CONFLICTOS ENTRE HUMANOS Y CARNÍVOROS SILVESTRES: DISMINUCIÓN DEL CONFLICTO HUMANO - GÜIÑA EN CHILE CENTRAL.

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A mis papás y a mi esposa

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RESUMEN

Los conflictos entre hombres y carnívoros aumentarían debido a la expansión de las actividades humanas hacia áreas silvestres así como a la recuperación de las poblaciones de carnívoros. Los carnívoros amenazados involucrados en conflictos son habitualmente perseguidos, por lo cual es necesario desarrollar métodos no letales para evitar estos conflictos. En este sentido, hice una revisión detallada de los estudios que examinan la relación entre la depredación de ganado por mamíferos carnívoros y las variables del paisaje o manejo de animales domésticos. A través de técnicas de modelación espacialmente explícita, utilicé estas variables para prever y evitar conflictos entre los humanos y la güiña, cuando los planes de recuperación de esta especie han sido exitosos. El aumento en el riesgo de depredación sobre animales domésticos a causa de la recuperación de la población de güiñas se evitaría manejando el sotobosque en plantaciones cercanas a las casas, así como incorporando gallineros a las casas, donde se protejan las gallinas durante la noche. Con el fin de facilitar su éxito, los programas de conservación de carnívoros involucrados en conflictos, en paisajes dominados por humanos, deben adoptar prácticas de manejo amigables con el medio ambiente, donde empleen las distancias a las áreas silvestres y a los asentamientos humanos, así como el uso de cercas y perros guardianes, para proteger a los animales domésticos jóvenes durante las horas de la noche.

INTRODUCCIÓN GENERAL

La depredación de animales domésticos por parte de carnívoros silvestres, así como el temor a que ello ocurra, genera conflictos entre las poblaciones humanas y los carnívoros silvestres (Treves y Karanth 2003). Estos conflictos son cada vez más frecuentes, tanto por la colonización humana de áreas que son hábitat de los carnívoros, como por la expansión o recolonización de las poblaciones de carnívoros hacia áreas con presencia humana (Treves y Karanth 2003).

En este contexto, si las medidas de manejo y conservación destinadas a recuperar la abundancia y distribución de carnívoros amenazados fuesen exitosas, estas especies usarían con más frecuencia áreas próximas a las zonas con actividades humanas y, por tanto, podría aumentar el conflicto entre humanos y carnívoros (Mech 1995). En efecto, el aumento en la distribución de lobos (*Canis lupus*) y osos pardos (*Ursus arctos*), como resultado de las acciones de conservación, trajo consigo un incremento en la frecuencia de ataques al ganado en campos de pastoreo cercanos a áreas silvestres (Harper *et al.* 2005, Wilson *et al.* 2006). De esta forma, el éxito de las medidas de conservación podrían generar una paradoja: aumentar un factor de mortalidad debido a la implementación de una estrategia de recuperación.

Los conflictos entre poblaciones humanas y carnívoros han sido tradicionalmente manejados mediante la persecución y muerte del carnívoro (Baker *et al.* 2008). Otra alternativa habitual para solucionarlos ha sido la reubicación de los carnívoros en áreas lejanas a las zonas de conflicto (Baker *et al.* 2008). Sin embargo, en muchos casos, la reubicación resulta en la muerte de los carnívoros, siendo entonces equivalente a la persecución (Fonturbel y Simonetti *en prensa*). Paralelamente, son pocas las iniciativas que, de manera preventiva, tratan de evitar el conflicto, y así la persecución de los carnívoros (e.g., Marucco y McIntire 2010, Recio y Virgos 2010). Desde el punto de vista de la conservación, la muerte de los carnívoros conflictivos es indeseable, dado que gran parte de las especies de carnívoros silvestres están amenazados a nivel local o global. Veinticuatro de 56 especies incluidas en la Lista Roja de Especies Amenazadas debido a la pérdida de hábitat a nivel mundial, están asociadas a conflictos con humanos (IUCN 2010). Por este motivo, es necesario generar alternativas de manejo que permitan evitar o disminuir los conflictos, al tiempo que se recuperan las poblaciones de carnívoros amenazados.

La probabilidad de depredación de animales domésticos por carnívoros silvestres, y por lo tanto la probabilidad de conflictos, sería una función de variables propias de los carnívoros, incluyendo su respuesta a atributos del paisaje que afectan su distribución, así como las características del manejo de los animales domésticos, tales como la presencia de cercas o perros guardianes y el resguardo durante la noche (e.g., Wilson *et al.* 2006). Por lo tanto, conocer en qué medida la depredación es afectada tanto por variables del paisaje como el manejo de animales domésticos, permitiría proponer acciones para disminuir o evitar la depredación y, con ello, el consecuente conflicto entre humanos y carnívoros silvestres. De hecho, en Montana (EEUU), la determinación de los atributos que incidían en la depredación de ganado por osos pardos, tales como la presencia de atrayentes (basureros con restos del ganado muerto y colmenas de abejas), y la distancia entre áreas de pastoreo y bosques, permitió proponer acciones para disminuir la depredación de ganado, incluyendo la remoción de atrayentes, el uso de cercos eléctricos, y el distanciamiento entre el ganado vulnerable y los bosques (Wilson y Clark 2007). Pese a la necesidad de evaluar si existen características generales que modulen los conflictos, no existe una revisión crítica de la información disponible.

La determinación de las variables que afectan la depredación permitirán prever y evitar conflictos entre las poblaciones humanas y los carnívoros, como aquellos que podrían generar las medidas de conservación de la güiña (*Leopardus guigna*) en la Región del Maule de Chile central. La güiña está declarada "vulnerable" por la IUCN debido a la pérdida de su hábitat y la persecución por represalia a los ataques a aves de corral (Acosta-Jamett y Lucherini 2008). En Chile central, las poblaciones de güiña tienen una baja probabilidad de persistencia si no se incrementa su distribución y conectividad (Acosta-Jamett *et al.* 2003). Ello podría lograrse si las guiñas empleasen, al menos ocasionalmente, las plantaciones forestales como hábitat o corredor, a través del cual se pudiesen conectar los individuos presentes en los remanentes de bosque nativo (Simonetti 2006). De hecho, la güiña usa con frecuencia plantaciones forestales con sotobosque bien desarrollado pero escasamente aquellas plantaciones desprovistas de sotobosque (Muñoz 2005). Por ello, se ha recomendado permitir el desarrollo de sotobosque en plantaciones ubicadas entre áreas protegidas publicas o privadas, lo cual permitiría tanto aumentar el hábitat disponible como conectar las poblaciones remanentes, actualmente aislados por plantaciones manejadas en forma tradicional, sin sotobosque (Simonetti 2006). Sin embargo, las plantaciones forestales colindan con asentamientos humanos y, por tanto, si la abundancia y distribución de la güiña aumenta por disponer de las plantaciones como hábitat (Simonetti 2006), entonces este carnívoro aumentaría el uso de áreas cercanas a los sitios de cría de aves domésticas, lo cual podría aumentar el riesgo de depredación o el temor de las personas a que esto suceda (Zorondo 2005). Como consecuencia, una acción dirigida a recuperar las poblaciones de güiña podría provocar o aumentar su persecución.

Como en otros carnívoros, el uso de hábitat por la güiña respondería a variables del paisaje, tales como la distancia a bosques nativos, la distancia a carreteras y la presencia de sotobosque, entre otras variables (Acosta-Jamett y Simonetti 2004, Muñoz 2005). Por lo tanto, sería posible predecir el uso del espacio, y con ello estimar donde existiría mayor probabilidad de contacto con poblaciones humanas. Así, se podrían evitar los ataques, y como consecuencia los conflictos.

En este sentido, acá propongo mecanismos que pudieran resolver la paradoja que emergerían a consecuencia del éxito en las medidas de conservación de los carnívoros, es decir, el aumento de la persecución de carnívoros debido a la aparición o aumento de los conflictos. Para esto, primero realicé una revisión crítica de la información disponible para identificar las variables del paisaje y las prácticas de manejo de animales domésticos que afectan su depredación. Luego, evalué si la depredación de animales domésticos por carnívoros silvestres podría ser prevista y evitada por el manejo de las variables ambientales y las prácticas identificadas en la revisión. Para realizar esta evaluación, determiné la probabilidad espacialmente explícita de presencia de la güiña, bajo la situación actual y en escenarios donde el uso de las plantaciones forestales permita el aumento de la distribución de güiñas. Luego, considerando los cambios potenciales en la distribución de la güiña, determiné la probabilidad espacialmente explícita del riesgo de depredación de aves de corral por este carnívoro. Finalmente, utilizando esta información, planteo acciones de manejo para evitar o disminuir el riesgo de depredación, y así evitar o disminuir el conflicto entre los humanos y carnívoros.

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CAPÍTULO I

Preventing human – carnivore conflicts: reviewing the effect of landscape variables and management practices on predation of domestic animals

Abstract

Conflicts between humans and carnivores are more frequent in recent decades, mainly due to the expansion of human populations into carnivore habitats. Carnivores engaged in conflicts are persecuted and killed. Because of many carnivore species are threatened, the use of non-lethal methods to avoid conflicts ought to be mandatory. Here, we review studies that examine the relationship between livestock predation by mammalian carnivores and both landscape and husbandry variables to identify the response of carnivores to these variables. Predation was affected by 12 variables, decreasing in pasture lands that were distant to wild areas, near houses, without woody cover, or with dogs, herdsman or fences. These variables and practices might therefore be adopted in both conservation programs and husbandry practices, planning spatially explicit conservation actions in human dominated landscapes.

Keywords

Human - wildlife conflicts, carnivore, predation, landscape attributes, husbandry, conservation, management practices.

Introduction

Predation of domestic animals by mammalian carnivores triggers conflicts between humans and wild carnivores (Treves and Karanth 2003). These conflicts are more frequent in recent decades, mainly due to the expansion of human populations into remote carnivore habitats (Treves and Karanth 2003). Lethal control and translocation as means to solve these conflicts are unethical, expensive, ineffective or unpopular (Massei *et al.* 2010, Fonturbel and Simonetti *in press*), albeit in several occasions justified as necessary (Mech 1995). Attending that many carnivore species engaged in conflicts are threatened, the use of non-lethal methods to solve these conflicts ought to be mandatory (Treves and Karanth 2003).

Predation of domestic animals would be a function of the overlap between the areas used by carnivores and humans, as well as the degree of difficulty to access to domestic animals by wild predators (e.g., Treves *et al.* 2004, Wilson *et al.* 2006, Gehring *et al.* 2010), Therefore, the assessment of both landscape attributes affecting carnivore's presence and husbandry practices that might prevent livestock predation would provide conservation tools to avoid human - carnivore conflicts, safeguarding endangered species.

Over the last 30 years, several studies have addressed the effects of landscape variables or husbandry practices on livestock predation. Predation is presumably affected by variables such as distance between native vegetation and pasture lands, distance between pasture lands and households, percentage of woody vegetation in pasture lands, availability of wild prey, and density of domestic animals as variables that might favor the contact between wild carnivores and livestock. At the same time, attempts to deter or stop predator raiding includes using husbandry practices such as presence of dogs, fencing and removal of attractants, such as carcasses. Nevertheless, available information is contradictory and inconclusive (e.g., Dar *et al.* 2009, Van Duyne *et al.* 2009), and studies usually assess only one species or a given landscape-husbandry variable (e.g., Michalski *et al.* 2006, Odden *et al.* 2008). A comprehensive review is therefore needed to assess which landscape attributes and husbandry practices might predict livestock predation. Here we review studies to determine key environmental variables or husbandry practices impinging upon the likelihood of carnivore predation to be managed in order to prevent conflicts between humans and wild carnivores, promoting conservation as well as environmentally responsible livestock rearing.

Methodology

We searched for studies that examine the relationship between predation of domestic animals and landscape variables or management practices by conducting keyword searches in ISI Web of Knowledge and Scielo databases. We searched combinations of the terms "conflict" and "predation" plus each of the following terms: "wildlife", "carnivore", "livestock", "Ursidae", "Canidae", "Felidae", "Mustelidae", "Hyaenidae". We found additional studies through the references cited in the retrieved works. In order avoid data duplication, we pulled out reviews as well as articles that used already published information.

We considered the effect of each variable and practice upon predation by a carnivore species and a location as one case. Therefore, publications that report multiple species and locations, more than one case was extracted from the same article. For each case, we recorded carnivore species and the landscape variable or husbandry practice which affected predation of domestic animals.

We used vote counting to synthesize research data, categorizing responses in positive or negative effects (Sokal and Rolf 2009). We consider a negative effect of a landscape variable or management practice if the decrease in this variable is associated to a decrease in predation. For each variable, the proportion of cases with positive/negative results was then analyzed with a sign test (Sokal and Rolf 2009).

Results

A total of 120 articles fitting our search criteria were published from January 1979 to September 2010. From these, 44 compared the effect of landscape variables and management practices on predation, containing 222 cases. It is remarkable that only 31 cases had quantitative data. Studies were conducted in 16 countries, mostly in United States, followed by Kenya, and Brazil; these three countries accounting for 51% of the studies (Appendix I). Felidae was the family with more cases studied (8 species, 101 cases), followed by Canidae (6 species, 81 cases), Ursidae (3 species, 20 cases), and Hyeanidae (1 species, 21 cases). *Canis lupus* was the most commonly studied species (40 cases), followed by *Panthera pardus* (30 cases) and *C. latrans* (28 cases). Most studies dealt with one species (69% of studies, mean 1.6 species, range 1 to 5 species per study) and two landscape variables or management practices (36% of studies, mean 2.4, range 1 to 8 variables per study).

A total of 18 landscape variables and management practices have been assessed, but only 12 variables had more than five comparisons, enabling statistical testing (Table 1). Eight variables referred to landscape variables, four referred to management practices.

The number of domestic animals preyed was significant and positively related to the abundance of carnivores (Table 1). In general, livestock predation in pasture lands significantly decreased with proximity to households, low woody or scrub vegetation in pasture lands, low abundance of domestic animals in the area, and reduced pasture size (Table 1). Livestock predation also decreased with increasing distance to wild areas, or when humans, fences or dogs where presents (Table 1). Carnivores generally preyed on domestic animals younger than one year old and attacks were generally launched through the night, except by *Acinonyx jubatus* and *Lycaon pictus*. The only one variable that showed no consistent effect on predation was wildlife prey abundance (Table 1).

Despite potential impact upon predation risk, several landscape and husbandry variables, such as use of deterrents (e.g. pepper gas), management of attractants (e.g. domestic animal carcasses), distance to roads, distance to

Table 1. Number of cases where comparisons of predation on domestic animals among different variable magnitudes were assessed, where + / 0 / - is the positive, neutral and negative tendency of the effect; p is the significance of the sign test.

	All species				Felids				Canids				Ursids			Hyenids		
	+	0	-	p	+	0	-	p	+	0	-	P	+	0	-	+	0	-
Landscape variable																		
Predator abundance	16			**<0.001**	4			*	8			**0.004**	3			1		
Distance pasture - wild areas		5	27	**<0.001**	0	4	15	**<0.001**			5	**0.031**			3		1	3
Distance pasture – houses	7	2		**0.008**	5	1		**0.031**	2	1		*						
Pasture's woody or scrub cover	16			**<0.001**	6			**0.016**	7			**0.008**	3			1		
Livestock abundance	12	3	2	**0.006**	6	2		**0.016**	4		2	0.234	2	1				
Wildlife prey abundance	5	1	3	0.219	3	1		*	2		3	0.313						
Pasture size	10			**<0.001**	4			*	5			**0.031**				1		
Night attack	10		3	**0.035**	4		3	0.273	4			*						
Husbandry variables																		
Fences presence		3	17	**<0.001**		2	5	**0.031**			10	**0.001**			1		2	1
Dogs presence	2	3	16	**<0.001**	1	2	5	0.094			8	**0.004**			1	1	1	1
Herdsmen presence	5	2		**0.031**		2	3	*				*			1			1
Livestock younger than one year old	1		7	**0.031**	1		4	0.156			2	*			1			

* p value was no calculated because low samples sizes.

rivers, slope, stockyard lighting in the night, could not assessed because low sample sizes (Table 1).

Discussion

Recovering of endangered carnivore populations due to conservation measures might generate conflicts if carnivores extend their distribution beyond wild and protected areas (Treves and Karanth 2003). Hence, successful conservation plans will require tools to avoid potential future conflicts between humans and wild carnivores. Our review has unraveled landscape variables and management practices that predictably affect livestock. Therefore, these variables and practices shall be duly considered to avoid or reduce conflicts where carnivore species might engage in conflicts. Locating cattle in safe areas, distant from native vegetation and close to human dwelling, and increasing protection at night, by fencing, predation decreases significantly. Additionally, our review showed that livestock younger than a year were more susceptible to be preyed, so the main effort must be directed to protect this age group, which increases the possibility of carrying out these actions when there are logistical constraints. Movement of cows with small calves to remote, forested pastures should be deferred, to reduce the probability of predation by carnivores (Wilson *et al.* 2006).

When landscape or husbandry variables are used to avoid conflicts, we must be careful to know the species involved in the conflict. For example, *Panthera pardus* and *C. crocuta* are exceptions to the patterns found in this study. These species killed guard dogs while were preying upon domestic animals (Holmern *et al.* 2007 Dar *et al.* 2009). Likewise, *P. pardus* could jump over fences made with post, which were effectives to avoid predation by *C. crocuta*, and vice versa (Woodroffe *et al.* 2007). *Canis mesomelas* used areas away from the protected wild area, unlike other carnivores in the same place (Gusset *et al.* 2009).

Therefore, caution must be applied when considering the best management practice to reduce likelihood of wild carnivore attacks.

Successful plans for restoring carnivore populations need to prevent and avoid conflicts, avoiding the persecution of these species. Predation of livestock can significantly be prevented or reduced by managing the location of livestock, placing that in areas distant to wild areas and near to people, and directing measures to safeguard principally young livestock, who are most vulnerable individuals. Consequently, conflict and persecution of carnivores will be reduced or avoided, improving the carnivore's conservation while environmentally responsible livestock breeding is carried out.

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APPENDIX 1

Publications used for Vote-Counting

Carnivore	Country	Livestock	Authors	Year	Reference
Canis latrans	United States	Sheep	Andelt, W.F	1992	Wildlife Society Bulletin, 20,55-62
Canis latrans	United States	Sheep	Andelt, W.F. & Hopper, S.N.	2000	Journal of Range Management, 53, 259-267
Canis lupus	Canada	Cattle	Bjorge, R.R.	1983	Journal of Range Management, 36, 20-21
Canis lupus	Canada	Cattle	Bjorge, R.R. & Gunson, J.R.	1985	Journal of Range Management, 38, 483-487
Canis latrans		Sheep	Bourne, J.	1980	Journal of Range Management, 33, 385-387
Canis lupus	United States	Sheep and cattle	Bradley, E.H. & Pletscher, D.H.	2005	Wildlife Society Bulletin, 33, 1256-1265
Panthera onca and *Puma concolor*	Brazil	Cattle	Cascelli, F.C. & Murray, D.L.	2007	Journal of Wildlife Management, 71, 2379-2386
Uncia uncia, Ursus thibetanus and *Canis aureus*	Pakistan	Sheep and goat	Dar, N.I., *et al.*	2009	Biological Conservation, 142, 2076-2082
Canis latrans	United States	Sheep	Datyton R.J.	1981	Journal of Wildlife Management, 45, 894-911
Canis latrans, Ursus americanus, Canis lupus and *Puma concolor*	Canada	Cattle	Dorrance, M.J.	1982	Journal of Range Management, 35, 690-692
Canis lupus	France	Sheep	Espuno, N., *et al.*	2004	Wildlife Society Bulletin, 32, 1195-1208
Canis latrans	United States	Sheep	Green, J.S. & Woodruff, R.A.	1994	Proceedings of the Sixteenth Vertebrate Pest Conference, 41-44
Canis lupus	Poland	Sheep, goat, cattle and horse	Gula, R.	2008	Journal of Wildlife Management, 72, 283-289

Carnivore	Country	Livestock	Authors	Year	Reference
Lycaon pictus Panthera leo, Panthera pardus, Acinonyx jubatus, Caracal caracal, Crocuta crocuta and *Canis mesomelas.*	Botswana	Goat, cattle, sheep and donkey	Gusset, M.,	2009	Oryx, 43, 67-72
Pantera leo, Panthera pardus, Crocuta crocuta and *Canis mesomelas*	Tanzania	Cattle, goat, sheep, donkey and pig	Holmern, T., *et al.*	2007	Biological Conservation, 135, 518-526
Panthera tigris	Laos	No information	Johnson, A., *et al.*	2006	Animal Conservation, 9, 421-430
Canis lupus	Finland	Sheep	Kaartinen, S.	2009	Biodiversity and Conservation, 18, 3503-3517
Crocuta crocuta, Panthera pardus and *Panthera leo*	Kenya	Goat and sheep	Kolowski, J. & Holekamp, K.	2006	Biological Conservation, 128, 529-541
Canis latrans	United States	Sheep	Linhart S.B.	1981	Eastern Wildlife Damage Control Conference, 1, 105-118
Panthera tigris	India	No information	Madhusudan, M.D.	2003	Environmental management, 31, 466-475
Puma concolor	Brazil	cattle, sheep and goat	Mazzolli, M.	2002	Biological Conservation, 105, 43-51
Canis lupus	United States	Cattle	Mech, L.D., *et al.*	2000	Wildlife Society Bulletin 28, 623-629
Puma concolor and *Panthera onca*	Brazil	Cattle	Michalski, F.,	2006	Animal Conservation, 9, 179-188
Canis lupus	Italy	Sheep	Musiani, M., *et al.*	2003	Conservation Biology, 17, 1538-1547
Canis lupus	United States	Sheep and goat	Nass, R.D., *et al.*	1984	Journal of Range Management 37:423-426
Lynx lynx		Sheep	Odden, J., *et al.*	2008	Journal of Wildlife Management, 72, 276-282
Panthera leo, Panthera pardus, Acinonyx jubatus and *Crocuta crocuta*	Kenya	Cattle, sheep and goat	Ogada, M.O., *et al.*	2003	Conservation Biology, 17, 1521-1530
Puma concolor and *Panthera onca*	Brazil	Cattle	Palmeira, F., *et al.*	2008	Biological Conservation, 141, 118-125

Carnivore	Country	Livestock	Authors	Year	Reference
Panthera leo and *Crocuta crocuta*	Kenya	Sheep and Cattle	Patterson, B.D., *et al.*	2004	Biological Conservation, 119, 507-516
Canis latrans	United States	Sheep	Robel, R.J., *et al.*	1981	Journal of Wildlife Management, 45, 894-911
Canis latrans	United States	Sheep	Sacks, B.N. & Neale, J.C.C.	2007	Journal of Wildlife Management, 71, 2404–2411
Ursus arctos	Norway	Sheep	Sagør, J.	1997	Biological Conservation, 81, 91-95
Panthera tigris, Panthera pardus and Ursus thibetanus	Bhutan	Cattle and horse	Sangay, T. & Vernes, K.	2008	Biological Conservation, 141, 1272-1282
Panthera leo, Panthera pardus, Acinonyx jubatus, Crocuta crocuta, and Lycaon pictus	Botswana	No information	Schiess-Meier, M., *et al.*	2007	Journal of Wildlife Management, 71, 1267-1274
Lynx lynx	France	Sheep	Stahl, P., *et al.*	2002	Journal of Applied Ecology, 39, 204-216
Canis latrans	United States	Sheep	Stoddart, L.C., *et al.*	2001	Journal of Range Management, 54, 15-20
Lynx lynx	Norway	Sheep	Sunde, P., et al.	1998	Wildlife Biology, 4,169-175
Canis lupus	United States	Cattle	Treves, A., *et al.*	2004	Conservation Biology, 18, 114-125
Canis lupus	Mongolia	Horse, cattle and goat	Van Duyne, C., *et al.*	2009	Journal of Wildlife Management, 73, 836-843
Uncia uncia, Ursus Thibetanus, Panthera tigris	Bhutan	Cattle, pig, horse and sheep	Wang, S. & Macdonald, D.	2006	Biological Conservation, 129, 558-565
Ursus arctos	United States	Cattle	Wilson, S., *et al.*	2006	Biological Conservation, 130, 47-59
Panthera leo, Panthera pardus, Acinonyx jubatus, Crocuta crocuta, and Lycaon pictus	United States	Cattle, sheep, goat, donkey and camel	Woodroffe, R.	2007	Biodiversity and Conservation, 16, 1245-1260

CAPÍTULO II

Preventing human-wildlife conflict: modeling poultry predation risk by kodkod (*Leopardus guigna*) in Central Chile

Abstract

Human-carnivore conflicts are expected to increase due to both the expansion of human activity into more remote areas and to the recovery of endangered carnivore populations. The development of non-lethal methods to avoid these conflicts is necessary. Here, we used landscape and husbandry variables to prevent human-carnivore conflicts through a spatially explicit modeling approach. Using Maxent, we predicted habitat use and, thereby, predation risk of poultry by kodkod (*Leopardus guigna*) as a case study, when recovery plans of this species are successful. Predation risk was mainly affected by density of forest or plantation with understory and coops presence, which must be managed to avoid conflicts between human and kodkod. In order to conserve kodkod populations, we exhort allowing the development of high percentage cover of understory in plantations located adjacent to private or public protected areas, as well as the construction of coops in households and an the environmentally responsible manages of guard dogs to avoid human – kodkod conflicts. Finally, human wildlife conflicts could be prevented and avoided by managing few landscape and husband variables, thereby, we recommend using similar cheap and low effort methodologies worldwide to develop carnivore conservation strategies.

Keyword

Human-wildlife conflict, modelling, predation, poultry, güiña, conservation, management practices.

Introduction

Human-carnivore conflicts are expected to increase due to both the expansion of human activity into more remote areas and to the recovery of endangered carnivore populations (Treves *et al.* 2002, Treves and Karanth 2003, Harper *et al.* 2005). Further, if conservation measures aimed to recover endangered carnivores are successful, these species would increase their abundance and consequently the use of areas close to humans, likely increasing the possibility of conflicts (Mech 2001, Marucco and McIntire 2010, Recio and Virgos 2010). Indeed, the recovery of the distribution by wolves (*Canis lupus*) as a result of conservation actions, increased livestock predation (Mech 2001).

Human-carnivore conflicts have traditionally been managed through persecution (Treves *et al.* 2002, Baker *et al.* 2008) or translocation of carnivores (Bradley *et al.* 2005, Baker *et al.* 2008), which frequently ends in equivalent results: death of the wild carnivore (Bradley *et al.* 2005, Fonturbel and Simonetti *in press*). Globally, 24 among 60 threatened species by habitat loss are related to conflicts with humans (IUCN 2010). Therefore, the use of non-lethal methods to avoid or solve these conflicts is necessary (Treves and Karanth 2003a, Baker *et al.* 2008).

Predation of domestic animals by wild carnivores is affected by landscape attributes and husbandry practices, such as the distance of pasture lands to wild areas, the percentage of woody vegetation within pasture lands, and the presence of dogs and fences (Chapter I). Hence, these variables could be used to prevent conflicts between humans and carnivores worldwide, such as those could be triggered if conservation measures of kodkod (*Leopardus guigna*) in Central Chile are successful.

Kodkod is a vulnerable small felid threatened by habitat loss and persecution in retaliation for poultry predation (Sanderson *et al.* 2002, Zorondo 2005, Silva-Rodriguez *et al.* 2007, Acosta-Jamett and Lucherini 2008). In Central Chile, kodkod populations are fragmented, thus the provision of habitat and presence of corridors would be an important component of their long term persistence (Acosta-Jamett *et al.* 2003). Kodkod inhabits forested areas with cover understory higher than 20% (Simonetti and Acosta-Jamett 2002, Muñoz 2005). Thereby, the use of exotic plantations, located among public or private protected areas, by allowing regeneration of the understory, could be an alternative to provide a supplementary habitat to kodkod and other endangered species (Simonetti and Acosta-Jamett 2002, Simonetti 2006, Najera and Simonetti 2010, Ramirez 2010). However, if kodkod populations are enlarged or movement is enhanced through forestry plantations, kodkods would increase the presence near to household areas. Therefore, it would also increase the likelihood of poultry predation or people's fear the occurrence of kodkod raiding on their properties (Zorondo 2005). Then, the success of conservation measures could create a paradox: increasing mortality factors due to a recovery strategy.

Within this framework, predicting the likelihood of predation of domestic animals we could avoid persecution of endangered carnivores when restoration of carnivores has been successful. In this way, our goal is to use landscape and husbandry variables to, first, predict the spatially explicit probability of poultry predation by kodkods if conservation measures to recover kodkod were successful and, second, manage these variables in order to model options to avoid conflict and the consequent persecution of carnivores.

Study area

We studied a 57 km^2 area in Central Chile (72°44'14.64"W – 35°56'45.24"S to 72°38'42.36"W – 36°01'39.72"S, Figure 1). The landscape comprises a mosaic of native forest, where the Los Queules National Reserve (147 ha) is located, Monterrey pine (*Pinus radiate*) plantations, shrublands, and bare soil. Four small villages are within or near this area, namely Canelillo, Ramadillas, Quile Bajo, and Salto de Aguas, at an average distance of 2190 meters from Los Queules National Reserve (Figure 1).

Pine plantations comprised 45.4% of the total area, low disturbed native forest 7.7%, medium to high disturbed forest 30.8%, which have mainly affected by selective logging. Pine plantations are regarded as the matrix that surrounds the native forest remnants. These plantations are at least 20–40 years old. Near 53% of plantation surface have a well developed understory.

Local people raise chickens to meet needs. Chickens sleep in coops or on trees near homes, and roam in the vicinity of the houses (Zorondo 2005). Chickens can leave the property toward surrounding vegetation including native forests and plantations, reaching an average distance of 150 meters (percentile 90 = 200 meters).

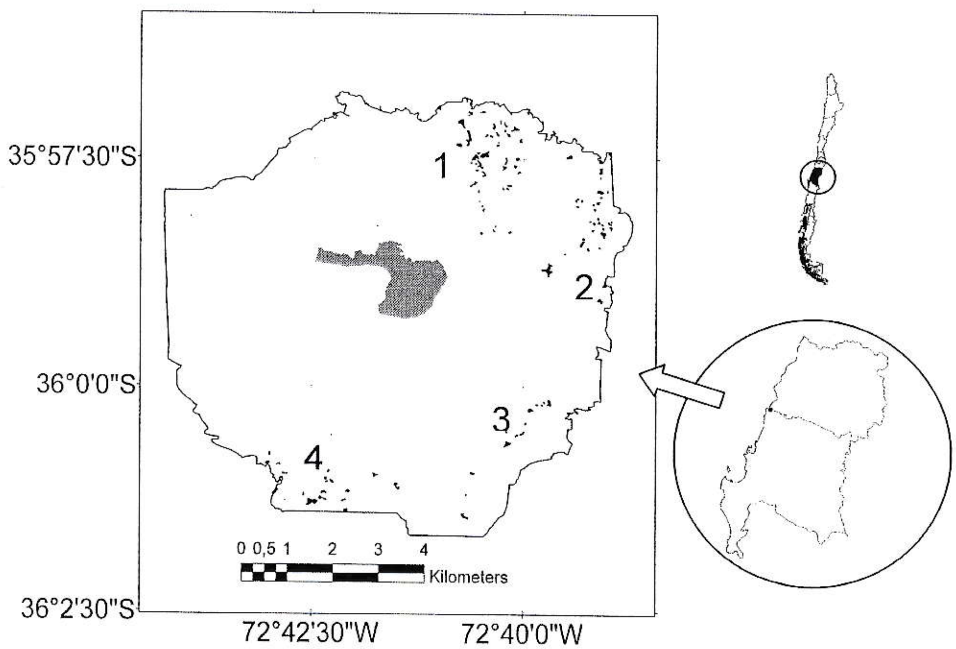

Figure 1. Study area, showing Los Queles NR (gray) and the households (black dots) in the small villages Salto de Aguas (1), Canelillo (2), Ramadillas (3), and Quile Bajo (4).

Methods

Data collection and environmental predictors

Thirty-nine kodkod occurrence data were collected from two different resources to model habitat distribution by kodkod. First, we used camera trapping and trackable substrates in 25% of the central-eastern sector of the study area from October 2009 to November 2010, totaling 37,839 trap hours. We also gathered records of kodkod from previous sampling in the study area (Acosta-Jamett and Simonetti 2004, Muñoz 2005).

Twenty-four data on poultry predation were collected from surveys to 46 householders from all villages to model predation risk of poultry by kodkod. From these surveys, we also obtained information about husbandry practices and perceptions of local people toward kodkod.

Based on available information regarding landscape variables that could affect presence of kodkod (see Acosta-Jamett and Simonetti 2004) and landscape and practice variables affecting predation of domestic animals by carnivores (Chapter 1), we selected variables to be used in modeling of kodkod habitat distribution and, thereby, predation risk on poultry (Table 1). These variables were digitalized in layers with 10 meters cell size from aerial images with 2.5 meters cell size. Using field data, we supervised the digitalization of variables, such as vegetation type and understory presence. Finally, we evaluated the performance of models where we jackknifed all variables to evaluate the importance of each landscape and practice variable in the current scenario and, hence, we selected the best group of variables to develop the final models (Table 1; Phillips *et al.* 2006, Pearson 2007). We used the area under the curve (AUC) of the receiver–operator characteristic (ROC) as a single measure of model performance (Phillips *et al.* 2006).

Model

We used modelling techniques that require presence-only data to calculate both the spatially explicit probability of kodkod presence and, thereby, the spatially explicit likelihood of poultry predation by kodkod. We selected MaxEnt because it has frequently outperformed other presence-only or presence/absence methods (Elith *et al.* 2006). To calculate the probability of kodkod presence and the poultry predation risk, ten individual MaxEnt models were run with the recommended default values, except: perform jackknife tests, random test percentage = 20, replicates 10, and maximum iterations = 10000.

We considered five scenarios to evaluate predation risk. The first scenario was the current landscape. Second, we considered that all plantations had a well developed understory. Third, all plantations had a low percentage cover of understory. Fourth, all plantations had a high percentage of understory cover but a belt of 200 meters inside the edge facing households. For the final scenario, we considered that all plantations had a well developed understory and all householder confined poultries in coops at night. Based on these scenarios, we evaluated the success of husbandry practices to reduce predation risk on poultries, estimating the reported frequency of kodkod attacks in both households where chickens are confined overnight and those where poultries slept on trees or other structures without shelter, presumably more exposed to predation (Pearson 2007).

Model test

The AUC of the ROC was used to test the degree of agreement between the observed occurrence and the projected distribution ($AUC_{training}$) and the predictive ability to the model (AUC_{test}) (Phillips *et al.* 2006). Based on this information, we defined as kodkod habitat all pixels with a probability of occurrence higher than the Maximum Training Sensibility Plus Specificity threshold (Liu *et al.* 2005), for each one of the scenarios.

Since Maxent model uses only occurrence data, we used a logistic regression to assess the discriminatory ability of the predation risk model to predict both the occurrence and the absence of kodkod attacks reported by householders in the current scenario.

Finally, to evaluate differences of predation risk in the current scenario against all other scenarios, we used Planed Comparisons in a Repeated Measures ANOVA. Predation risk was assessed as the probability of predation in an area of 200 meters around each house (percentile 90 of the distance that poultry reach when they foray away from households). Only houses separated 400 meters or more where included in the analysis in order to avoid pseudoreplication.

Results

Kodkod habitat

Projected distribution of kodkod showed a discriminatory ability to agreement between the occurrence data and the projected distribution of kodkod of $AUC_{training}$ = 0.87, and a predictive ability to the model AUC_{test} = 0.78. Kodkod presence is higher in or near to native forest or pine plantation with a high percentage cover of understory, in areas distant to main roads. The probability of kodkod to be present was never nil, even in the vicinity of houses and within disturbed areas

Kodkod habitat currently comprises 1,160 ha (Figure 2). This area increases 29% when all plantations have a well developed understory (Figure 2). On the other hand, kodkod habitat decreased in 62% when plantations had no understory, restricting kodkods to Los Queules National Reserve and adjoining native forest. (Figure 2). Finally, kodkod habitat increased 27% when all plantation forests have a well developed understory, except an edge area of 200 meters (Figure 2)

Table 1. Landscape variables and attributes used to model probability of kodkod presence and predation risk.

Variable	Characteristic
Kodkod habitat model	
Land cover	Landscape covered by native forest, disturbed native forest, plantation (low and high percentage cover of understory), bare soil, and crops
Abundance of native forest	Abundance of native forest in a 400 meters radius around each point into the study area
Distance to main roads	Distance to closest main road, which are roads that connect small villages
Distance to secondary roads*	Distance to closest secondary road, which are smaller and less transited roads than principal roads
Poultry predation model	
Abundance of kodkod habitat	Abundance of kodkod habitat in a 400 meters radius around each point into the study area
Abundance of understory cover	Abundance of forest or plantations with high cover percentage of understory in a 400 meters radius around each point into the study area
Distance to houses*	Distance to each point into the study area to the closest house
Abundance of dogs*	Abundance of dog in a 400 meters radius around each point into the study area

* Variables excluded in the models because a low explanatory value, according to the AUC of the variables jackknife test

Predation risk by kodkod

Models of poultry predation risk by kodkod showed an $AUC_{training}$ of 0.94 and an AUC_{test} of 0.94. That is, there is consistency between occurrence of poultry predation as reported by local people and areas of high predation risk as predicted by the model. Similarly, the absence of claims of poultry predation was related to areas of predicted by the model as low predation risk (logistic regression, B=10.42, p=0.024). Predation risk is lower in areas with low abundance of kodkod habitat and areas with low abundance of forests or plantations with well developed understory.

Predation risk in the current scenario had a mean ± standard error of 0.14 ± 0.03 (Figure 3). If all plantations had a well developed understory, predation risk significantly increases to 0.23 ± 0.04 ($t = -7.68$, $p = <0.001$; Figure 3). On the other hand, predation risk decreases in next scenarios. Predation risk decreases to 0.09 ± 0.03 ($t = 5.32$, $p = <0.001$; Figure 3) when all plantations had a low percentage cover of understory. It also decreases when all plantations had a high percentage of understory cover but a 200 meter belt inside the edge facing households. In this scenario, predation risk decreases to 0.09 ± 0.03 ($t = 9.20$, $p = <0.001$; Figure 3).

Finally, reports of predation by kodkod in households where poultries were confined at night decreased by 57.8%. Concomitantly, predation risk decreased in the scenario where despite all plantations had a well developed understory, poultry is confined at night 0.10 ± 0.02 ($t = 8.89$, $p = <0.001$; Figure 3).

Surveys showed that currently 24 households (58%) reported attacked by kodkod, hence seven (17%) were affected during the first half of 2011. Eleven affected householders (46%) wished kill kodkod if they could, twelve (50%) preferred frighten them.

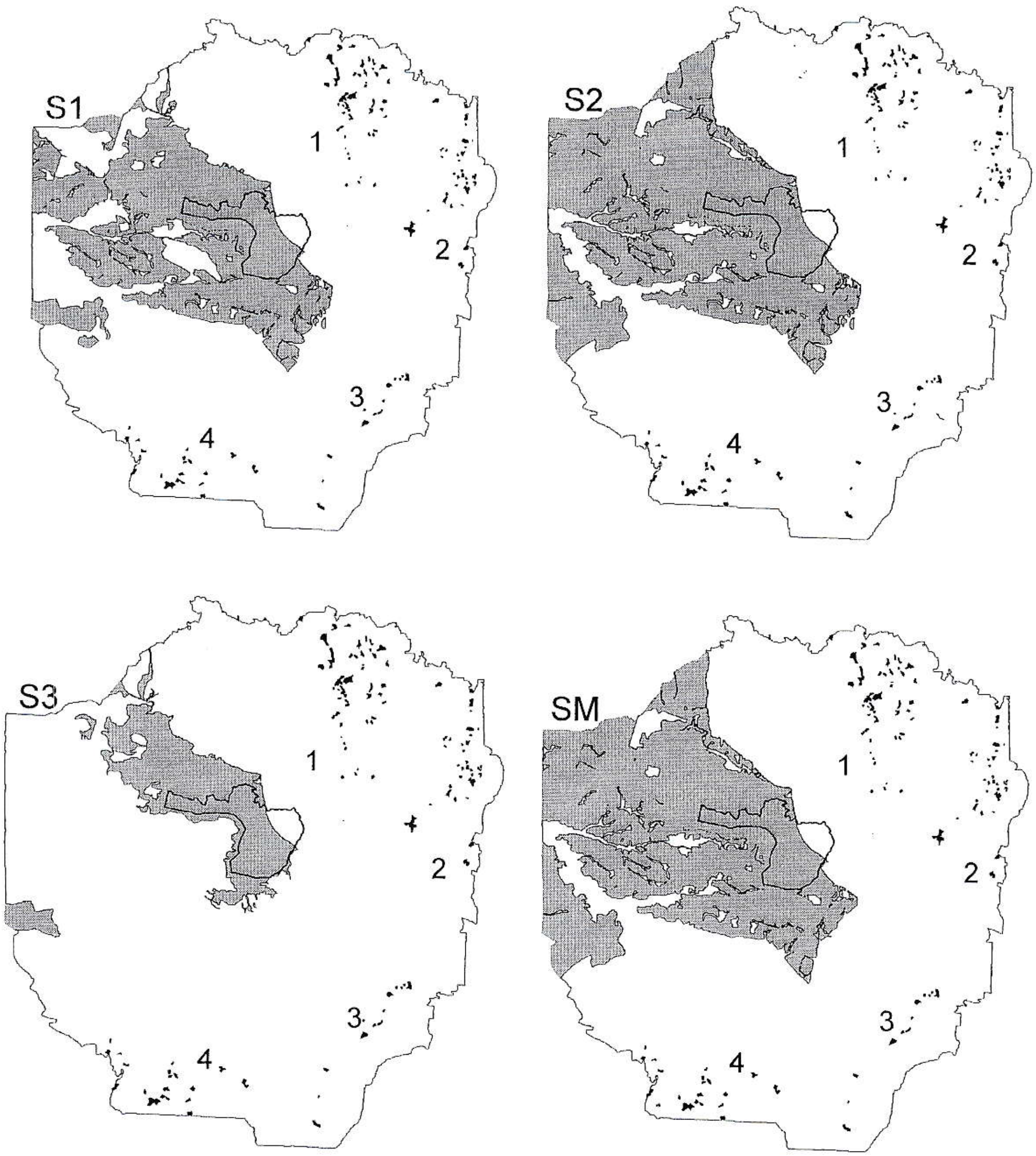

Figure 2. Kodkod habitat in the scenarios current (S1), all plantations with understory (S2), all plantation without understory (S3), all plantations with understory except a 200 meter belt (SM), where colors represent: gray areas = kodkod habitat, black areas = housing areas, black lines = Los Queules NR.

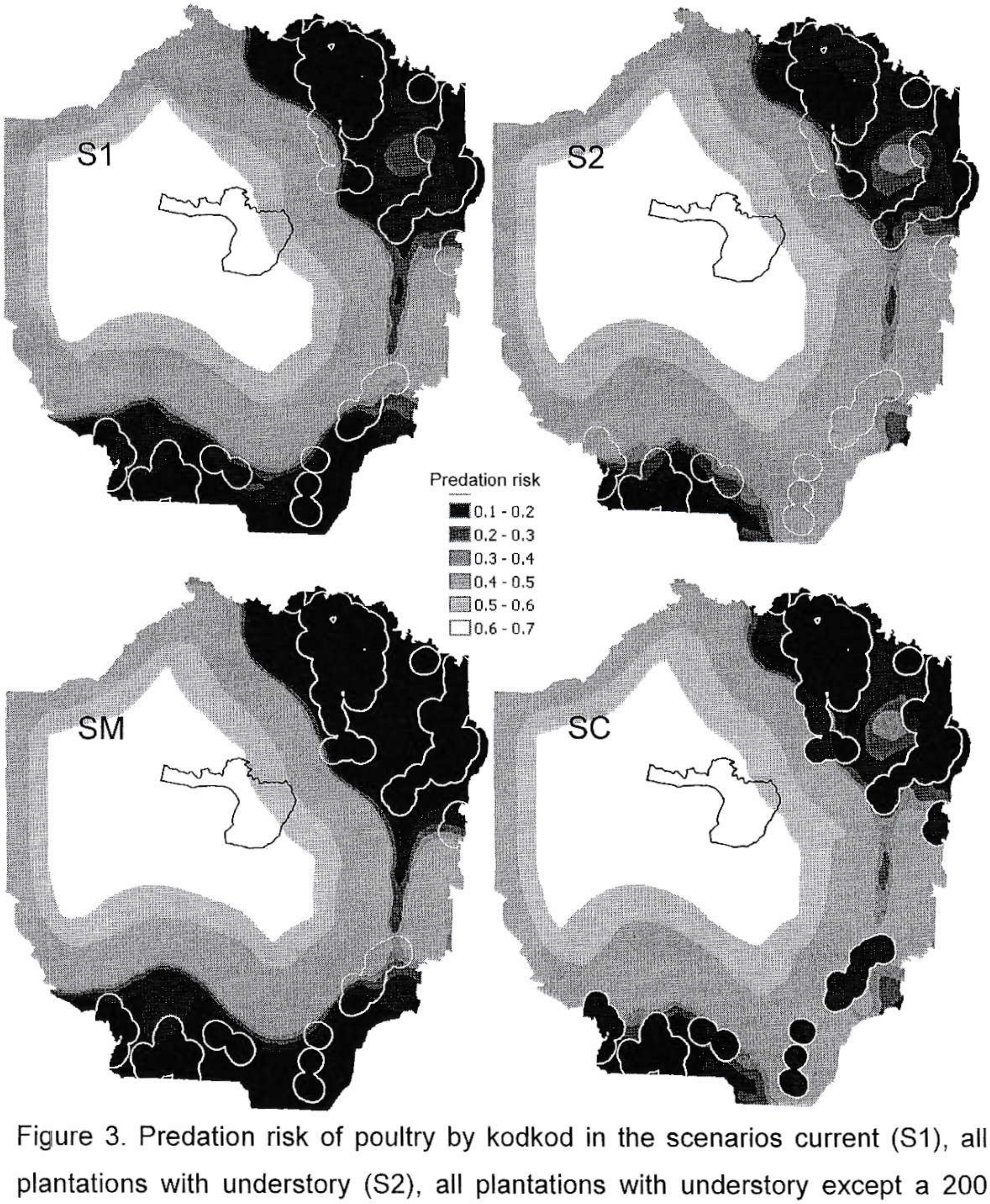

Figure 3. Predation risk of poultry by kodkod in the scenarios current (S1), all plantations with understory (S2), all plantations with understory except a 200 meter belt (SM), all plantations with understory and in all households poultry are confined at night (SC) where colors represent: gray areas = probabilities of predation (from 0.0 - dark gray to 0.7 light gray), white lines = 200 meters around houses, black lines = Los Queules NR.

Discussion

Kodkod habitat is largely related to areas with forest with a complex structural composition, such as it is observed in native forests (Simonetti and Acosta-Jamett 2002) or exotic plantations with well developed understory (Muñoz 2005). As proposed by Simonetti and Acosta-Jamett (2002), we found kodkod habitat would increase by allowing a well developed understory in exotic plantations adjacent to protected areas. This could be an important measure to conserve the endangered and fragmented populations of kodkod in the central Chile (Acosta-Jamett *et al.* 2003). Management of understory under plantations has already been recommended to enhance biodiversity conservation, with little or no reduction in production of exotic plantations (Hartley 2002). Furthermore, Chileans prefer plantations with a well developed understory over plantations without understory (Püschel 2010), given social support to that management measure. Moreover, increases in use and presence of native animals in exotic plantations due to the improvement of the structural complexity have been observed in diverse groups, such as birds and mammals (Najera and Simonetti 2010, Ramirez 2010).

Nevertheless, recovery of carnivores engaged in conflicts has sometimes triggered their persecution (Linnell *et al.* 1999; Harper *et al.* 2005). Here we found if a threatened species engaged in conflict as kodkod increases the use of plantations near to households, and conflicts are not avoided, this species will be persecuted due to increasing predation on domestic animals or fear to attack happen (Sanderson *et al.* 2002, Acosta-Jamett and Lucherini 2008). We determine that householders around Los Queules National Reserve are prone to chase kodkods in retaliation or simply at sight, due to its reputation of poultry predator, as reported by Zorondo (2005), although in some areas poultry could be infrequent or imperceptible in the kodkod diet (Correa and Roa 2005). Persecution of kodkod could also be trigged if local people fear that raiding might happen, which could be a consequence of increase in sightings of kodkods. Moreover, guard dogs living in villages could be another important threat to kodkod, killing animals that approach to the households (Silva-Rodriguez et al. 2007, Pereira *et al.* 2010).

Our research confirms that abundance of forest (native or plantations) with well developed understory has an important effect on the presence of kodkod (see also Simonetti and Acosta-Jamett 2002, Muñoz 2005). Thereby, abundance of predator habitat as well as fencing animals at night (i.e. coop) had an important significant effect on likelihood of poultry predation, which has also been observed in several carnivore species (Chapter One). Consequently, these variables and practices could be used to avoid or reduce the human-kodkod conflicts, as well conflicts of several carnivore species in areas dominated by human.

Presence of coops and the development of understory in exotic plantations must be managed to avoid poultry predation risk by kodkod and the conflict might emerge from their recovery. Both management actions do not compromise the area gained for kodkod, shows a significant reduction of predation risk from the current scenario, and do not represent a significant cost for householders.

Predation could be reduced facilitating the construction of coops, and enclosing poultries at night. As shown by Zorondo (2005), this proposal have a social support, given that people agree with the recovery of carnivore species as long as they were subsidized to build coops in order to protect poultries at night. Nevertheless, the use of coop and the management of understory in the edge of plantations have limitations. Facilitating the construction of coops prevents poultry predation but do not preclude the approach of kodkod to villages. Thereby, kodkods could be persecuted and killed by guard dogs, which is considered an important threat for small wild cats (Silva-Rodriguez et al. 2007, Pereira *et al.* 2010). Hence, management actions to recover endanger small cats also require more rigorous practices of guard dogs to avoid another threat rising.

Traditional management of plantation implies control of potential competitors around each seedling at the initial stages. Expanding this procedure to a belt of 200 meters in plantations facing houses permanently, might be possible to reduce the conflict with little or no reduction in production, following good practices standards regarding vegetation control (e.g. Katto 2009). Nevertheless, the management of understory in plantations to prevent the interaction between kodkod and housing areas is inapplicable in areas where native forests are adjacent to households, which is the case of Ramadilla in our analysis.

The selection between two similar management measures requires knowledge about costs. The material to build coops to all households in the area (131 houses), with a dimension of 7.5 square meters, have a market value of US$ 14,425. On the other hand, the areas buffer of 200 meter in exotic plantations facing households reach a size of 891 ha, and the pruning of an hectare of understory have an value around US$ 128 (Ramos 2006), so the management of understory to prevent the interaction between kodkod and housing areas has a total value to US$ 114,050. This estimate is conservative as it considers only one event of pruning which might not be the case as plantations stands for over 12 years. Therefore, in economic terms, subsidizing coop construction ought to be preferred.

As shown by kodkod in central Chile, landscape and husbandry variables might be used to more accurately predict distribution of predation risk due to the recovery of the carnivore populations and select accurate spatially explicit management actions to avoid or reduce human-carnivore conflict. In fact, managing distance of domestic animals to forests or plantations and the difficulty of carnivores to attack domestic animals, trough the management of understory and the use of fences, might prevent and avoid raids that otherwise could happen if our conservation strategies to recover endangered carnivore populations are successful.

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APPENDIX 2.

CARACTERIZACIÓN DEL MANEJO DE AVES DE CORRAL

Financiamiento:	Fondecyt 1095046	
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Estoy de acuerdo en responder este cuestionario. Declaro que lo hago voluntariamente, y que se me ha proporcionado toda la información necesaria para entender los objetivos y alcances de este estudio

Nombre: ______________________ Lugar: ______________

Firma: ______________________ Fecha: ______________

DATOS DEL ENCUESTADO: Género M F Edad _____
Profesión u ocupación____________________ Tiempo de residencia________
Número de personas en la casa _______ Número de personas que trabajan ________
Ingresos familiares (miles de pesos) 0-100-200-300-400-500-600-700-800-más

PRESENCIA DE ANIMALES

1.- Usted recibirá seis fotografías numeradas de animales de Chile. Por favor diga el nombre de cada animal que reconozca. Si no lo conoce, no importa.
1____________________2____________________3____________________
4____________________5____________________6____________________

2.- ¿ha visto alguno de estos animales? SI NO
¿cuáles? (ind #) *¿dónde? ¿a que distancia?* *¿cuántas veces este año?*

AVES DE CORRAL

3.- ¿tiene gallinas? SI NO ¿tiene pavos? SI NO
¿cuántas gallinas tiene? ________ ¿cuántos pavos tiene? ________

4.- ¿se le pierden gallinas? SI NO ¿se le pierden pavos? SI NO
¿cuál ave se pierde? ¿por qué se pierde? *¿cómo se dio cuenta?*

5.- Si usted o sus vecinos perdieran gallinas o pavos por animales silvestres
¿qué le gustaría hacer? ____

____
____
____

6.- ¿usted lo hace? ____
____
____

7.- ¿tiene gallineros?
SI ¿cuándo encierra las gallinas? de día ___ de noche ___ siempre ___
¿cuándo encierra los pavos? de día ___ de noche ___ siempre ___
NO ¿dónde permanecen de día: ¿las gallinas______________ ¿los pavos? ____________
¿dónde permanecen de noche: ¿las gallinas______________ ¿los pavos? ____________

8._ si las deja sueltas, donde comen ¿las gallinas?____________ ¿los pavos?___________
hasta donde se mueven ¿las gallinas? ______________ ¿los pavos?_____________

9.- ¿cuántos perros tiene? ________ ¿deja sueltos a los perros? _________
¿sus perros van al bosque? SI NO ¿ha visto perros del vecino en su casa? SI NO

10.- ¿cuántos gatos tiene? ______ ¿salen los gatos de la casa?__________
¿sus gatos van al bosque? SI NO ¿ha visto gatos del vecino en su casa? SI NO

CARACTERÍSTICAS DEL AMBIENTE

11.- ¿puedo recorrer los alrededores de su casa para tomar unas mediciones de la vegetación, los gallineros y los lugares donde vio animales?

Objeto *Geoposición o distancia a la casa*
Casa ____
Gallinero o dormidero ____
Bosques ____
Plantaciones ____
Cultivos ____

Porcentaje de cobertura bajo bosques o plantaciones a 0,5 y 2 metros
Bosques ____
Plantaciones ____

____

animales vistos *Geoposición o distancia a la casa*

____
____
____
____
____
____
____
____
____
____

ANEXO 1. CARACTERIZACIÓN DEL MANEJO DE AVES DE CORRAL

INFORMACIÓN A ENTREGAR VERBALMENTE A CADA POTENCIAL ENTREVISTADO ANTES DE REALIZAR LA ENCUESTA

Mi nombre es Robert Márquez. Somos investigadores de la Universidad de Chile y estamos realizando una investigación para conocer si las características del paisaje y del manejo de aves de corral pueden afectar la pérdida de aves de corral por diferentes causas.

El proyecto se llama "Plantaciones forestales como hábitat de fauna" y es financiado por el Fondo Nacional de Desarrollo Científico y Tecnológico mediante su proyecto Fondecyt 1095046. Los nombres y números de teléfono de los investigadores responsables de este proyecto, así como de los comités de ética que aprobaron esta encuesta aparecen en el encabezado de la encuesta en caso que usted los requiera.

Por medio de esta encuesta nos interesa conocer si reconoce un grupo de animales y dónde los ha visto. Así mismo, nos interesa conocer si tiene aves de corral y algunos aspectos del manejo que da a estos. Finalmente, nos interesa medir algunas características de la vegetación, los gallineros y los lugares donde vio animales que reconoció.

La información que usted nos entregue será usada exclusivamente en este estudio, sin ningún costo, riesgo o beneficio para usted o los investigadores. La información será manejada confidencialmente y el resultado del análisis de la información será publicado en una revista científica, sin revelar los nombres de los encuestados.

La información será almacenada en el Laboratorio de Conservación Biológica de la Facultad de Ciencias, bajo responsabilidad del Dr. Javier Simonetti y no será usada para ningún otro fin que el presente proyecto.

Si decide colaborar, le agradecemos firme su consentimiento en la hoja de respuestas. Usted puede dejar de responder una pregunta particular o la encuesta cuando lo desee sin dar explicaciones. En este caso, los datos serán almacenados pero no serán usados en el análisis. Para el estudio usaremos solamente las encuestas respondidas en su totalidad.

Esperamos que nos ayude al responder las preguntas e, independiente de su participación, le agradecemos el tiempo prestado a esta entrevista.

CONCLUSIONES GENERALES

Especies de mamíferos carnívoros implicados en conflictos están amenazadas a nivel global y local, debido a la pérdida de hábitat y la persecución por humanos. Paradójicamente, si las estrategias para recuperar carnívoros amenazados son exitosas el aumento en los conflictos provocaría la persecución de estas especies.

Planes exitosos para la recuperación de las poblaciones de carnívoros necesitan prever y evitar conflictos, y de esta manera evitar la persecución de estas especies. La depredación de animales domésticos puede preverse mediante el uso de pocas variables, por medio de prácticas de manejo que permitan ubicar al ganado en zonas distantes a las áreas silvestres y cercanas a las personas, y medidas para salvaguardar principalmente a animales domésticos jóvenes, quienes son los individuos más vulnerables, como son la presencia de perros y de cercas y el resguardo de los animales durante la noche.

Las variables del paisaje y prácticas de manejo determinadas acá son buenos descriptores de la depredación de animales domésticos por los carnívoros. Por tanto, estas deberían ser usadas para predecir con mayor exactitud la probabilidad de depredación a causa de la recuperación de las poblaciones de carnívoros y seleccionar acciones de manejo precisas, espacialmente explicitas, para evitar y reducir los conflictos entre humanos y carnívoros. De hecho, el uso de cercas y prácticas de manejo para distanciar animales domésticos del bosque o plantaciones habitadas por carnívoros prevendrían ataques que de otra manera sucederían si nuestras estrategias de conservación para recuperar poblaciones de carnívoros en peligro, como las de la güiña en Chile central, son exitosas.