Hara, K., Walters, B., 2003. Planted forests and biodiversity. Journal of Forestry. 104, 65-77.

Ceballos, G., P.R. Ehrlich, J. Soberón, I. Salazar and J.P. Fay. 2005. Global mammal conservation: what must we manage?. Science **39**: 603-607.

Christian, D.P., J.M. Hanowski, M. Reuvers-House, G.J. Niemi, J.G. Blake and W.E. Berguson. 1996. Effects of mechanical strip thinning of aspen on small mammals and breeding birds in northern Minnesota, U.S.A. Canadian Journal of Forest Research **26**: 1284-1294.

Christian, D.P., W. Hoffman, J.M. Hanowski, G.J. Niemi and J. Beyeas. 1998. Bird and mammal diversity on woody biomass plantations in North America. Biomass and Bioenergy **14**: 395-402.

Cohen, J. 1988. Statistical power analysis for the behavioral science. Lawrence Erlbaum Associates, New Jersey.

Daily, G.C. 2001. Ecological forecasts. Nature **411**:245.

FAO (Food and Agriculture Organization of the United Nations). 2009. State of the World's Forests, Rome.

Fischer, J., B. Brosi, G.C. Daily, P.R. Ehrlich, R. Goldman, J. Goldstein, D.B. Lindenmayer, A.D. Manning, H.A. Mooney, L. Pejchar, J. Ranganathan and H. Tallis 2008. Should agricultural policies encourage land sparing or wildlife-friendly farming? Frontiers in Ecology and the Environment **6**: 380-385.

Grez, A.A., P. Moreno and M. Elgueta. 2003. Coleopteros (Insecta: Coleoptera) epígeos asociados al bosque maulino y plantaciones de pino aledañas. Revista Chilena de Entomologia **29**: 9-18.

Hartley, M. 2002. Rationale and methods for conserving biodiversity in plantation forests. Forest Ecology and Management **155**:81-95.

IUCN (International Union for Conservation of Nature and Natural Resources). 2008. The IUCN red list of threatened species. Available from http://www.iucnredlist.org (Accessed on February 22).

Lindenmayer, D.B., R. Hobbs and D. Salt. 2003. Plantation forests and biodiversity conservation. Australian Forestry **66**:62-66.

Lindenmayer, D.B. and R. Hobbs. 2004. Fauna conservation in Australian plantation forests-a review. Biological Conservation **119**:151-168.

MacArhtur, R.H. 1972. Geographical ecology: patterns in the distribution of species. Princeton University Press, New York.

Maehr, D.S. and J.A. Cox. 1995. Landscape features and panthers in Florida. Conservation Biology **9**: 1008-1019.

Moguel, P. and V.M. Toledo. 1999. Biodiversity conservation in traditional coffee systems of Mexico. Conservation Biology **13**: 11-21.

Musters, C.J., H.J. De Graaf and W.J. Ter Keurs. 2000. Can protected areas be expanded in Africa?. Science **287**: 1759-1760.

Nájera, A. and J.A. Simonetti. 2010. Enhancing avifauna in commercial plantations. Conservation Biology **24**: 319-324.

Nájera, A. and J.A. Simonetti. Can oil palm plantations become bird friendly?. Agroforestry Systems, in press; DOI: 10.1007/s10457-010-9278-y.

Naughton-Treves, L., M. Buck Holland and K. Brandon. 2005. The role of protected areas in conserving biodiversity and sustaining local livelihoods. Annual Review of Environment and Resources **30**: 219-252.

Norton, D. 1998. Indigenous biodiversity conservation and plantation forestry: options for the future. New Zealand Forestry **43**: 34-39.

Pimentel, D., U. Stachow, D. Takacs, H. Brubaker, A. Dumas, J. Meaney, J. O'Neil, D. Onsi and D. Corzilius. 1992. Conserving biological diversity in agricultural/forestry systems. BioScience **42**: 354-362.

Pullin, A.S. and G.B. Stewart. 2006. Guidelines for systematic review in conservation and environmental management. Conservation Biology **20**: 1647-1656.

Simonetti, J.A. 1998. Áreas silvestres protegidas: ¿protegidas y protectoras?. Pages 123-131 in Díaz-Pineda, F., J.M. de Miguel and M.A. Casado, editors. Diversidad biológica y cultura rural en la gestión ambiental del desarrollo. Ediciones Mundi-Prensa, Madrid.

Sutherland, W.J., A.S. Pullin, P.M. Dolman and T.M. Knight. 2004. The need for evidence-based conservation. Trends in Ecology and Evolution **19**: 305-308.

Vitousek, P.M., H.A. Mooney, J. Lubchenco and J.M. Melillo. 1997. Human domination of Earth´s ecosystems. Science **277**: 494-499.

Western, D. 1989. Conservation without parks: wildlife in the rural landscape. Pages 158-165 in Western, D. and M.C. Pearl, editors. Conservation for the twenty-first century. Oxford University Press, New York.

Wund, M. and P. Myers. 2005. "Mammalia". Animal Diversity Web. Available from http://animaldiversity.ummz.umich.edu/site/accounts/information/Mammalia.html (accessed on December 22, 2009).

Zar, J.H. 1996. Biostatistical Analysis. Prentice Hall, New Jersey.

APPENDIX 1

Publications used for meta-analysis that compared native forest and plantations

Plantation	Country	Authors	Year	Reference
Coffe	Brazil	Passamani, M. and Ribeiro D.	2009	Brazilian Journal of Biology 69:305-309
Oil palm	Malasia	Bernard, H. et al.	2009	Mammal Study 34:85-96
Eucalypt	Brazil	Parry, L. et al.	2009	Biological Conservation 142:1777-1786
Cacao	Brazil	Pardini, R. et al.	2009	Biological Conservation 142: 1178-1190
Araucaria, pinus and eucalypt	Brazil	Fonseca, C.R. et al.	2009	Biological Conservation142:1209-1219
Pinus	Australia	Lindenmayer, D.B. et al.	2008	Ecological Monographs 78:567-590
Oil palm	Democratic Republic of the Congo	Gambalemoke, M. et al.	2008	Mammalia 72:203-212
Eucalypt	Brazil	Lyra-Jorge M.C. et al.	2008	Biodiversity and Conservation 17:1573-1580
Rubber	Indonesia	Nasi, R. et al.	2008	Biodiversity and Conservation 17:1105-1126
Pimienta dioica	Nicaragua	King, D.I. et al.	2007	Biodiversity and Conservation 16:1299-1320
Timber, coconut, mango and cashew nut	Kenya	Anderson, J. et al.	2007	Biological Conservation 135:212-222
Coffe	Costa Rica	Pacheco, J. et al.	2006	Revista de Biología Tropical 54:219-240
Coffe	Mexico	Gordon, C. et al.	2007	Agriculture Ecosystems & Environment 118:256-266
Acacia	Australia	Firth, R.S.C. et al.	2007	Journal of Biogeography 33:1820-1837
rubber	Malaysia	Nakagawa, M. et al.	2006	Forest Ecology end Management 231:55-62
Cacao and banana	Costa Rica	Harvey, C.A. et al.	2006	Biodiversity and Conservation 15:555-585

Pinus	Chile	Saavedra, B. and Simonetti J.A.	2005	Mammalia 69:337-348
Pinus	Chile	Guerrero, C. et al.	2006	Revista Chilena de Historia Natural 79:89-95
Coffe	Costa Rica	Daily, G.C. et al.	2003	Conservation Biology 17:1814-1826
Eucalypt	Australia	Hobbs, R. et al.	2003	Agroforestry sistems 58:195-212
Acacia and eucalypt	Madagascar	Ganzhorn, J.U.	2003	Animal Conservation 6:147-157
Eucalypt	United States	Sax, D.F.	2002	Global Ecology and Biogeography 11:49-57
Pinus	Uganda	Zanne, A.E. et al.	2001	African Journal of Ecology 39:399-401
Teak	Tanzania	Hinde, R.J. et al.	2001	African Journal of Ecology 39:318-321
Eucalypt, acacia and pinus	India	Shanker, K.	2001	Journal of Zoology 253:15-24
Acacia mangium	Malaysia	Laidlaw, R.K.	2000	Conservation Biology 14:1639-1648
Pinus	Australia	Lindenmayer, D.B. et al.	2000	Journal of Mammalogy 81:787-797
Araucaria	Australia	Bentley, J.M. et al.	2000	Conservation Biology 14:1075-1087
Eucalypt	Ghana	Ryan, J.M. and Attuquayefio D.	2000	Biodiversity and Conservation 9:541-560
Timber	Ghana	Decher, J. and Bahian L.K.	1999	Journal of Zoology 247:395-408
Acacia adn eucalypt	India	Shanker, K. and Sukumar R.	1999	Journal of Animal Ecology 68:50-59
Pinus adn eucalypt	New Zeland	King, C.M. et al.	1996	New Zealand Journal of Ecology 20:215-240
Teak	India	Chandrasekar-Rao, A. and Sunquist M.E.	1996	Journal of Tropical Ecology 12:561-571

Cacao, coffee, orange tree and *Pimienta dioica*	Mexico	Estrada, A. et al.	1994	Ecography 17:229-241
Cacao-coffee	Ivory Coast	Churchfield, S. et al.	2004	Acta Theriologica 49:1-15
Banana and cacao	Costa Rica	Vaughan, C. et al.	2007	Biodiversity and Conservation 16:2293-2310
Cacao	Brazil	Cassano, C.R. et al.	2009	Biodiversity and Conservation 18:577-603
Eucalypt	Brazil	Barlow, J. et al.	2007	PNAS 104:18555-18560
Pinus	Chile	Muñoz-Pedreros, A. and Murúa R.	1989	Turrialba 59:143-150

APPENDIX 2

Publications used for meta-analysis that compared simple and complex plantations

Plantation	**Country**	**Authors**	**Year**	**Reference**
Eucalypt	Brazil	Parry, L. et al.	2009	Biological Conservation 142:1777-1786
Coffee	México	Gordon, C. et al.	2007	Agriculture Ecosystems & Environment 118:256-266
Cryptomeria japonica	Taiwan	Hsiao-Wei, Y. et al.	2005	Zoological Studies 44:393-402
Poplar	United States	Moser B.W. et al.	2002	Northwest Science 76:158-165
Coffee	Mexico	Gallina, S. et al.	1996	Agroforestry sistems 33:13-27
Pinus	Chile	Muñoz, J.L.	2005	Honor´s Thesis. Universidad de Chile