UNIVERSIDAD DE CHILE
FACULTAD DE CIENCIAS AGRONOMICAS

Santiago, agosto 28 de 2014

Señor
Jorge Albiña Aguayo
Fiscal Instructor
División de Sanción y Cumplimiento
Superintendencia del Medio Ambiente
<u>Presente</u>

SUPERINTEND
DEL MEDIO
29 AGO 2014
OFICINA DE

De nuestra consideración, mediante la presente tenemos a bien entregar los antecedentes que obran en nuestro poder para ser presentados en la causa ROL N° D-012-2014 que instruye la Superintendencia del Medio Ambiente en la División de Sanción y Cumplimiento.

Atentamente,

Estación Experimental Germán Grave Silva ADMINISTRACION

Marcelo A. Orellana Reyes Administrador General Estación Experimental Agronómica Germán Greve Silva –Rinconada de Maipú	Alejandro León Stewart Ph.D. Director Ciencias Ambientales y Recursos Naturales Renovables

INTRODUCCIÓN

La Hacienda La Rinconada de Lo Espejo fue adquirida por la Universidad de Chile en el año 1933 por Decreto N° 1158 del 29 de Abril de 1933, firmándose la escritura de compraventa en la notaría Abraham del Río el 6 de Mayo de 1933 para el bien de la enseñanza durante la presidencia de don Arturo Alessandri Palma, siendo ministro de instrucción don Domingo Durán Morales y rector de la Universidad de Chile don Juvenal Hernández Jaque y Decano de la Facultad de Agronomía y Veterinaria don Germán Greve Silva y fue inscrita con fecha 10 de mayo de 1933, a fojas 1674 N° 2759, en el registro de Propiedad de Conservador de Bienes Raíces de Santiago.

La Estación Experimental Agronómica de la Facultad de Ciencias Agrarias y Forestales de la Universidad de Chile pasó a llamarse "Estación Experimental Agronómica Germán Greve Silva, Rinconada de Maipú, el 20 de Mayo de 1994, nombre con el cual se conoce actualmente. La encargada de su administración en la actualidad es la Facultad de Ciencias Agronómicas.

La Estación Experimental cuenta con aproximadamente 3.000 ha, de las cuales 1.500 ha. corresponden a cerros incluyendo la Quebrada de la plata con 800 ha; 1.250 ha corresponden a secano y 206 con riego gravitacional. (Figura 1).

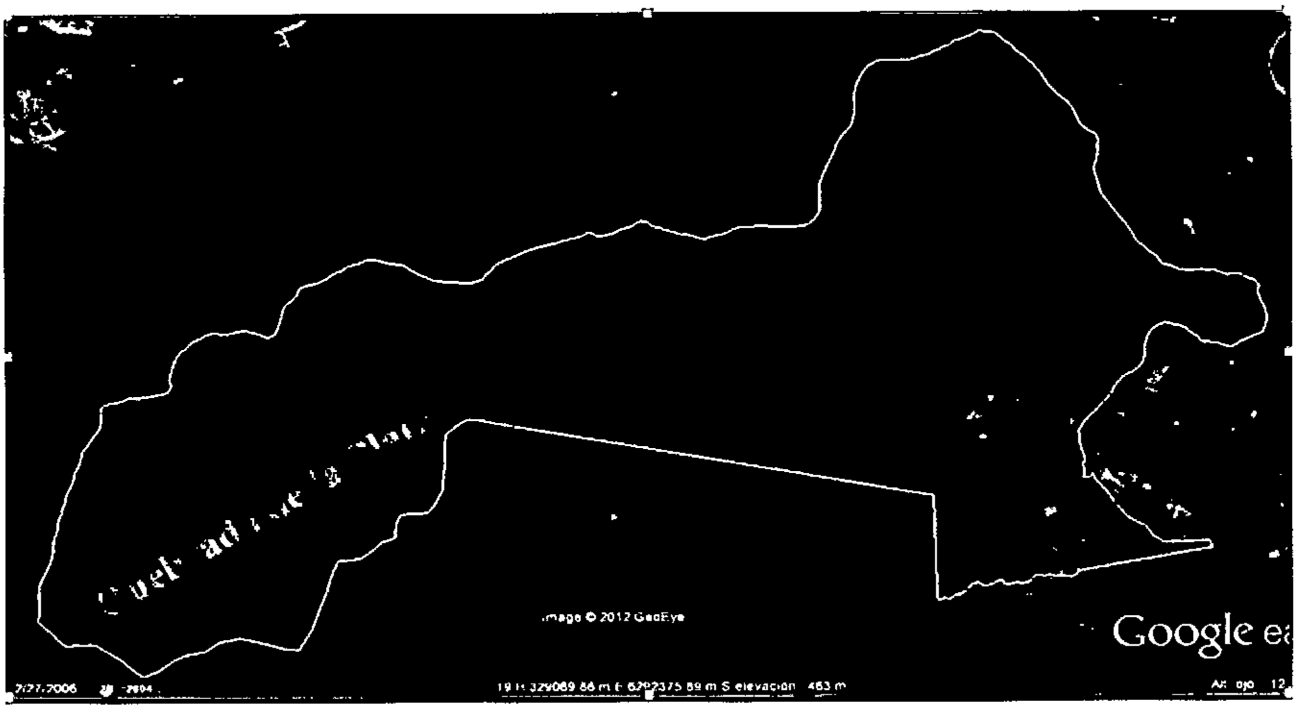


Figura 1: Límites prediales en blanco correspondiente a la totalidad de la Estación Experimental Agronómica Germán Greve Silva (3.200 ha) y en rojo el sector denominado Quebrada de la Plata (800 ha).

Ubicación Geográfica ODP:

La Quebrada de La Plata geográficamente está ubicada a 30 km al suroeste de la ciudad de Santiago, inserta en el primer cordón montañoso de la Cordillera de la Costa, en el extremo poniente de la Comuna de Maipú, Región Metropolitana de Chile. Sus coordenadas geográficas son: 33° 29' 26 Latitud Sur y 70° 53' 15" Longitud Oeste. El cordón norte limita con la cuesta Lo Prado y el cordón sur con la cuesta Barriga, mientras que por el oeste limita con la Comuna de Curacaví. (Figura 2).

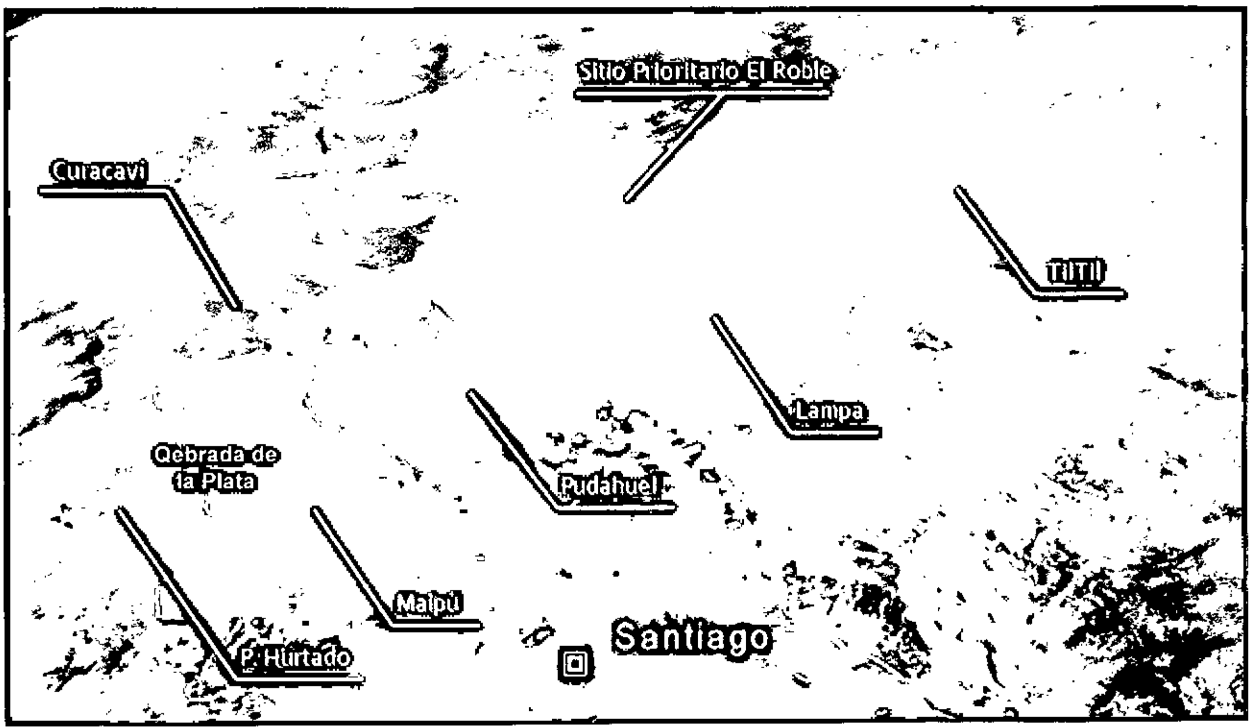


Figura 2: Límites territoriales del Sitio prioritario El Roble N° 2 y Quebrada de La Plata.
(Fuente: Línea Base del Departamento de Recursos Naturales y Ordenamiento Territorial de CONAMA RM, 2006)

Características Ecosistémicas de la QDP:

La Quebrada de La Plata está dentro de uno de los 34 hot spots de la biodiversidad del mundo, con cerca del 1% de la biodiversidad mundial. En el caso de Chile, se trata del Bosque Esclerófilo, que concentra más de 1.500 especies de flora y fauna endémicas. La mayoría de estas especies han sido catalogadas por la Unión Internacional para la Conservación de la Naturaleza (UICN) en su Lista Roja como 'vulnerables' y 'en peligro de extinción'.

Para ello se ha adoptado la definición de área protegida del Convenio sobre Diversidad Biológica (en adelante "el Convenio", o CBD por su sigla en inglés), del cual Chile forma parte desde 1994. El Convenio establece que la conservación in situ se entiende como: "la conservación de los ecosistemas y los hábitats naturales y el mantenimiento y recuperación de poblaciones viables que Chile ratificó el Convenio sobre la Diversidad Biológica (www.cdb.int), el 9 de Septiembre de 1994 mediante Decreto Supremo N°1963 del Ministerio de Relaciones Exteriores, el que fue publicado en el Diario Oficial con fecha 6 de Mayo de 1995 (Sierralta et al., 2011).

Por otra parte, en el marco de la Estrategia para la Conservación de la Biodiversidad de la Región Metropolitana de Santiago, la Comisión Nacional del Medio Ambiente (CONAMA) en 2004 propuso 27 zonas como 'sitios prioritarios' para la conservación y ratificado por oficio ordinario N° 100143 del 15 de noviembre de 2010 por el SEA, ampliándose a 64 los sitios prioritarios para efectos del SEIA. Uno de ellos es el sitio denominado "El Roble", que incluye la Quebrada de la Plata, que corresponde al acceso sur del Sitio (Figura 2). También la Quebrada de La Plata está catalogada, en el Plan Regulador Metropolitano de Santiago (PRMS), como 'Zona de Preservación Ecológica' (PRMS-92-1.A.)

Finalmente, desde 1933 la Quebrada de la Plata ha sido un laboratorio natural para el estudio e investigaciones científicas de alumnos de pre y posgrado y académicos de diferentes universidades del país, que guardan en memorias, tesis y publicaciones (muchas de ellas indexadas), tanto nacionales como internacionales, gran parte del conocimiento de la biodiversidad representativa de la vertiente oriental de la Cordillera de la Costa.

Características Geomorfológicas de la QDP:

La Quebrada de La Plata es de topografía abrupta, aunque es posible encontrar algunos sectores de pequeñas dimensiones relativamente planos. Gran parte del área presenta un relieve muy escarpado, conformado por cordones de una altura media de 450 m y una garganta de apreciable profundidad, en cuyo fondo se juntan las laderas de los cerros en forma de V, encontrándose a menudo pendientes entre un 50 y 70% (Fernández y Seguel, 1947). La mayoría de las cumbres de la zona presentan formas suaves y redondeadas. Sin embargo es posible encontrar, en algunos cerros ubicados en la parte baja de la Quebrada y en la ladera de exposición norte, cumbres que presentan un estado muy avanzado de denudación, con grandes afloramientos rocosos de aspecto dentado (Fernández y Seguel, 1947). Las más altas cumbres de la cuenca corresponden a los cerros "Morros del Fraile" con 1.123 m.s.n.m. y "Las Buitreras" con 1.085 m.s.n.m. (Schlegel, 1963). Debido a la poca altura que alcanzan las cumbres, no es común que en los meses de invierno éstas se encuentren nevadas. (Figura 3).

El suelo de la Quebrada de la Plata es de formación coluvial y de origen granítico. Presenta texturas franco-limosas a franco-arcillosas con gravas, limitando con una capa compacta (Schlegel, 1963). Las lomas presentan un estado muy avanzado de denudación, aflorando en muchos puntos, la roca fundamental completamente estéril; en los faldeos se observa la existencia de arenilla y arena junto al limo; en la base de los cerros la arcilla se agrega a los demás constituyentes del suelo de los lomajes (López, 2000). El suelo de las formaciones boscosas posee un horizonte A_{00} abundante en detritus orgánico, con acumulación de materia orgánica y presencia de abundantes raíces gruesas y delgadas de los árboles (Schlegel, 1963).

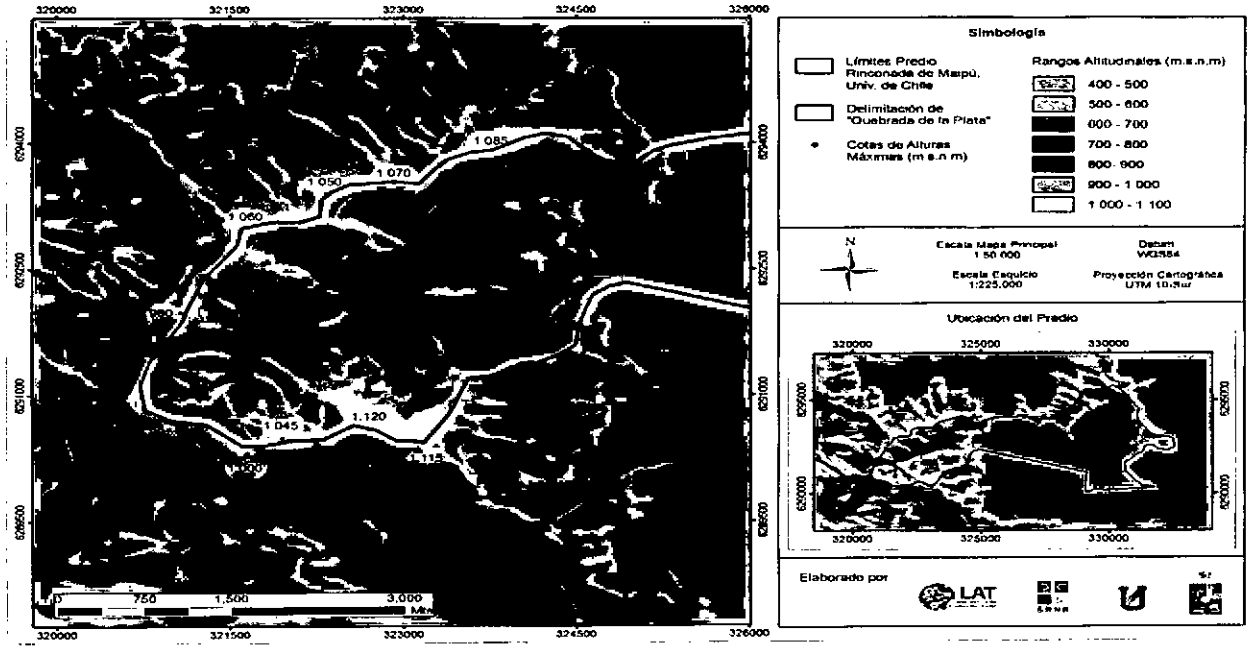


Figura 3: Alturas relevantes de la Quebrada de la Plata, en cuyo fondo se juntan las laderas de los cerros en forma de V.

Vegetación del sector Quebrada de la Plata:

En el sector Quebrada de la Plata, en el extremo sur del sitio prioritario El Roble, se identifican 11 agrupaciones vegetacionales diferenciadas en cuanto a su estructura, especies dominantes y ambiente en el que se desarrollan (Tapia 2005). Estas agrupaciones corresponden a Puya berteroniana-Echinopsis chiloensis, donde la primera es la especie más representativa, en la que también se desarrollan Proustia cinerea y Colliguaja odorifera en el nivel arbustivo; Baccharis linearis; Cryptocarya alba, donde también frecuentemente se presentan ejemplares de Quillaja saponaria; Quillaja saponaria-Lithraea caustica, donde la segunda especie se presenta como matorrales, en los que se puede encontrar ejemplares de Retanilla trinervia y Acacia caven; Peumus boldus-Lithraea caustica, donde estas dos son las especies más representativas, acompañadas por Quillaja saponaria, Colliguaja odorifera y Retanilla trinervia; Acacia caven, desarrollándose en los sectores más bajos, en laderas de exposición norte; Flourensia thurifera, a veces acompañada por la presencia de Puya berteroniana cuando se presentan suculentas en la agrupación; Proustia cinerea, que suele estar acompañada por Colliguaja odorifera, Baccharis paniculata o Retanilla trinervia; Proustia cuneifolia; Retanilla trinervia-Colliguaja odorifera; y Senna candolleana, donde aisladamente se puede observar individuos de Retanilla trinervia y Colliguaja odorifera. (Tabla 1).

Tabla 1: Especies de plantas registradas en Quebrada de La Plata

Familia	Nombre científico	Nombre común	Origen
Fabaceae	*Acacia caven*	Espino	Nativa
Elaeocarpaceae	*Aristotelia chilensis*	Maqui	Nativa
Poaceae	*Avena barbata*	Teatina	Alóctona
Asteraceae	*Baccharis linearis*	Romerillo	Nativa
Asteraceae	*Baccharis paniculata*	Falso romerillo	Nativa
Euphorbiaceae	*Colliguaja odorifera*	Colliguay	Nativa
Lauraceae	*Cryptocarya alba*	Peumo	Nativa
Cactaceae	*Echinopsis chiloensis*	Quisco	Nativa
Geraniaceae	*Erodium cicutarium*	Yerba del platero	Alóctona
Saxifragaceae	*Escallonia illinita*	Barraco	Nativa
Asteraceae	*Eupatorium salvia*		Nativa
Asteraceae	*Flourensia thurifera*	Incienso	Endémica
Rosaceae	*Kageneckia oblonga*	Huallo, Boyén	Endémica
Anacardiaceae	*Lithrea caustica*	Litre	Nativa
Celastraceae	*Maytenus boaria*	Maitén	Nativa
Monimiaceae	*Peumus boldus*	Boldo	Nativa
Asteraceae	*Podanthus mitiqui*	Mitiqui	Nativa
Asteraceae	*Proustia cuneifolia*	Huañil blanco	Endémica
Bromeliaceae	*Puya berteroniana*	Chagual	Nativa
Rosaceae	*Quillaja saponaria*	Quillay	Nativa
Rhamnaceae	*Retanilla trinervis*	Tebo	Nativa
Asteraceae	*Senecio adenotrichius*	Senecio	Nativa
Fabaceae	*Senna candolleana*	Quebracho	Nativa

Fuente: Línea Base del Departamento de Recursos Naturales y Ordenamiento Territorial de CONAMA RM, 2006

Respecto de las características biogeográficas, de acuerdo con Gajardo (1994), la formación vegetacional de la Quebrada de la Plata corresponde a la del Matorral Espinoso del Secano Costero. La vegetación está compuesta por comunidades de matorrales y bosques esclerófilos que en la Región han sido alteradas fuertemente en el pasado y actualmente amenazadas por la expansión urbana (Tapia, 2005). (Figura 4).

La Quebrada de la Plata presenta una alta diversidad en la vegetación, ya que es posible encontrar un estrato herbáceo, arbustivo y arbóreo, además de especies suculentas. Los principales tipos de vegetación presentes en la Quebrada de la Plata corresponden a bosque esclerófilo y matorral espinoso. En el área existen un total de 315 taxas, de las cuales 245 corresponden a especies nativas (77,8%) y 70 a especies exóticas (22,2%). Del total de especies presentes 254 especies (80,6%) son herbáceas, 47 (14,9%) son arbustivas y 5 (1,6%) son arbóreas. Las familias que reúnen mayor número de especies son: Asteraceae (18,7%), Poaceae (9,2%), Fabaceae (6,7%), Scrophulariaceae (5,7%) y Apiaceae (4,4%) (Schlegel, 1963).

De acuerdo con Gallardo (1993), la ladera de exposición norte presenta mayoritariamente especies arbustivas como: colliguay (Colliguaya odorifera) y tevo (Trevoa trinervis); y por vegetación arbórea bien desarrollada en su parte media, y a medida que se asciende por la ladera de exposición sur, la vegetación se presenta cada vez más vigorosa y densa (Schlegel, 1963). (Figura 4).

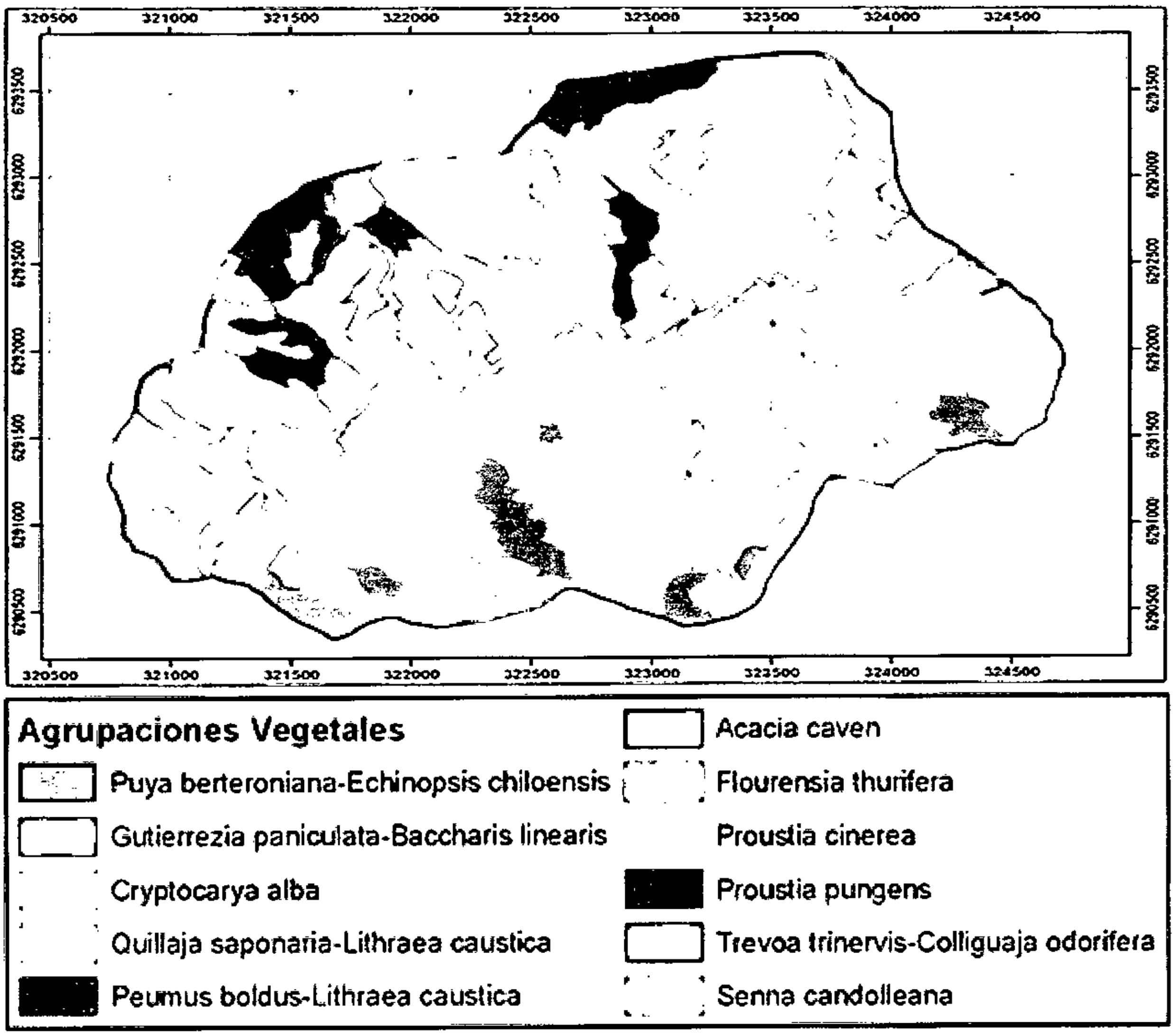


Figura 4: Distribución Geográfica de las comunidades Vegetales existentes en la Quebrada de la Plata (Fuente: Tapia, D. 2005).

La diversidad cromática de la vegetación se hace más evidente en los meses primaverales, debido a los variados colores aportados por la floración de muchas especies. Las laderas de exposición Norte y exposición Sur presentan un marcado contraste, dado por la composición de especies y, por tanto, los distintos tonos cromáticos de la vegetación. Por lo anterior se podría decir que, la mayor belleza escénica del paisaje se evidencia durante la primavera.

Características climáticas de la QDP:

La Quebrada de La Plata posee un clima de tipo mediterráneo semiárido, con un promedio de temperaturas mínimas y máximas de 7° C y 23° C respectivamente, siendo julio el mes más frío y enero el más cálido. La pluviosidad es de 330 mm y la humedad relativa de un 67% (Di Castri, 1975). Las precipitaciones se concentran en los meses de junio a septiembre, presentando un período seco de 8 meses. El área presenta 231 días libres de heladas, con un promedio de 11 heladas por año. La estacionalidad térmica es moderada, propia de climas templados (Santibáñez et al., 1990).

Predominan los vientos alisios provenientes del suroeste, los cuales son más intensos en verano. Sólo en invierno sopla el viento noroeste el que provoca las precipitaciones. En invierno y primavera son frecuentes las lengüetas de la nubosidad costera en las partes altas, sobre todo en el final oeste de la cuenca. Este fenómeno aumenta por su condensación la cantidad de precipitaciones y/o evita la rápida pérdida de humedad del suelo y de la vegetación. Las lengüetas de niebla que se presentan en las partes altas de la sección superior de la cuenca, son consecuencia del efecto directo de los vientos provenientes de la costa (Schlegel, 1963).

Disponibilidad de Agua en QDP:

En cuanto a la disponibilidad de agua, la Quebrada de La Plata se surte sólo mediante escurrimientos estacionales. El escurrimiento máximo se produce en los meses invernales, y se hace prácticamente nulo en los meses del período estival, lo que limita el flujo hídrico del área (López *et al.*, 1998). No obstante, a lo largo de la Quebrada, es común que se formen pequeñas pozas o pozones, debido a que las piedras y rocas existentes en el fondo de la Quebrada, contribuyen a que el agua proveniente de las precipitaciones se acumule. Aún en los meses estivales se puede observar agua en algunas pozas, las que presumiblemente son alimentadas por pequeñas vertientes. Cabe destacar la existencia de una ligera caída de agua denominada comúnmente por los lugareños como 'La Cascada'. La cantidad de agua que lleva la Quebrada está en directa relación con el nivel de precipitaciones caídas durante el invierno.

Valores asociados a la Quebrada de La Plata:

Ecoturísticos: El nombre de la Quebrada de la Plata se atribuye, por relatos de lugareños, a los acontecimientos acaecidos inmediatamente después de la Batalla de Maipú, el 5 de abril de 1818. Luego de que Los Patriotas derrotaran a Los Realistas, estos huyeron. En su huída, una unidad se perdió, internándose por la Quebrada. Para hacer más liviana su carga, enterraron allí algunos objetos de valor. De ahí el nombre que hoy lleva el lugar. Una segunda interpretación obedece a la presencia de rocas con inserciones de cariz plateado que resplandecen a la luz del sol. También es posible encontrar ornamentos o utensilios mapuches dada su utilización como lugar de tránsito de las comunidades. Dadas las características de la Quebrada, se cree que habría servido como lugar de vigía y puente entre los sectores de Curacaví, María Pinto y Padre Hurtado con el valle de Santiago, utilizado por las huestes de Machimalonco en el asalto (11 de Septiembre de 1541) a la recién fundada ciudad de Santiago.

Senderos y Miradores: Existe un Sendero principal, de aproximadamente 4,5 kms. de extensión y 2 mts. de ancho, supuestamente utilizado para la extracción de minerales a inicios del siglo XX. Sirve para acceder al bosque de peumos y más arriba a un bosque de encinas. Desde este sendero principal se llega a los dos miradores naturales hacia el valle de Maipú y el valle de Curacaví. Destacan además el Sendero de la Quebrada de los Maquis y el Sendero del Minero, que corresponden a huellas de bajada a la Quebrada principal.

Antigua actividad minera: En el sector conocido como 'Hornos Caleros' existen construcciones de piedra de 7 metros de altura, que presentan diferentes niveles de conservación. Su origen es de fines del siglo XIX, y fueron construidos para fundir mineral de caliza que se extraía del lugar. Otra historia que se escucha de lugareños, es que fueron construidos por los incas para fundir plata.

La Quebrada de la Plata, dada su topografía, al clima mediterráneo, su ubicación, además del grado de aislamiento que otorgan sus características orográficas, posee una flora y fauna representativa de la zona mediterránea de Chile, con una alta riqueza (número de especies) y abundancia en su fauna (número de individuos), incluyendo endemismo en especies de aves y mamíferos. Este componente biótico, presenta dependiendo de la especie, variaciones en su ciclo anual, relacionado a la alta estacionalidad climática (Di Castri & Hajek 1976). Reflejo de esta particular biodiversidad es la intensa realización de investigación y docencia que se desarrolla este lugar (ver anexo N° investigaciones).

La Quebrada de La Plata antes de las actividades mineras presentaba un abundante desarrollo de la vegetación sin intervención de senderos que eran ocupados por los alumnos que salían a terreno en cursos de ecología, ecología forestal, recursos naturales renovables, botánica etc. Así como también representantes de viveros para la recolección de semillas de guayacanes y otras para reproducirlos en condiciones controladas y luego ser llevados a terreno para la renovación.

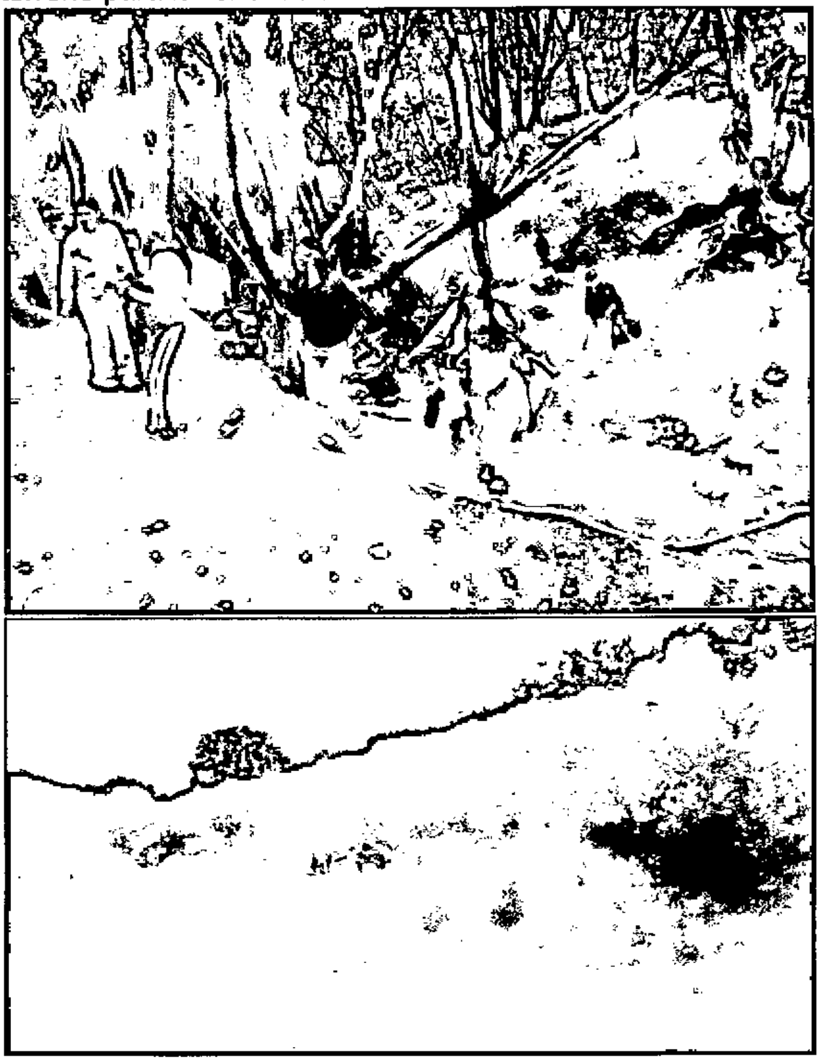
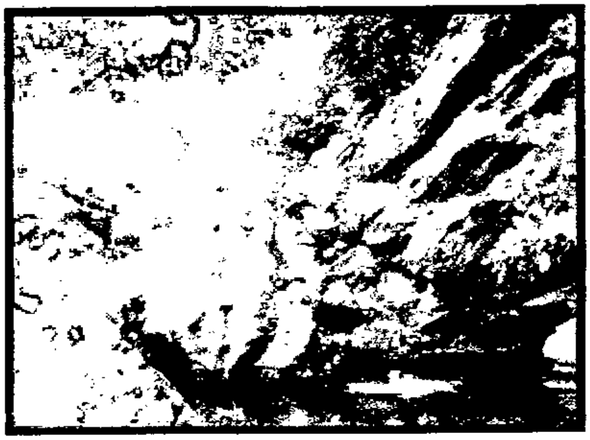


Figura 5: Desarrollo de la vegetación y usos de sus senderos en Quebrada de La Plata

ATRACTIVO FOCAL NATURAL: LA CASCADA

Ubicación: Se ubica a 1.200 m del inicio del Sendero de La Plata, en el lecho de la Quebrada, a 580 m.s.n.m. No es visible desde el Sendero, ya que se encuentra escondida por la exuberante vegetación que allí se desarrolla. A modo de referencia, el lugar se encuentra a escasos metros de la primera desviación que presenta el Sendero, comúnmente denominada como "vuelta alta".

Coordenadas UTM: 323.396 Este y 6.292.248 Norte



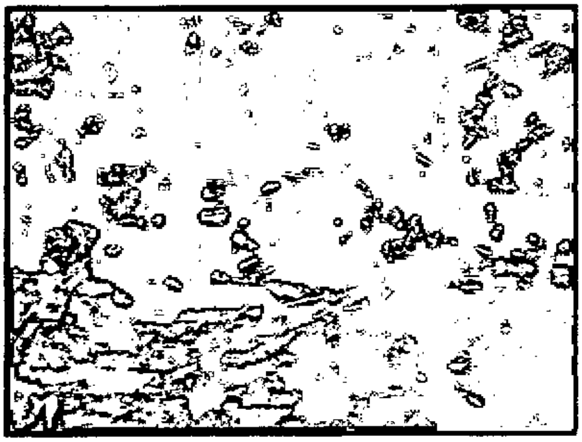
Descripción general del lugar: Primer atractivo focal desde el ingreso al Sendero de La Plata y el único atractivo ecoturístico que se podría clasificar como hidrológico. El lugar cuenta con suficiente sombra, proporcionada principalmente por individuos de peumo y litre, que hacen al sector apto para hacer un descanso en el recorrido. La mayor parte del terreno presenta una topografía abrupta. Al internarse por las huellas se llega a pozas que permiten que el agua se acumule y que, en determinadas ocasiones, se conserve hasta la estación estival, apreciándose una hermosa caída de agua comúnmente llamada por los lugareños como "La Cascada". En las pozas y sus alrededores habita el sapo de rulo y, por todo el lugar, es posible observar una variada avifauna. Sobre las rocas que conforman la caída de agua crecen chaguales y quiscos. En el lugar es frecuente encontrar restos de fogatas y basura, lo cual delata la constante presencia de personas.

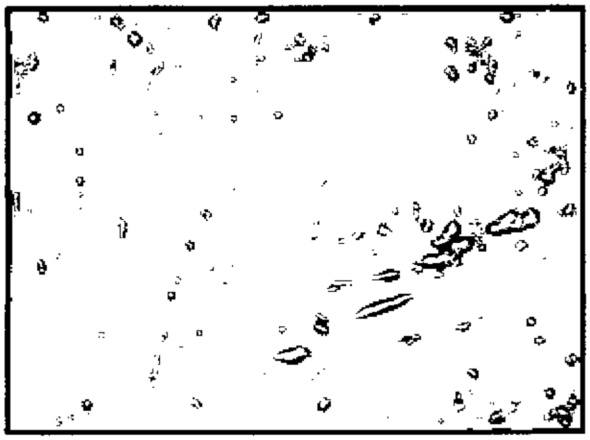
Requerimiento de infraestructura: Habilitar una huella que permita que el visitante se aproxime a la caída de agua y recorra el sector sin causar deterioros en la vegetación y daños en las pozas donde habita sapo de rulo. Se propone agrandar y profundizar las pozas, para que se acumule una mayor cantidad de agua. Instalar señalética, un basurero y asientos rústicos (tipo troncos), para que los visitantes realicen un pequeño descanso en su recorrido.

ATRACTIVO FOCAL NATURAL: EL BOSQUE

Ubicación: Sector ubicado a una distancia aproximada de 2.500 m del inicio del Sendero de La Plata, a un costado de éste, en la ladera de exposición sur, junto al cauce de la Quebrada, a 680 m.s.n.m.

Coordenadas UTM: 322.494 Este y 6.291.951 Norte





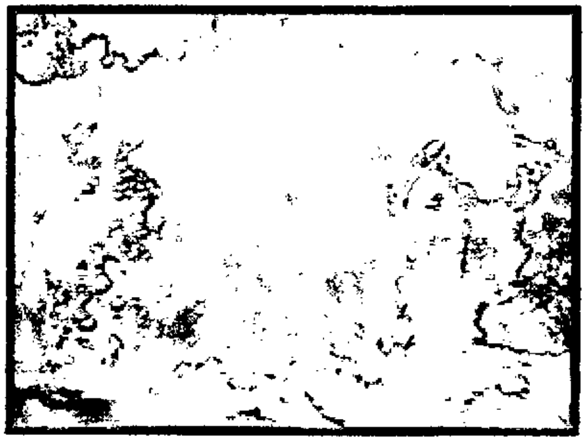
Descripción del lugar: Corresponde a un sector dominado por especies vegetales arbóreas típicas del bosque esclerofilo de la Zona Central, distinguiéndose por su altura el peumo y el quillay. Al internarse entre los árboles, se puede apreciar que en el lugar se genera un microclima que difiere al del resto del área, ya que los árboles presentes otorgan un amplio sector sombreado. En invierno y primavera, el cauce de la Quebrada presenta escurrimiento, cuya magnitud esta directamente relacionada con el nivel de las precipitaciones; en la estación seca, por lo general el agua no escurre, lo cual genera que el agua se acumule en charcos. El terreno presenta pendientes moderadas que hacen posible seguir una huella, generada naturalmente entre los árboles, cuya extensión bordea los 100 m. El lugar es frecuentemente visitado por aves pertenecientes al orden passeriformes, tales como el colilarga y el rayadito, entre otras. Frente a este sector se encuentra un pique minero abandonado.

Requerimiento de infraestructura: Habilitación de un sendero interpretativo y de dos pasarelas o puentes colgantes que permitan atravesar el lecho de la Quebrada de un lado a otro, de manera tal de evitar accidentes y la erosión del terreno por el constante paso de los visitantes. A fin de evitar la destrucción del mantillo, se sugiere que el circuito se construya a unos pocos centímetros sobre el nivel del suelo. Instalación de señalética que contenga información referente a las especies arbóreas allí presentes y breves reseñas que contribuyan a educar y sensibilizar al visitante acerca de la importancia de conservar este tipo de ecosistemas tan escasos y amenazados en la actualidad.

ATRACTIVO FOCAL HISTÓRICO: HORNOS CALEROS

Ubicación: Sector ubicado en la parte alta de la Quebrada, a unos 3.000 m del inicio del Sendero de La Plata, a una altura aproximada de 750 m.s.n.m. Para llegar al lugar se debe tomar un desvío hacia el norte que presenta el Sendero.

Coordenadas UTM: 321747 Este y 6291760 Norte



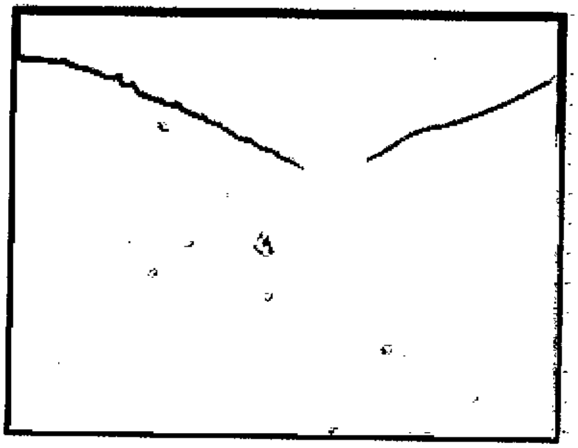
Descripción del lugar: Sector que se destaca por la presencia de tres hornos de piedra, el mayor de ellos alcanza una altura de 7 m, que probablemente fueron construidos hace más de 100 años y en ellos se fundía mineral de caliza. Dos caminos permiten observar los hornos desde su base y su parte superior. Desde este sector se puede acceder al Sendero Quebrada de los Maquis, que recorre la quebrada del mismo nombre, ubicada en la ladera de exposición sur. La vegetación presente en el lugar está representada por especies típicas del bosque esclerofilo como el litre, el peumo, el quillay y el espino, entre otras. La fauna posible de observar está representada principalmente por aves. Desde este sector se obtiene una excelente vista panorámica de ambas laderas que conforman la Quebrada. Si se continúa por el Sendero Quebrada de los Maquis se puede llegar hasta la parte más alta de la cuenca.

Requerimiento de infraestructura: Instalación de señalética con indicaciones prácticas para que el visitante pueda escoger qué sendero continuar recorriendo. Habilitar una huella que posibilite hacer un recorrido corto por la base de la Quebrada de los Maquis y un sector de pequeñas dimensiones provisto de asientos rústicos. Instalación de un letrero que contenga una breve reseña histórica de los hornos.

ATRACTIVO FOCAL NATURAL: MIRADOR VALLE DE MAIPÚ

Ubicación: Sector ubicado a un costado del Sendero de La Plata, a 1.500 m aproximadamente del inicio de éste y a menos de 500 m de distancia del sector "La Cascada". Se sitúa frente a una pequeña quebrada lateral denominada "Quebrada Vuelta Alta", a 600 m.s.n.m.

Coordenadas UTM: 323.307 Este y 6.292.210 Norte



Descripción del lugar: Corresponde a un afloramiento rocoso ubicado en la ladera de exposición norte, frecuentemente utilizado como mirador natural, ya que desde este lugar se puede obtener una maravillosa vista panorámica de gran parte de la Quebrada de la Plata y del valle de Maipú. Es un sector muy expuesto a las condiciones meteorológicas, ya que carece de vegetación que proteja de los rayos solares y de las precipitaciones. El terreno circundante presenta abruptas pendientes, encontrándose a un costado del Sendero un profundo acantilado y al otro una escarpada ladera. Las especies vegetales más próximas son chaguales, quiscos y espinos. Desde este punto se puede apreciar la marcada diferencia de vegetación que presentan las laderas de exposición norte y sur. La fauna más representativa y posible observar en este lugar son lagartijas del género Liolaemus y algunas aves como la loica, el pitío y la codorniz.

Requerimiento de infraestructura: Construcción de un mirador rústico, de preferencia de piedra, de tal manera que se conserven las características rocosas del sector. El mirador debe representar un lugar seguro y confortable, que le permita al visitante realizar una detención en su recorrido, disfrutar de la belleza escénica del paisaje, observar la flora y fauna, y tomar algunas fotografías. Debido a lo expuesto del sector, se sugiere que el mirador posea un techo o toldo. El lugar debe contar con una adecuada señalización y con un basurero.

ATRACTIVO FOCAL NATURAL: MIRADOR VALLE DE CURACAVÍ

Ubicación: Sector ubicado en el límite predial a 875 m.s.m.n., a una distancia aproximada de 4.500 m del inicio del Sendero de La Plata, correspondiendo al último atractivo y fin del Sendero.

Coordenadas UTM: 320.789 Este y 6.291.406 Norte

Descripción del Lugar: Es el punto más alto en el recorrido del Sendero de La Plata, situado en el límite provincial de Santiago y Melipilla. El lugar destaca por presentar una excelente visión panorámica de los valles aledaños a la Quebrada. Hacia el oeste se observan los valles agrícolas de Curacaví y Maria Pinto, mientras que hacia el este se observan los valles de Maipú y Santiago, además de los cordones montañosos que atraviesan la depresión intermedia y el macizo andino. Las pendientes del terreno son moderadas y abruptas. En este sector la vegetación arbórea no es muy abundante, representada por algunos quillayes, predominan las arbustivas como el colliguay, el espino y el tevo. Es común observar águilas volando cerca de las cumbres de los cerros, también es posible divisar al ratón cola de pincel o degú y una variada avifauna. En el lugar existen rasgos de degradación del suelo causado principalmente por el continuo paso de motos por las laderas de los cerros, las que logran ingresar debido a los serios daños que presenta el cercado en este punto. A poca distancia se sitúan grandes torres del tendido eléctrico.

Requerimiento de infraestructura: Se precisa la construcción de un mirador en altura (torre de observación), a fin de observar en toda su magnitud los valles. Por tratarse del punto más alejado del Sendero de La Plata, se requiere habilitar un sector de descanso y merienda donde los visitantes recobren fuerzas para hacer el recorrido de regreso. Instalación de señalética y un basurero. Se requiere mejorar el cercado en este punto, ya que por este sector ingresan motociclistas.

ATRACTIVO COMPLEMENTARIO NATURAL: LOS QUEBRACHOS

Ubicación: Primer sector en el trayecto del Sendero de La Plata, a unos 500 m del inicio de éste. Se ubicado en la sección baja de la cuenca, bordeando los 550 m.s.n.m., en exposición Noreste y al final de la quebrada lateral que lleva el mismo nombre.

Coordenadas UTM: 323.939 Este y 6.292.203 Norte

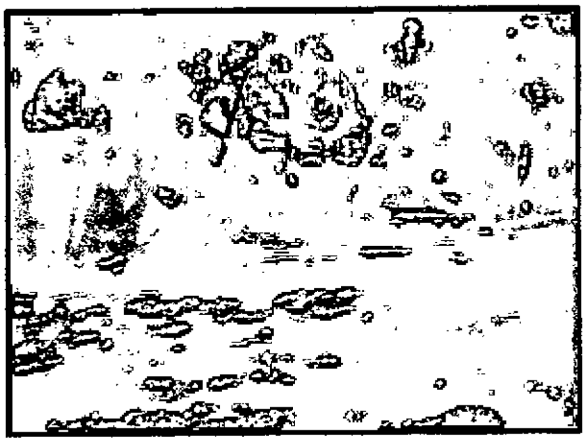
Descripción del lugar: Es un sector que presenta una pendiente media, predominado por quebrachos que no superan los 8 m de altura, los cuales proporcionan lugares sombreados en la ladera de exposición norte. También entre las especies vegetales es posible encontrar palqui, colliguay, litre, espino y tevo, entre otros. Entre la fauna que es relativamente fácil de observar se encuentran lagartijas del género Liolaemus, culebras, mariposa negra o de la oreja de zorro y diversas especies de aves, siendo las más frecuentes las loicas, tórtolas, codornices, turcas y tencas. Internándose ladera arriba se puede obtener una excelente vista de los cerros que rodean la cuenca de la Quebrada y de la ladera de exposición sur. En primavera, en las laderas menos escarpadas crecen los huillis.

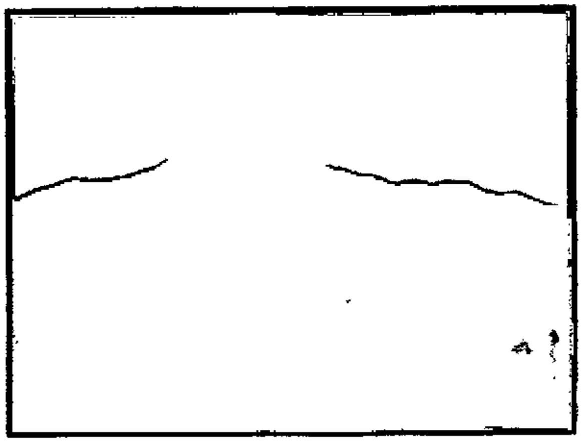
Requerimiento de infraestructura: Habilitación de un pequeño sendero o huella, que se interne por el lugar, y que conduzca a una zona de descanso a la sombra de los quebrachos, que cuente con asientos rústicos, señalética y un basurero.

ATRACTIVO COMPLEMENTARIO NATURAL: QUEBRADA DE LOS MAQUIS

Ubicación: Sector ubicado en la sección alta de la Quebrada, ladera de exposición sur, a una altura de 770 m.s.n.m. El acceso se realiza mediante el Sendero de La Plata hasta el sector de los Hornos Caleros, donde se toma el sendero lateral ubicado al norte de éstos.

Coordenadas UTM: 321.695 Este y 6.291.924 Norte





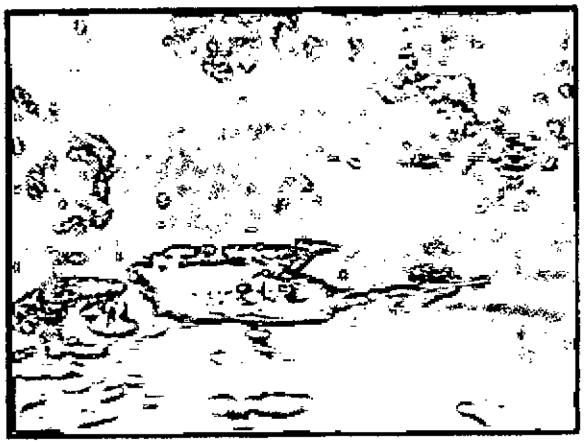
Descripción del lugar: Sendero de aproximadamente 1.3 km de longitud, que sigue el curso de una pequeña quebrada lateral, denominada "Quebrada de los Maquis". En su recorrido se pueden apreciar especies de flora típica del bosque esclerofilo de exposición sur, tales como: peumo, maqui y maiten. En la mitad del sendero se encuentra un horno en ruinas utilizado antiguamente para fundir ladrillos. En la sección final de este sendero se llega a una altura de 950 m.s.n.m., obteniéndose una excelente vista panorámica, donde se puede observar el valle de Curacaví y el yacimiento minero de Lo Aguirre. Cabe destacar que el ancho del sendero es considerablemente menor que el del Sendero de La Plata. Al llegar al final del sendero se encuentra el cerco que delimita la propiedad de la Universidad de Chile, no obstante, este se encuentra en mal estado, razón por la cual es frecuente que ingresen personas a practicar actividades que van en contra del cuidado del medio ambiente, así como "motocross" y caza furtiva.

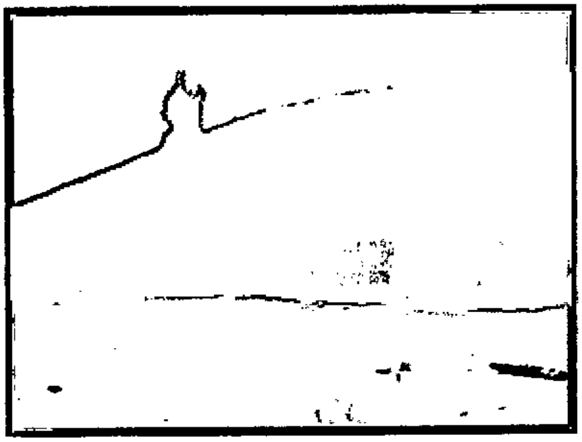
Requerimiento de Infraestructura: Realizar trabajos tendientes a mejorar y habilitar el sendero, instalar señalética informativa al inicio y al final de éste, y habilitar un sector en la parte final del sendero a modo de mirador natural, que además cuente con sectores de descanso y merienda. Reparar el cerco para evitar que ingresen personas por los accesos no autorizados.

ATRACTIVO COMPLEMENTARIO NATURAL: LAS PIRCAS

Ubicación: Este sector se encuentra en parte alta de la Quebrada, a 725 m.s.n.m., a tan sólo unos pocos metros de la segunda vuelta que presenta el Sendero de La Plata, no siendo necesario salirse del recorrido de éste.

Coordenadas UTM: 321.925 Este y 6.291.741 Norte





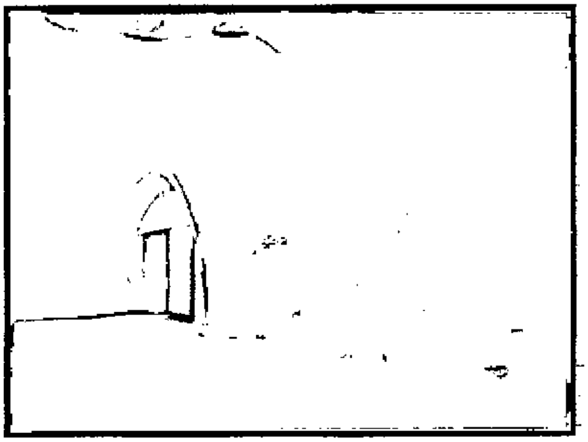
Descripción del lugar: Corresponde a uno de los pocos sectores planos que existe a lo largo del Sendero de La Plata y que además cuenta con lugares sombreados a ambos lados del camino. El nombre del sector se debe a la presencia de construcciones de piedras que reciben el nombre de pircas. Lo que hace atractivo a este sector es la belleza de sus paisajes y las características planas del terreno. En primavera el lugar se cubre de flores silvestres tales como alstroemerias y huillis. Desde este punto se puede acceder a la "Quebrada de los Maquis" internándose por huellas casi imperceptibles que recorren una pequeña porción del bosque que esta quebrada posee. Entre las especies de fauna que más frecuentemente se pueden oír u observar se encuentran la turca, el tapaculo y algunas lagartijas. A ambos lados del sendero principal se puede distinguir fácilmente la diferenciación de la vegetación existente en las laderas de exposición norte y sur.

Requerimiento de infraestructura: Construir una estación de educación e interpretación ambiental (centro interpretativo) y habilitar un sitio de merienda y descanso. La estación educativa tendría por objetivo hacer un breve resumen explicativo de lo visto en el recorrido hasta este punto, aclarando dudas y conceptos, así como también instando al visitante para que recorra la totalidad del sendero. Instalación de señalética que indique claramente el camino a tomar, el tiempo y la distancia del Sendero de La Plata y del Sendero Quebrada de los Maquis.

ATRACTIVO COMPLEMENTARIO HISTÓRICO: LOS POLVORINES

Ubicación: Sector ubicado en la Zona de Uso Público Intensivo a 500 m.s.n.m. El acceso se realiza a través del camino que conduce a la entrada principal, desde el cual se sigue por un camino pavimentado que recorre el sector.

Coordenadas UTM: 324.605 Este y 6.292.771 Norte



Descripción del lugar: Como su nombre lo indica, lo más representativo del lugar es la presencia de seis "bunkers" o polvorines que fueron construidos en la década de los 70' por las Fuerzas Armadas y que actualmente se encuentran abandonados. En la misma situación se encuentran dos casetas de vigilancia y una casa en ruinas. La sección oeste del sector limita con cerros que, en algunos casos, presentan grandes afloramientos rocosos en sus cumbres y superan los 1000 m.s.n.m. Destaca el fácil acceso y la belleza escénica otorgada por el paisaje circundante. Entre las especies de flora más características se encuentran baccharis spp, espinos, pimientos y quillayes. En los alrededores es posible observar al ratón cola de pincel o degú y varias especies de aves, siendo frecuente divisar águilas realizando planeos circulares alrededor de las más altas cumbres de los cerros aledaños. Ascendiendo unos pocos metros por alguna de las colinas se obtiene una privilegiada vista panorámica del lugar.

Requerimiento de infraestructura: Habilitación de la infraestructura de origen militar existente para fines ecoturísticos, como por ejemplo convertir las antiguas casetas de vigilancia en miradores, algunos de los polvorines como centros interpretativos, centros de información, etc. Instalación de servicios básicos, juegos infantiles de madera, sectores de picnic, señalética y basureros. Se sugiere también reforestar con especies de rápido crecimiento, tales como el pimiento, con finalidades ornamentales y para otorgar sombra.

La figura 6, muestra el primer denuncio de una actividad minera ilegal en el sector Norponiente de la Quebrada de la plata, para ello se realiza denuncio a SEREMI de medio ambiente quienes desarrollan un COF con varios organismos del Estado que tenían competencias en la materia: Sernageomín, DGA, MOP, SAG, CONAF, SECPLA Maipú y U. de Chile. Al tiempo de la fiscalización la empresa minera abandona el lugar dejando restos del campamento.

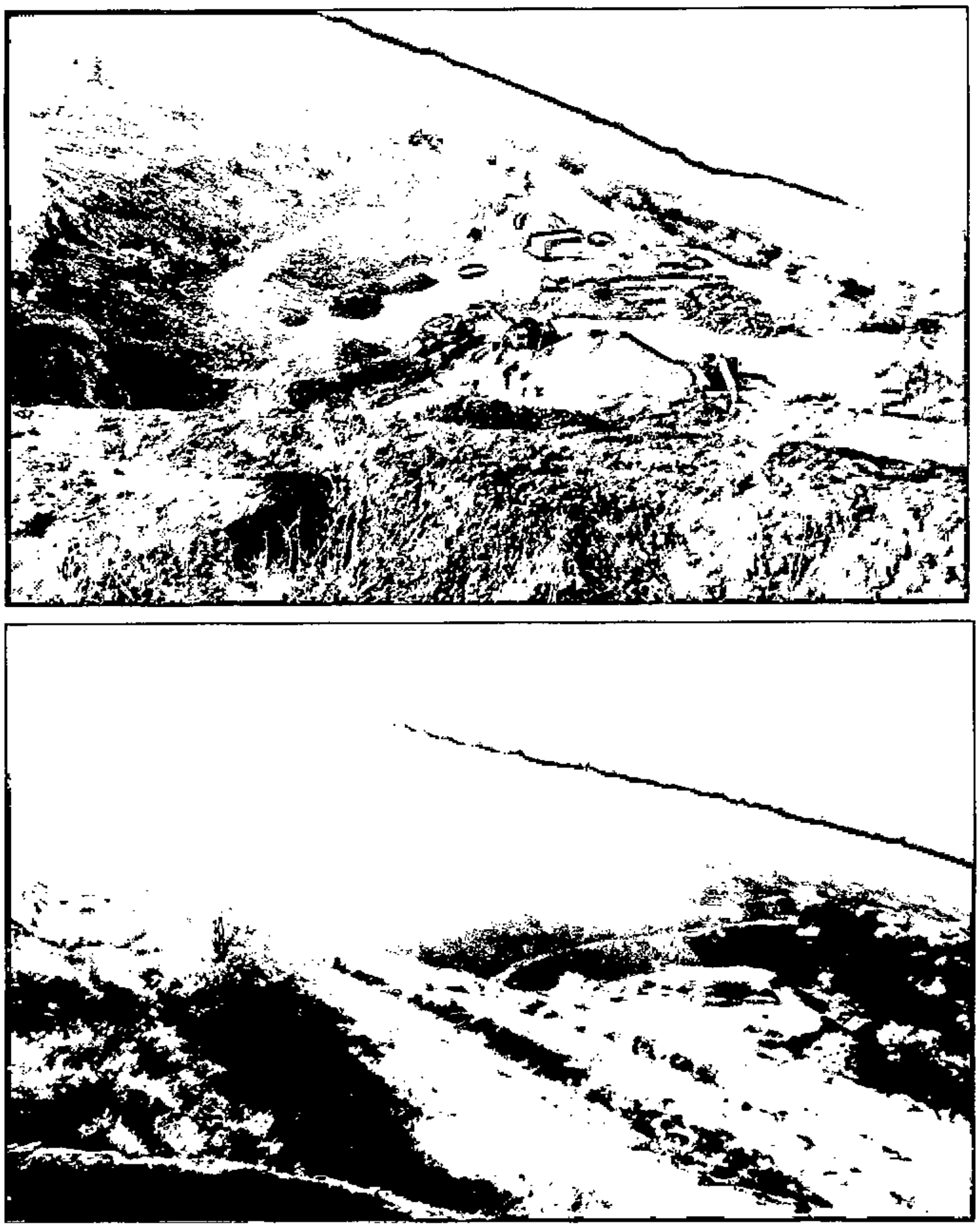


Figura 6: Actividad de la minera Española Chile Limitada en sector Norponiente de la Quebrada de La Plata, sistema de coordenadas WGS84: 322650,17 6293262,87.
Fuente: COF, realizado con organismos del Estado el 19/7/2011.

Posteriormente, la misma empresa Española Chile Limitada, ingresa a la Quebrada de La plata con dos proyectos mineros de exploración y sondaje en el corazón de la Quebrada sin presentar ningún documento ni permisos que lo acredite a realizar tal actividad.

El punto denunciado se aprecia en la Figura 6 y 7, información entregada por inspectores del SERNAGEOMIN de la ciudad de Quilpué en inspección del 3 de diciembre de 2012. En su oportunidad son paralizados por los inspectores, dado a que el nivel de daños al medio ambiente: Flora y Fauna eran evidentes. (Figura 7)

Figura 7: Punto denunciado de excavación profunda y de explotación a gran escala al interior de la Quebrad de La Plata.

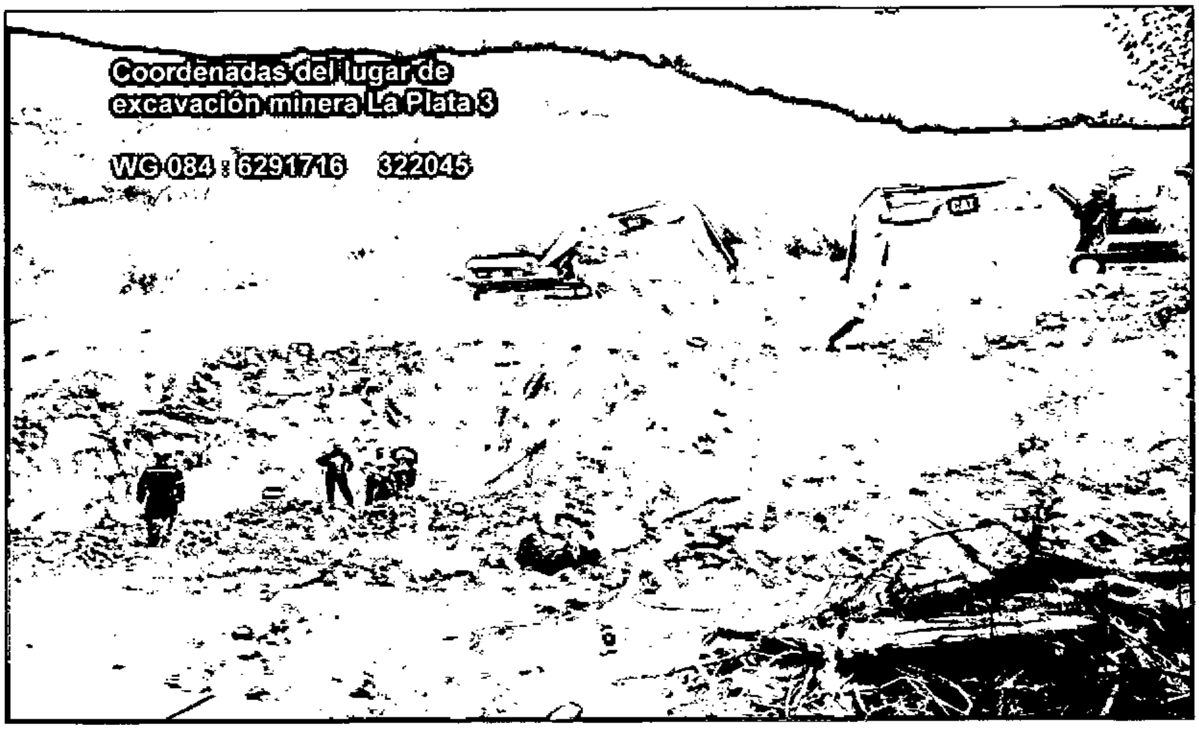


Figura 8: Sector de excavación profunda con coordenadas WG 084: 6291716 322045 mostrando el avance en destrucción del sector Quebrada de La Plata en una semana según se constata en visita del 03 de diciembre de 2012 con personal del SERNAGEOMÍN. (ver anexo visita SERNAGEOMÍN.)

MATERIAL FOTOGRÁFICO DEL DESASTRE ECOLÓGICO Y DESTRUCCIÓN DE FLORA ENDÉMICA DEL LUGAR CONSIDERADO SITIO PRIORITARIO

Tal como queda en evidencia fotográfica los principales daños han sido la destrucción del entorno natural de la quebrada de la plata, es decir, la instalación de campamentos con container, interrupción de senderos con material depositado (10 ton. Aprox.) que impiden el ingreso y últimamente cercaron con alambres de púas todad la quebrada por lo cual el ingresos natural al sector se encuentra interrumpido, ampliación de senderos de 2 metros a 4 y más de anchos por donde circula maquinaria pesada tales como retroexcavadoras, camiones de alto tonelaje, máquinas topos etc..

Al ir abriéndose caminos van destruyendo el bosque esclerófilo típico del sitio prioritario y con ello especies en peligro de extinción y protegidas como guayacanes, litres, peumos, espinos, romerillo etc.. Además la faena realizó un socavón depositando el material a la base de la quebrada y se arrasó con el bosque esclerófilo y las lluvias han empezado a arrastrar material sedimentado hacia la Quebrada, lo que provocará el nacimiento de cárcavas hacia el fondo de la misma.

También han realizados caminos explotando lo cerros con gran movimiento de suelo que van desplazando en la medida de sus avances.

El ingreso de camiones de alto tonelaje por el camino de ingreso a la Quebrada de La Plata, ha ocasionado la destrucción total de la vegetación tanto arbustiva como arbórea en 2 a 3 metros hacia ambos lados del camino. Hacia el interior de la quebrada principal llegando al inicio de uno de los principales bosques de Peumo (Cryptocarya alba), se pudo observar la destrucción de árboles de más de 80 años de edad.

Por otra parte, en el fondo de la quebrada no hay agua y aparentemente la napa freática ha desaparecido. Cabe preguntarse si la explotación minera es causal de esta disminución en el agua ya que ellos requieren de este vital elemento en el desarrollo de sus labores de explotación.

La empresa minera no sólo ha afectado el paisaje al ingreso de la quebrada y notablemente en el sector donde están explotando minerales, sino que además, se ha arrogado la Facultad de impedir el ingreso de los propios académicos y del Sr. Administrador de la Estación Experimental a sectores que son parte del predio que pertenece a la Universidad de Chile.

En las fiscalizaciones además se pudo apreciar que TODO el material producto de la actividad minera son enterrados en el mismo lugar produciendo contaminación del subsuelo.

Las tronaduras han hecho que la población del ratón Degú, especie en peligro de extinción hayan desaparecido según trampeos realizados por académicos que realizan investigación de ésta especie.

El movimiento constante de camiones y tronaduras de cerros impulsan la nube de polvo en suspensión al interior del valle de Maipú contaminando el aire de la comuna afectando la salud de la comunidad de Rinconada, adultos mayores y niños.

Figura 9: La figura muestra e avance en destrucción del sector Quebrada de la Plata en el transcurso de una semana en el mismo lugar de coordenadas **WG 084: 6291716 322045. A)** Inspección con carabineros y personal municipal el lunes 26 de noviembre de 2012; **B)** inspección con personal del SERNAGEOMÍN el lunes 03 de diciembre de 2012.

Figura 10: Destrucción del sector Quebrada de la Plata de coordenadas WG 084: 6291716 322045. durante inspección con personal del SERNAGEOMÍN el lunes 03 de diciembre de 2012.

En términos biológicos y cualitativos, a pesar del grado de intervención antrópica que presenta La Quebrad de La Plata y la principal amenaza de origen antrópico que representa la extracción de roca para la minería, y otras que se evidencian por la existencia de senderos para vehículos motorizados y el hallazgo eventual de desperdicios o cartuchos que sugieren presión de caza en la zona o el ingreso de ganado vacuno, este lugar presenta óptimas condiciones para el desarrollo de especies *sensibles* a la contaminación y alteraciones antrópicas, favoreciendo la existencia de especies de vertebrados endémicos y en peligro de conservación (e.g. *Spalacopus cyanus*) en toda su superficie. Así, y antes del inicio de la faena de explotación minera durante el pimer semestre 2013, era posible observar en la zona la presencia de líquenes desde el ingreso de la estación agronómica experimental, forma de vida que requiere bajos niveles de toxicidad en el aire para su desarrollo. Del mismo modo, la presencia de al menos 78 especies de aves de diversos gremios (17 % del total de especies presente en Chile), desde granívoras estrictas (e.g. *Diuca diuca*) a depredadores tope (e.g. *Geranoaetus melanoleucus*), sugieren la existencia de tramas tróficas completas y de complejas interacciones ecológicas con integrantes mayoritariamente nativos, que a excepción de un par de especies migrantes invernales, se reproducen en esta área. Más interesante, pero existencia de murciélagos, ya que Quebrada de la Plata contendría cerca del 50% de las especies de Quirópteros insectívoros presentes en Chile, orden de mamíferos cuyos ambientes requieren de especial cuidado, conociéndose que algunas especies son altamente específicas en la selección de sus hábitats y especialmente sensibles a la alteración antrópica (Aguirre 2002, Canals & Cattan 2008). Esta gran diversidad faunística presentada, no tendría sustrato estructural ni base trófica, si no fuera por el ensamble vegetal de esta zona, compuesta en su mayoría por flora endémica representativa de la zona mediterránea.

En estos momentos (Agosto de 2014) la principal amenaza que afecta a la Quebrada de la Plata es la actividad minera, que ha destruido parte importante del área de la cabecera de la Quebrada (Figura 6). Observaciones no científicas indican que una parte relevante de la fauna autóctona ha migrado debido a las detonaciones y al constante tráfico de camiones y maquinaria pesada.

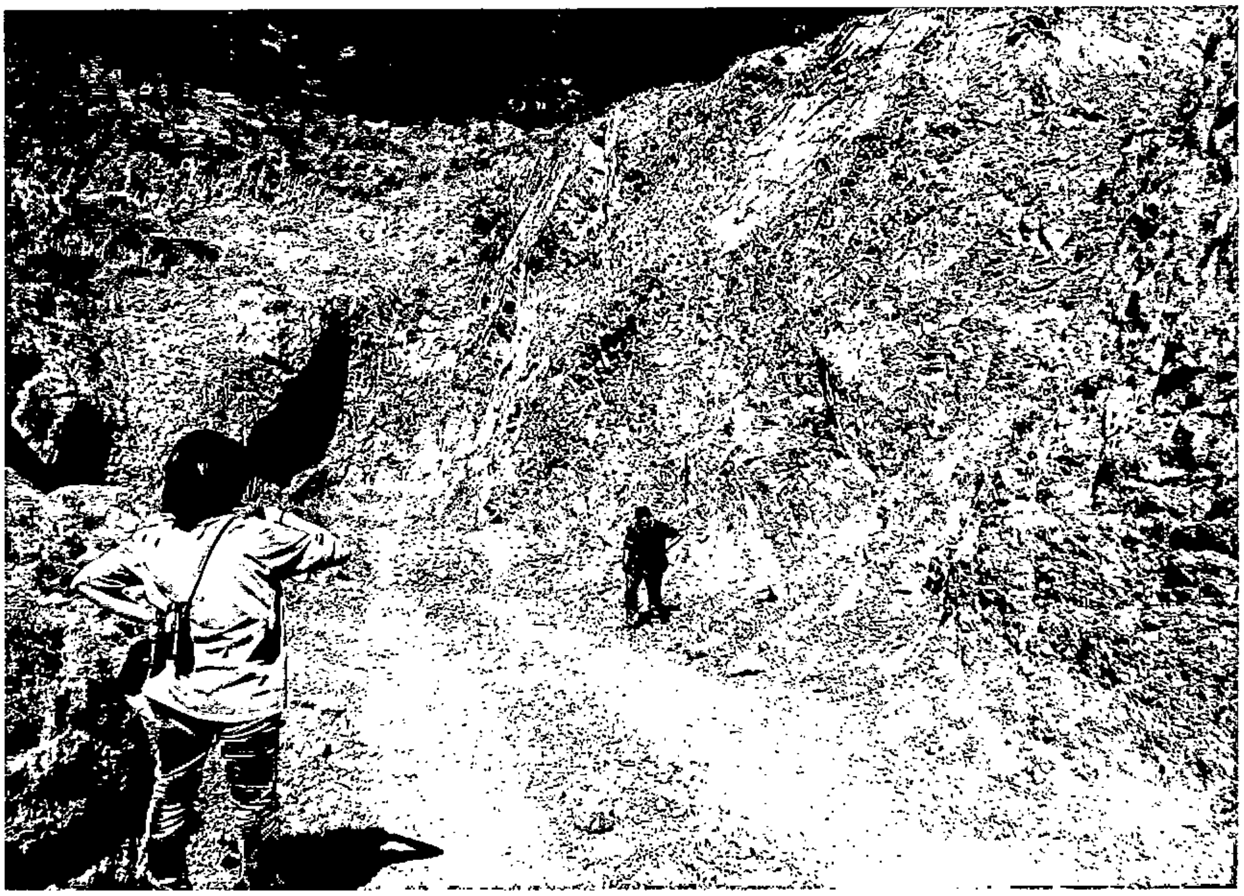


Figura 11: Magnitud de la destrucción de la de la Sur de exposición Norte de la Quebrada de La Plata inspeccionadas por el SAG. (ver anexo fiscalización SAG).

Figura 12: Avance en destrucción de cerros y quebradas en inspección del 4 de julio de 2013

Figura 13: Entierro de basuras producto de la actividad minera en el sector Quebrada de La Plata.

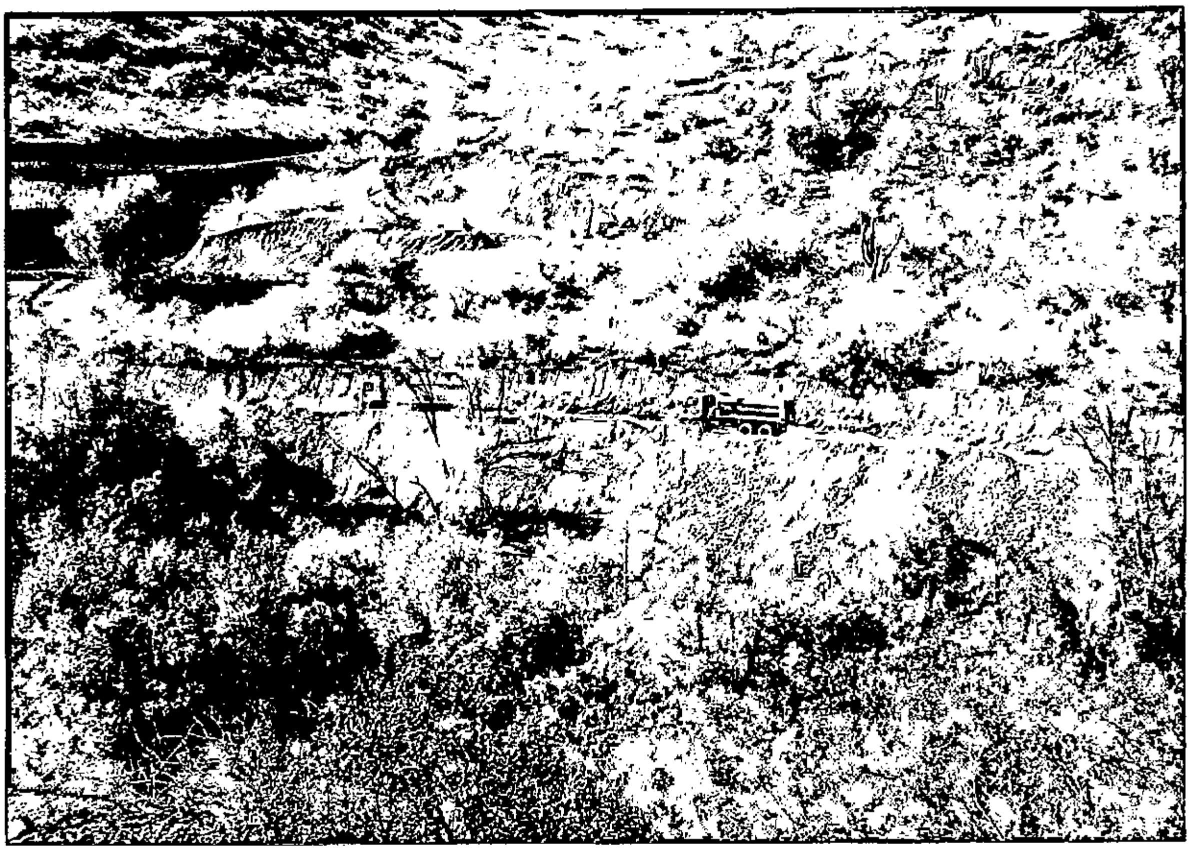


Figura 14: Construcción de caminos cuyo material es depositado en la base de la Quebrada La Plata.

Figura 16: La figura muestra uno de los puntos de extracción de material, encontrándose tres puntos de igual magnitud producto de la actividad minera en el sector Quebrada de La Plata.

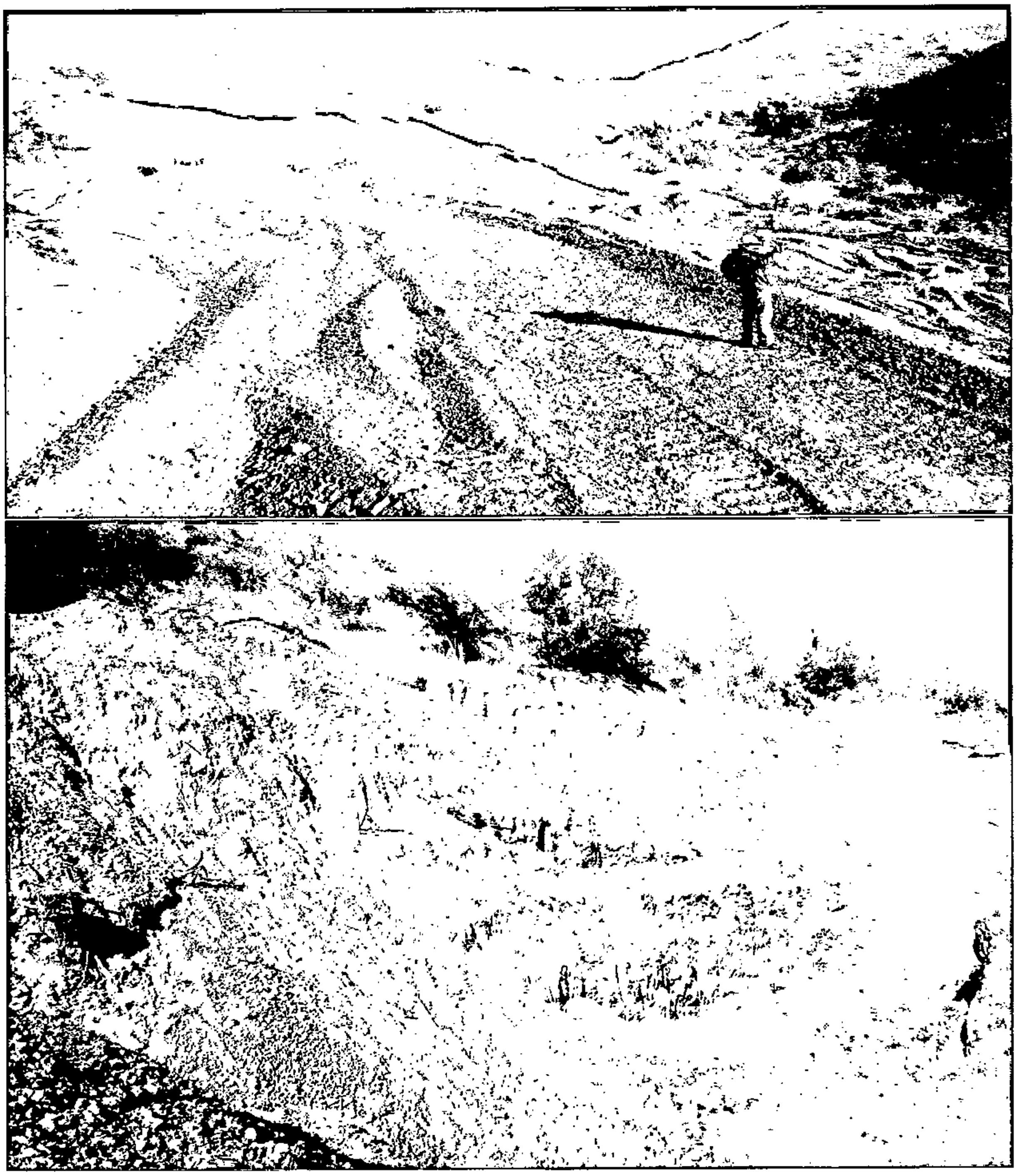


Figura 18: Destrucción de la ladera Sur de exposición Norte y cortes de cerros, con desprendimiento de material y destrucción del matorral y bosque esclerófilo existentes en la Quebrada de La Plata.

La institución a cargo de la gestión y administración de la Quebrada de la Plata es la Universidad de Chile, a través de la Facultad de Ciencias Agronómicas y, más específicamente, del equipo profesional, personal técnico y colaboradores de campo a cargo de la Estación Experimental Agronómica Germán Greve.

En el futuro inmediato, mediante proyecto que pretende incorporarla a un Tramo del Sendero de Chile, tendrá una administración compartida mediante convenio entre la Fundación Sendero de Chile, la Facultad de Ciencias Agronómicas titular del predio y la Ilustre Municipalidad de Maipú. (ver anexo proyecto "Parque Natural Quebrada de La Plata").

La investigación científica se ha desarrollado en la QDP desde hace décadas. Sin embargo, debido a las actividades actuales de extracción minera partes significativas del área han sido destruidas. Una vez que cesen estas actividades extractivas, serán necesarios nuevos estudios científico-técnicos que determinen impactos y los pasos a seguir en el corto, mediano y largo plazo con el propósito de recuperar el ecosistema.

Para recuperar la vegetación destruida, será necesario recurrir al vivero de especies autóctonas que la Universidad de Chile mantiene en la Facultad de Ciencias Forestales.

Actualmente los senderos de la QDP son utilizados por deportistas en moto, bicicleta y peatones. Será necesario demarcar estos senderos de manera de sensibilizar a los usuarios para evitar el uso de senderos no habilitados, además de programas de educación ambiental: con la participación de la comunidad académica y científica, se diseñarán programas de educación ambiental dirigidos a la comunidad local (Maipú) con el propósito de sociabilizar resultados científicos, participar en actividades como plantación de especies, observación de flora y fauna. En este mismo sentido, se organizarán visitas guiadas con las escuelas locales.

Estos se pueden resumir en un objetivo general, cuyo propósito es contribuir a la conservación de la biodiversidad en la Región Metropolitana, promoviendo la gestión sustentable de las características, servicios y potencialidades regionales, de manera de resguardar su capacidad vital y garantizar el acceso a los beneficios para el bienestar de las generaciones actuales y futuras.

Para alcanzar esta meta, se debe implementar esta nueva estrategia, los investigadores a cargo del estudio propusieron siete ejes estratégicos de trabajo, cada uno de ellos fundamentado, con claros objetivos y con propuestas de acción planteadas:

1. Cultura para la conservación de la biodiversidad: Para lograr el empoderamiento a escala local y regional, por parte de actores públicos y privados que resultan relevantes en la gestión del patrimonio natural del territorio, se consideran la educación ambiental y la participación ciudadana como herramientas clave.

2. Integración de biodiversidad en sistemas naturales, urbanos y productivos: Ello, pues muchos de los asentamientos humanos y las actividades productivas se ubican en o cerca de sistemas naturales que aportan biodiversidad y servicios ecosistémicos, sin que

3. Conservación de la biodiversidad en la adaptación al cambio climático: Los cambios proyectados para la región, supondrán efectos en la biodiversidad debido al aumento de las temperaturas extremas, menores precipitaciones y más concentrada en el año, menor aporte nival y mayor torrencialidad de los cauces en eventos de lluvia.

4. Los servicios ecosistémicos en la conservación de la biodiversidad: La biodiversidad aporta con diversos servicios ecosistémicos que mejoran directa o indirectamente la calidad de vida de las personas. La protección y mejoramiento de las condiciones en las cuáles estos servicios ecosistémicos son provistos, tienen una incidencia directa en el bienestar de la población regional.

5. Conservación de la biodiversidad en los sitios prioritarios: Se reconoce en los sitios prioritarios un mecanismo clave para la gestión de la biodiversidad a escala local. La existencia de ellos permite recoger a una escala local las particularidades de los diferentes ecosistemas de la región.

6. Gestión de información para la conservación de biodiversidad: Ella no se concentra en temas relevantes para la conservación, está dispersa, inaccesible y/o poco comprensible para tomadores de decisión.

7. Red público-privada para la conservación: Las organizaciones comunitarias, ONG's, comunidades escolares y propietarios han tenido un rol clave en la implementación de actividades y acciones de conservación, apoyan la gestión y la intervención tanto en los sistemas naturales y rurales, cómo en los espacios urbanos y periurbanos de la Región. (CED, 2013)

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MARCELO ALEJANDRO ORELLANA REYES
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9.- Proyecto en Quebrada de La Plata: "Implementación de un Estudio a Largo Plazo del Potencial de Restauración Pasiva del Bosque Esclerófilo de Chile Central". Organismos participantes CONAF e Instituto de Ecología y Biodiversidad, Universidad de Chile (IBE).

10.- Proyecto desarrollado en la Quebrada de la Plata. "Evaluación de técnicas de producción de *Plántulas de Quillaja saponaria* (Mol.) con énfasis en el mejoramiento de su calidad morfológica y fisiológica, sobrevivencia y crecimiento inicial en ambientes mediterráneos semiáridos de Chile central." Pontificia Universidad Católica de Chile, Departamento de Ecosistemas y Medio Ambiente.

11.- Proyecto desarrollado en Quebrada de La plata: " Evaluación de técnicas pasivas para la recuperación del bosque esclerófilo de Chile central", financiado por CONAF y encargado del proyecto profesor Pablo Becerra.

12.- Comunidades Vegetales de la Quebrada de La Plata, RM: (Chloris Chilensis). Daniel Tapia C. 2005.

13.- Paper escritos en el extranjero y en revistas INTERNACIONALES sobre investigaciones realizadas en la Quebrada de La Plata.

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ANEXOS

1.- Sentencia Proceso Nº 2800-13 del Segundo Juzgado de Policía Local de Mipú del dos del julio de 2014, condena a Minera Española Chile Limitada al pago de 800 UTM y 10 UTM.

2.- Actas de fiscalización a faenas mineras donde se expone de manera evidente mediante material visual los avances de los daños al bosque esclerófilo, matorrales, fauna etc..de la minera Española Chile Limitada.

3.- Informe técnico de visita al sector de los académicos de la Facultad de Ciencias Agronómicas de la Universidad de Chile, Ing. Agr. MSc. Jaime Rodríguez M. y el Ing. Agr. Dr. Máximo Alonso.

4.- Proyecto Parque Natural Quebrada de La Plata, Resumen Ejecutivo, Presentación, Localización y Antecedentes Biofísicos de proyecto en Quebrada de La Plata.

5.- Solicitud para la Declaración de Santuario de la Naturaleza a la Quebrada de La Plata (documento en desarrollo, 2 borrador).

6.- Informe de Desarrollo del Tour Trekking Ecoturístico en Quebrada de La Plata 2004-2009.

6.- Consultoría para establecer una línea base y zonificación para la conservación de la biodiversidad en el Sitio Prioritario Nº 2 "El Roble" de la Región Metropolitana de Santiago. CONAMA 2006.

7.- Resúmenes de publicaciones ISI y tesis de pre y post grado desarrolladas en sector de La Quebrada de La Plata por los investigadores Dr. Pablo Sabat del Dpto. de Cs. Ecológicas de la Facultad de Ciencias de la U. de Chile, y por el Dr. Luis Ebensperger del Depto. De Ecología de la Pontificia U. Católica de Chile.

8.- Unidad de Investigación: "Cambios Estacionales en la Avifauna de La Quebrada de La Plata, RM." del profesor Dr. Michel Sallberry Ayerza del Depto. De Ciencias Ecológicas, Facultada de Ciencias, Universidad de Chile.

ANEXOS

SEGUNDO JUZGADO POLICIA LOCAL
MAIPU

Proceso N° 2800-13

Maipú, ______ de 07 AGO. 2014 de 20____

Señor: Marcelo Orellana Reyes

Camino Rinconada - Estación Experimental
Germán Greves Silva - Fundo U. de Chile

* En ______________ a ______________ de Maipú de 20____

notifico a Ud. la sentencia que se acompaña en cédula adjunta.

* El Funcionario deberá completar los blancos indicando lugar, día, mes y año, cuando realice la notificación.

SEGUNDO JUZGADO DE POLICÍA LOCAL
MAIPÚ

MAIPÚ, dos de julio de dos mil catorce.

VISTOS:

1.- A fojas 3 y 4, la denuncia por infracción a la Ley N° 20.283, de fecha 13 de marzo de 2013, interpuesta por **MARCELO ALEJANDRO ORELLANA REYES**, en representación de **ESTACIÓN EXPERIMENTAL GERMÁN GREVES SILVA FUNDO UNIVERSIDAD DE CHILE**, ambos con domicilio en Camino Rinconada, Maipú, en contra de **MINERA ESPAÑOLA CHILE LIMITADA**, representada por **BRANKO DONOSO VIDAL**, ambos con domicilio en calle Vicuña Mackenna N° 039, Melipilla, por la corta no autorizada de bosque nativo por el ensanchamiento de un camino existente en el sector denominado Quebrada de la Plata, en el predio llamado Estación Experimental Agronómica Germán Greve ubicado en esta comuna. Señala que las especies que han sido cortadas y explotadas son: Espino, Peumo, Litre, Maitén y Quillay, entre otras.

2.- A fojas 5, 6, 7, y 8, ocho fotografías a color del sector denominado Quebrada de la Plata certificadas por Carabineros de Chile y en que se muestran los trabajos realizados por maquinarias en el lugar.

3.- A fojas 12, indagatoria de **MARCELO ALEJANDRO ORELLANA REYES**, director de **ESTACIÓN EXPERIMENTAL AGRONÓMICA GERMAN GREVE SILVA**, quien ratificó los hechos denunciados.

4.- A fojas 17, indagatoria de **BRANKO DONOSO VIAL** quien en representación de la denunciada señala que ésta cuenta con todos los permisos para la realización de las obras denunciadas.

5.- A fojas 18, y con fecha 21 de agosto de 2013, se celebró la audiencia de contestación y prueba en rebeldía de las partes, y

CONSIDERANDO:

PRIMERO: Que no se ha controvertido por la denunciada los hechos referidos en el parte de fojas 3 y 4 por lo que éstos se tiene por acreditados.

SEGUNDO: Que la denunciada si ha señalado que todos sus trabajos están en regla, sin embargo, no ha acompañado antecedentes alguno que acredite dicha aseveración. Que además, lo declarado por el representante legal de **MINERA ESPAÑOLA CHILE LIMITADA**, quien alega sólo hostigamiento por parte de las autoridades municipales y demás entidades relacionadas no desvirtúa los hechos denunciados

TERCERO: Que de conformidad al plano regulador de la comuna de Maipú el sector en que se efectuaron los trabajos denunciados corresponde a una zona destinada preservación ecológica, sector que se encuentra en el polígono El Roble, descrito como sitio prioritario en la Estrategia para la Conservación de la Biodiversidad en la Región Metropolitana de Santiago, la cual esta refrendada en la estrategia nacional de conservación de la biodiversidad de la comisión nacional del Medio Ambiente.

CUARTO: Que no consta en autos que la denunciada haya acompañado el Plan de Manejo de reforestación, dentro del plazo de 60 días contados desde la denuncia, según lo dispone el artículo 8 del Decreto Ley N° 701 del año 1974 al señalar que "Toda acción de corta de bosque nativo, cualquiera sea el tipo de terreno en que éste se encuentre, deberá hacerse previo plan de manejo de reforestación aprobada por la CONAF...", por lo que apreciados los antecedentes de conformidad a la Ley, se establece la responsabilidad de **MINERA ESPAÑOLA CHILE LIMITADA**, representada por **BRANKO DONOSAO VIDAL**, por los hechos denunciados a fojas 3 y 4, infraccionando lo dispuesto en los artículos 5 de la Ley 20.283 y el artículo 8 del Decreto Ley N° 701 del año 1974.

Con lo relacionado y teniendo presente, además, lo dispuesto en los artículos 14,17, 23 y 24 de la Ley N° 18.287 y Ley 20.283, se resuelve:

1) Se condena a **MINERA ESPAÑOLA CHILE LIMITADA**, representada por **BRANKO DONOSO VIDAL** al pago de una multa equivalente a 800 UTM (Ochocientas Unidades Tributarias Mensuales) de conformidad a lo establecido en el considerando Cuarto.

Si no se pagare la multa dentro de quinto día, despáchese orden de reclusión nocturna por quince noches en contra de su representante legal, a razón de una noche por cada quinto de Unidad Tributaria Mensual, por vía de sustitución y apremio, conforme lo dispone el artículo 23 de la Ley 18.287.

2) Se condena a **MINERA ESPAÑOLA CHILE LIMITADA**, representada por **BRANKO DONOSO VIDAL** al pago de una multa equivalente a 10 UTM (Diez Unidades Tributarias Mensuales) por no presentar un plan de manejo de reforestación con especies nativas para la superficie intervenida, dentro del plazo de 60 días contados desde la denuncia, ante la Corporación Nacional Forestal, según lo dispuesto en el artículo 54 letra e) de la Ley 20.283 sobre Recuperación del Bosque Nativo y Fomento Forestal de conformidad a lo establecido en el considerando Cuarto.

Si no se pagare la multa dentro de quinto día, despáchese orden de reclusión nocturna por quince noches en contra de su representante legal, a razón de una noche por cada quinto de Unidad Tributaria Mensual, por vía de sustitución y apremio, conforme lo dispone el artículo 23 de la Ley 18.287.

ROL N° 2800-2013

DICTADA POR **CLAUDIA DÍAZ-MUÑOZ BAGOLINI**, JUEZA SUBROGANTE.

AUTORIZADA POR **ANITA VIVANCO GÓMEZ**, SECRETARIA SUBROGANTE.

HF.

UNIVERSIDAD DE CHILE
FACULTAD DE CIENCIAS AGRONÓMICAS
ESTACIÓN EXPERIMENTAL AGRONÓMICA ***"GERMÁN GREVE SILVA"***
ADMINISTRACIÓN GENERAL

Lunes 03 de diciembre de 2012

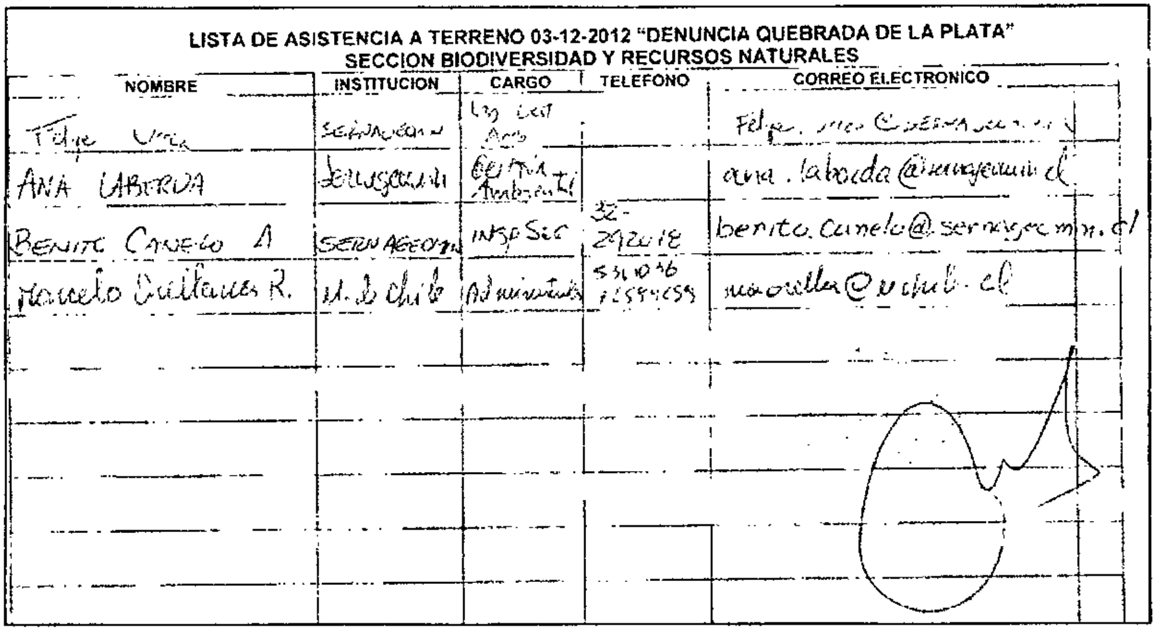
ACTA INSPECCIÓN QUEBRADA DE LA PLATA CON PERSONAL DEL SERNAGEOMÍN

Como resultado de una denuncia pública realizada por un tercero respecto a trabajos de explotación de la minera La Plata 3 en el sector de la Quebrada de la Plata, el día lunes 03 de diciembre se comunican con la administración de rinconada personal del SERNAGEOMIN de la ciudad de Quilpué (Fig.1), los cuales viene a inspeccionar la minera La Plata 3 si cumplen con las normativas de seguridad y si corresponden o no a los dueños de La Plata 3 señores **Branko Donoso Vidal** y su hermano **Josue Donoso Vidal**, los cuales tiene un permiso de 6 meses de exploración en el sector y aún no están constituidos.

El personal del SERNAGEOMÍN solo paralizó las obras, dado a que no poseen una carta de impacto ambiental, y cuando la tengan continuaran las exploraciones.

El personal del SERNAGEOMÍN tomo las coordenadas y se colocaron en el sistema de la página web del sernageomín y el punto cae dentro de una concesión minera llamada PANALES 1/54, personal del sernageomín nos comunica que ellos no tiene la competencia de paralizar las faenas por encontrarse en otra concesión, que eso lo debe resolver el dueño de la concesión y realizar las acciones legales pertinentes.

Figura 1: Lista de asistentes que concurrieron a la inspección en el sector de la Quebrada de La Plata



LISTA DE ASISTENCIA A TERRENO 03-12-2012 "DENUNCIA QUEBRADA DE LA PLATA"
SECCION BIODIVERSIDAD Y RECURSOS NATURALES

NOMBRE	INSTITUCION	CARGO	TELEFONO	CORREO ELECTRONICO
Felipe Urra	Sernageomin	Ing. Civil Amb.		Felipe.urra@sernageomin.[illegible]
ANA LABORDA	Sernageomin	Gestión Ambiental		ana.laborda@sernageomin.cl
BENITO CANELO A	SERNAGEOMIN	INSP SEC	32-2920 18	benito.canelo@sernageomin.cl
Marcelo Orellana R.	U. de Chile	Administrador	5311036 7559455	maorella@uchile.cl

Para una mayor seguridad de las coordenadas se procedió a cambiar el formato del GPS en modo WG 084 que entrega las coordenadas en UTM, formato que usa el SERNAGEOMÍN.
En terreno se pudo constatar que el daño avanza de manera gigantesca y no hay resguardo de NADIE por el destrozo de vegetación y excavaciones profundas que la semana del lunes 26 cuando se realizó una inspección con personal de la municipalidad y carabineros de la 52° comisaría no estaba.
En conversación con uno de los trabajadores comentó que le daba mucha pena lo que estaba sucedinado, pero él era solo un trabajador y señala que abrirán camino por el cerro de la QUEBRADA DE LA PLATA hasta llegar a la veta, que según mapa corresponde a la minera PANALES del 1/54.
Las coordenadas tomadas por el señor Benito Canelo del semageomín en el sector de trabajo de las maquinarias y donde están haciendo una excavación profunda son:

SAD 56	: 6292036	322245
Corrección en mts.	: 320	200
WG 084	: 6291716	322045

Al colocar estas coordenadas en sistema se visualiza que se encuentran dentro de la minera PANALES 1/54.

Figura 2: Sector de excavación profunda con coordenadas **WG 084: 6291716 322045** mostrando el avance en destrucción del sector Quebrada de La Plata en una semana según se constata en visita del 03 de diciembre de 2012 con personal del SERNAGEOMÍN.

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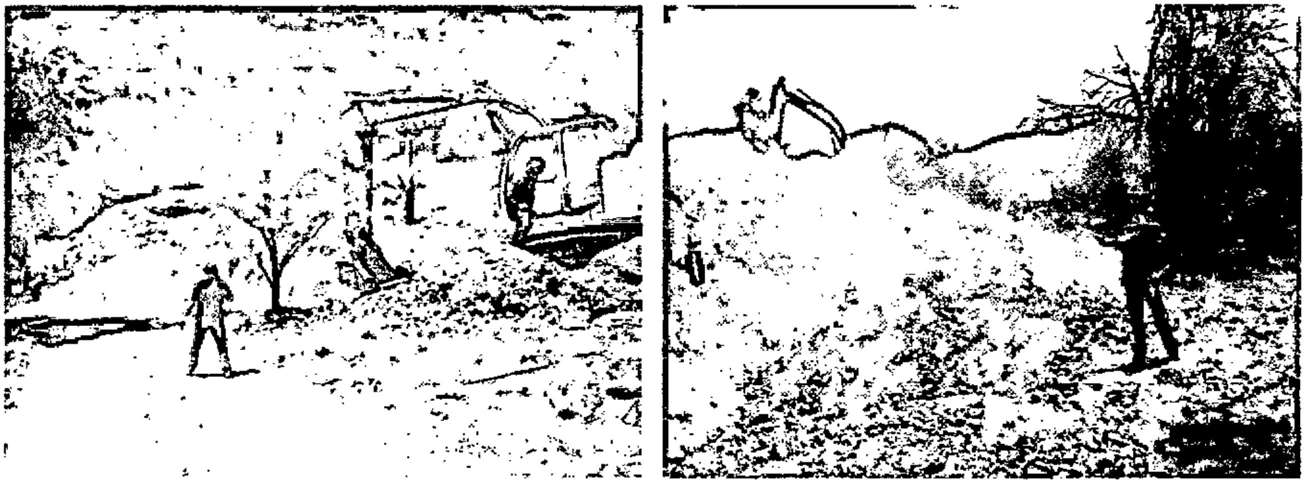
MATERIAL FOTOGRÁFICO DEL DESASTRE ECOLÓGICO Y DESTRUCCIÓN DE FLORA ENDÉMICA DEL LUGAR CONSIDERADO SITIO PRIORITARIO

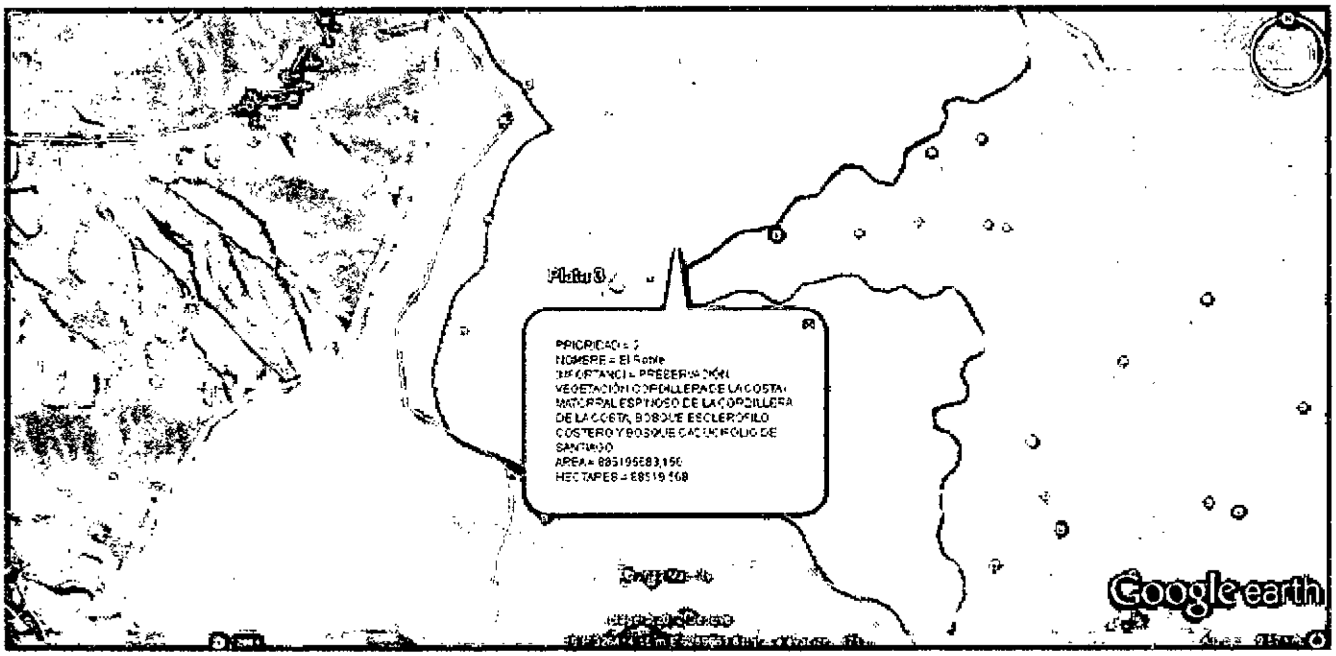

A) Inspección lunes 26 de noviembre de 2012

La figura muestra e avance en destrucción del sector Quebrada de la Plata en el transcurso de una semana en el mismo lugar de coordenadas **WG 084: 6291716 322045. A)** Inspección con carabineros y personal municipal el lunes 26 de noviembre de 2012; **B)** inspección con personal del SERNAGEOMÍN el lunes 03 de diciembre de 2012.



La figura muestra e avance en destrucción del sector Quebrada de la Plata en el transcurso de una semana en el mismo lugar de coordenadas **WG 084: 6291716 322045. A)** Inspección con carabineros y personal municipal el lunes 26 de noviembre de 2012; **B)** inspección con personal del SERNAGEOMÍN el lunes 03 de diciembre de 2012.

Figura 5: Destrucción del sector Quebrada de la Plata de coordenadas **WG 084: 6291716 322045.** durante inspección con personal del SERNAGEOMÍN el lunes 03 de diciembre de 2012.



PRIORIDAD = 2
NOMBRE = El Roble
IMPORTANCIA = PRESERVACIÓN VEGETACIÓN CORDILLERA DE LA COSTA: MATORRAL ESPINOSO DE LA CORDILLERA DE LA COSTA, BOSQUE ESCLERÓFILO COSTERO Y BOSQUE CADUCIFOLIO DE SANTIAGO
AREA = 885195683,156
HECTARES = 88519,568

Figura 6: Sector Quebrada de la Plata de coordenadas **WG 084: 6291716 322045.** con trabajos de exploración y explotación de la minera **La Plata 3** y cuyo sector se encuentra bajo protección de SITIO PRIORITARIO Nº 2 EL ROBLE, lunes 03 de diciembre de 2012.

OTRAS COORDENADAS DEL SECTOR TOMADAS EL DÍA 03 DE DICIEMBRE DE 2012:

1.- Coordenadas de un hito nuevo mensurado por la minera Panales:

SAD 056	:	**6292445**	**323208**
Corrección en mts	:	**320**	**200**
WG 084	:	6292125	323108

2.- Coordenadas sector de trabajos 1 de la minera La Plata 3:

SAD 056	:	**6292036**	**322245**
Corrección en mts	:	**320**	**200**
WG 084	:	6291716	322045

3.- Coordenadas sector de trabajos 2 de la minera La Plata 3:

SAD 056	:	**6292039**	**322252**
Corrección en mts	:	**320**	**200**
WG 084	:	6291719	322052

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ADMINISTRACIÓN GENERAL

Martes 11de diciembre de 2012

ACTA INSPECCIÓN QUEBRADA DE LA PLATA CON PERSONAL DE LA BIDEMA DE LA PDI

En marco de una denuncia realizada en la Fiscalía de Maipú por el señor Pedro Lazo por grave daño al patrimonio y la biodiversidad en el sector denominado QUEBRADA DE LA PLATA, ubicada al interior de la Estación Experimental Agronómica Germán Greve Silva de la Facultad de Ciencias Agronómicas de la Universidad de Chile.

En virtud de lo anterior se dio orden de investigar por el fiscal adjunto señor Eduardo Jeria Lara, RUC de la causa Nº 1200912606-4 a la BIDEMA (brigada de delitos medio ambientales de la PDI) cuya labor recayó en el subcomisario señor Marco Orellana Campo (morellanac@investigaciones.cl) y el inspector señor Jaime Pérez Aguilera **(fig. 1).**

Así el día Martes 11 de diciembre se comunican con la administración de rinconada personal de la **BIDEMA** y se realiza a las 12:00 hrs una inspección al lugar de explotación ILEGAL en la QDP por la concesión minera La Plata 3, cuyos dueños corresponden a los señores **Branko Donoso Vidal** y su hermano **Josue Donoso Vidal**, los cuales tiene un permiso de 6 meses de exploración en el sector y aún no están constituidos.

En el lugar se aprecia maquinaria pesada y conteiner **(fig. 4 a)** sin trabajos aparentes y un guardia que impide el ingreso más arriba (sector hornos caleros) aludiendo que por seguridad de acuerdo a la ley por uso de explosivos no pueden dejar ingresar a nadie al lugar de explotación.

Como íbamos con personal de la **BIDEMA**, el guardia acepta que sigamos y llama al capataz de las faenas, al seguir caminando por el sector aproximadamente unos 2 km el daño causado es IMPRESIONANTE: caminos ensanchados, material depositado en quebradas, destrucción de árboles (guayacánes), interrupción del cauce natural de la quebrada de la plata, construcción de una zona de carga y descarga de material etc...(fig. 2,3,4,5,6,7).

Al llegar al sitio de personal del la BIDEMA se entrevistan con el Capatáz y solo lo citan al representante legal de LA PLATA 3 para el lunes 17 a la BIDEMA para la toma de declaración. Como el suscrito andaba con GPS, se toma punto WG 084 del nuevo sector en destrucción (fig 8).

LISTA DE ASISTENCIA A TERRENO 11-12-2012 "DENUNCIA QUEBRADA DE LA PLATA" ADMINISTRACIÓN RINCONADA Y BIDEMA-PDI

NOMBRE	INSTITUCION	CARGO	TELEFONO	CORREO ELECTRÓNICO
Marcelo Orellana	Estación Experimental	Administrador	76594259	maorella@uchile.cl
Marco Orellana	BIDEMA-PDI	Subcomisario	74762379	morellanac@investigaciones.cl
Jaime Pérez	BIDEMA-PDI	Inspector	---------	------------------------------

Fig. 1: Lista de asistencia terreno Quebrada de La Plata.

Figura 2: Destrucción de árboles endémicos en el sector de la Quebrada de La Plata.

Figura 3: Sector de ensanchamiento del camino con depósito de material hacia la quebrada con destrucción de laderas y arbustos endémicos.

Figura 4: Fiscalización BIDEMA-PDI, subcomisario Marco Orellana Campo.

Figura 5: Canchas de carga y descarga a dos km pasado el campamento.

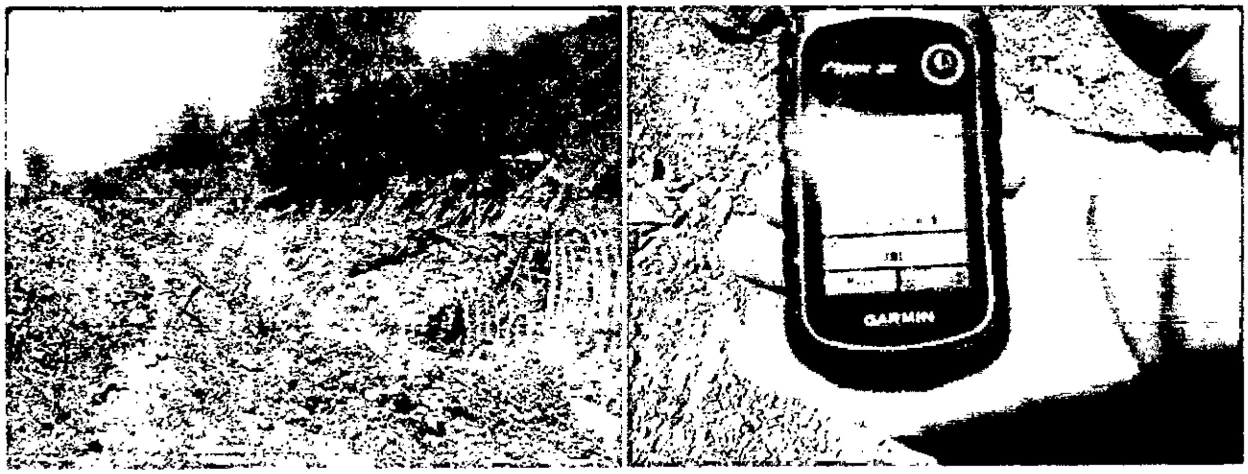


Figura 6: Punto georeferencial del nuevo lugar de explotación (WG 084: 6291458 – 0321573)

Atentamente,

Estación Experimental Germán Greve Silva ADMINISTRACIÓN

MARCELO ALEJANDRO ORELLANA REYES
Administrador General
Estación Experimental Agronómica
Germán Greve Silva-Rinconada de Maipú

UNIVERSIDAD DE CHILE
FACULTAD DE CIENCIAS AGRONÓMICAS
ESTACIÓN EXPERIMENTAL AGRONÓMICA ***"GERMÁN GREVE SILVA"***
ADMINISTRACIÓN GENERAL

Martes 12 de Marzo de 2013

FISCALIZACIÓN DE FAENAS MINERAS EN QUEBRADA DE LA PLATA CON PERSONAL DE LA 52° COMISARIA DE MAIPÚ

En virtud del recurso de protección N° ING: 144-2013 Folio: 37014 interpuesto por la Facultad de Ciencias Agronómicas de la Universidad de Chile en la corte de apelaciones de Santiago en contra de la MINERA LA ESPAÑOLA CHILE LIMITADA RUT: 76.170.116-9 CUYO REPRESENTANTE LEGAL ES EL SEÑOR BRANKO DONOSO VIDAL RUT: 20.085.555-3 CON DOMICILIO EN AVENIDA VICUÑA MACKENA N° 039, COMUNA DE MELIPILLA, SANTIAGO, el cual se declara admisible el 4/01/2013 y con fecha 07 de enero de 2013 proveyendo al primer otrosí de fs. 1: **se concede la orden de no innovar sólo en cuanto se ordena la paralización de las actividades denunciadas.**

A raíz de lo anterior se procede con la fuerza pública, carabineros de Chile, pertenecientes a la 52° comisaria de Maipú, los señores sargento 1° H. López S. y cabo Javier González Riquelme a constatar en terreno como ministros de fe que la minera LA ESPAÑOLA sigue trabajando en el sector denunciado y que no ha respetado la orden de no innovar concedida por la Ilustrísima Corte de Apelaciones de Santiago, en cuanto DEBEN PARALIZAR LAS OBRAS.

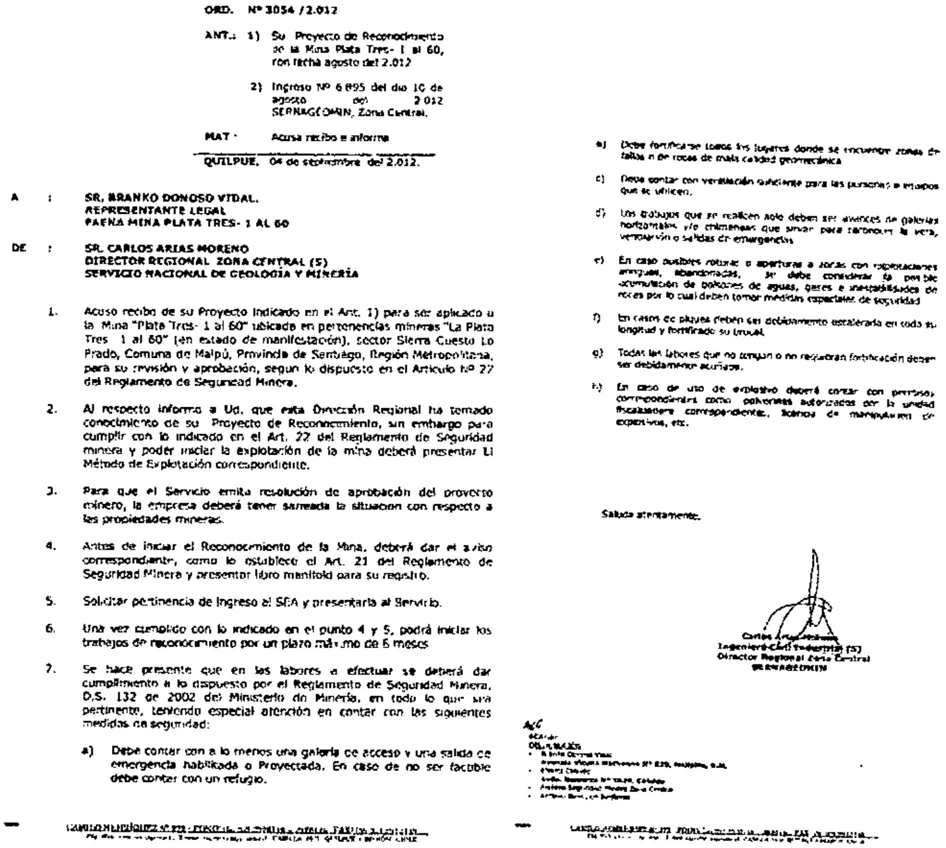
En terreno se encontraban trabajando 7 máquinas oruga-retroescavadoras marca CAT, 6 camiones tolva de alto tonelaje, una máquina TOPO realizando túneles de grueso diámetro, 3 camionetas color rojo marca nissan con personal en su interior dirigiendo las labores de excavación, acopio de material triturado, carga de camiones y explotación de laderas y cerros con vegetación endémica del lugar, como Guayacán, Peumos, Litres; Espinos y Quillay entre otra especies arbóreas.

Cabe hacer mención que el señor BRANKO DONOSO VIDAL, representante legal de la minera Española Chile Limitada, presentó un proyecto de Reconocimiento de la MINA PLATA TRES 1 al 60 en oficio ordinario N° 3054/2.012 del mes de agosto de 2012 al señor Carlos Arias Moreno, Director Regional Zona Central (S) del SERVICIO NACIONAL DE GEOLOGÍA Y MINERÍA de la ciudad de QUILPUÉ, el cual acusa recibo del proyecto e informa dando aprobación del Proyecto de Reconocimiento con un plazo máximo de seis meses, los cuales ya expiraron. Además para cumplir con el Art. 22 de Reglamento de Seguridad Minera y poder iniciar la explotación de la mina DEBERÁ presentar "EL MÉTODO DE EXPLOTACIÓN CORRESPONDIENTE", y para que el SERNAGEOMÍN emita resolución de aprobación del proyecto minero, la empresa DEBERÁ tener saneada la situación con respecto a las propiedades mineras, y antes de iniciar el Reconocimiento de la mina, deberá dar aviso correspondiente, como lo establece el Art. 21 del Reglamento de Seguridad Minera y presentar libro manifold para su registro y solicitar pertinencia de ingreso al SEA y presentarla al servicio y una vez cumplido con lo anterior podrá iniciar los trabajos de reconocimiento por un plazo máximo de 6 meses (fig. 1)

Con fecha 03 de Diciembre de 2012 por denuncia realizada al SERNAGEOMÍN de Quilpué por trabajos de explotación de la minera La Plata 3 en el sector de la Quebrada de la Plata y los dueños de La Plata 3 señores **Branko Donoso Vidal** y su hermano **Josue Donoso Vidal**, según inspectores del SERNAGEOMÍN SOLO tienen un permiso de 6 meses de exploración en el sector y aún no están constituidos.

El personal del SERNAGEOMÍN, señores Benito Canelo, Ana Laborda y Felipe Urrea, solo paralizaron las obras, dado a que no poseen una carta de impacto ambiental, situación que se comprobó en terreno que no cumplieron y continuaron trabajando en el sector con un daño al ecosistema evidente (fig. 2)

En la fiscalización del día de ayer Martes 12 de marzo de 2013 en presencia de carabineros de la 52° comisaria de Maipú (fig 3) señores Sargento 1° Héctor López Solís y personal a su cargo comprueban faenas de extracción, explotación a gran escala y atajo abierto (fig. 4) y se confecciona un nuevo parte policial N° 1110 en el cual se relatan los hechos y se envió a la Fiscalía de Maipú y otro parte N° 04 al Servicio Agrícola y Ganadero (SAG) por infracción a la ley de medio ambiente.



ORD. N° 3054 /2.012

ANT.: 1) Su Proyecto de Reconocimiento de la Mina Plata Tres- 1 al 60, con fecha agosto del 2.012

2) Ingreso Nº 6 895 del dia 10 de agosto del 2 012 SERNAGEOMIN, Zona Central.

MAT.: Acusa recibo e informa

QUILPUE, 04 de septiembre del 2.012.

A : SR. BRANKO DONOSO VIDAL.
REPRESENTANTE LEGAL
FAENA MINA PLATA TRES- 1 AL 60

DE : SR. CARLOS ARIAS MORENO
DIRECTOR REGIONAL ZONA CENTRAL (S)
SERVICIO NACIONAL DE GEOLOGÍA Y MINERÍA

1. Acuso recibo de su Proyecto Indicado en el Ant. 1) para ser aplicado a la Mina "Plata Tres- 1 al 60" ubicada en pertenencias mineras "La Plata Tres 1 al 60" (en estado de manifestación), sector Sierra Cuesta Lo Prado, Comuna de Maipú, Provincia de Santiago, Región Metropolitana, para su revisión y aprobación, segun lo dispuesto en el Articulo Nº 27 del Reglamento de Seguridad Minera.

2. Al respecto informo a Ud. que esta Dirección Regional ha tomado conocimiento de su Proyecto de Reconocimiento, sin embargo para cumplir con lo indicado en el Art. 22 del Reglamento de Seguridad minera y poder iniciar la explotación de la mina deberá presentar El Método de Explotación correspondiente.

3. Para que el Servicio emita resolución de aprobación del proyecto minero, la empresa deberá tener saneada la situacion con respecto a las propiedades mineras.

4. Antes de iniciar el Reconocimiento de la Mina, deberá dar el aviso correspondiente, como lo establece el Art. 21 del Reglamento de Seguridad Minera y presentar libro manifold para su registro.

5. Solicitar pertinencia de Ingreso al SEA y presentarla al Servicio.

6. Una vez cumplido con lo indicado en el punto 4 y 5, podrá iniciar los trabajos de reconocimiento por un plazo máximo de 6 meses

7. Se hace presente que en las labores a efectuar se deberá dar cumplimiento a lo dispuesto por el Reglamento de Seguridad Minera, D.S. 132 de 2002 del Ministerio de Minería, en todo lo que sea pertinente, teniendo especial atención en contar con las siguientes medidas de seguridad:

   a) Debe contar con a lo menos una galería de acceso y una salida de emergencia habilitada o Proyectada. En caso de no ser factible debe contar con un refugio.

   b) Debe fortificarse todos los lugares donde se encuentre zonas de fallas o de rocas de mala calidad geomecánica

   c) Debe contar con ventilación suficiente para las personas o equipos que se utilicen.

   d) Los trabajos que se realicen solo deben ser avances de galerías horizontales y/o chimeneas que sirvan para reconocer la veta, ventilación o salidas de emergencias

   e) En caso posibles roturas o aperturas a zonas con explotaciones antiguas, abandonadas, se debe considerar la posible acumulación de bolsones de aguas, gases e inestabilidades de rocas por lo cual deben tomar medidas especiales de seguridad

   f) En casos de piques deben ser debidamente escalerado en toda su longitud y fortificado su brocal.

   g) Todas las labores que no tengan o no requieran fortificación deben ser debidamente acuñadas.

   h) En caso de uso de explosivo deberá contar con permisos correspondientes como polvorines autorizados por la unidad fiscalizadora correspondiente, licencia de manipulación de explosivos, etc.

Saluda atentamente,

Carlos Arias Moreno
Ingeniero Civil Industrial (S)
Director Regional Zona Central
SERNAGEOMIN

Figura 1: Proyecto de Reconocimiento de la Mina La Plata Tres 1 al 60 y su fecha de término en el punto N° 6 del documento adjunto.

Figura 2: Sector de excavación profunda con coordenadas **WG 084: 6291716 322045** mostrando el avance en destrucción del sector Quebrada de La Plata según se constata en visita del 03 de diciembre de 2012 con personal del SERNAGEOMÍN.

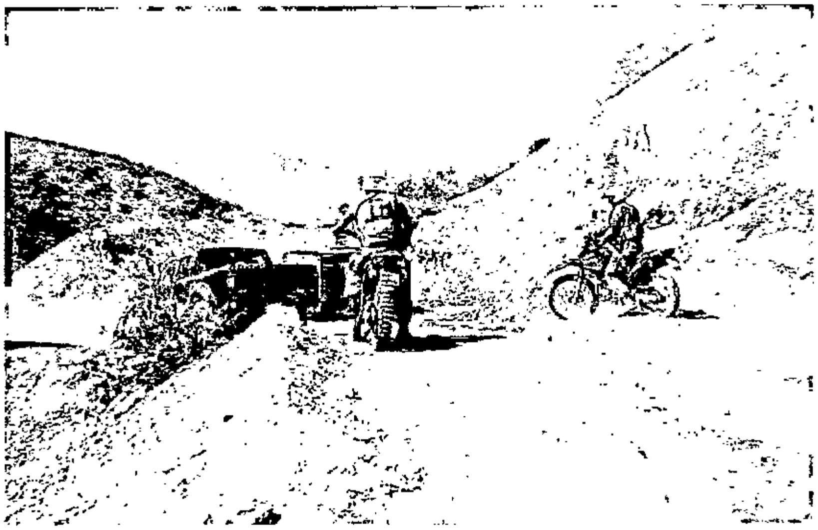
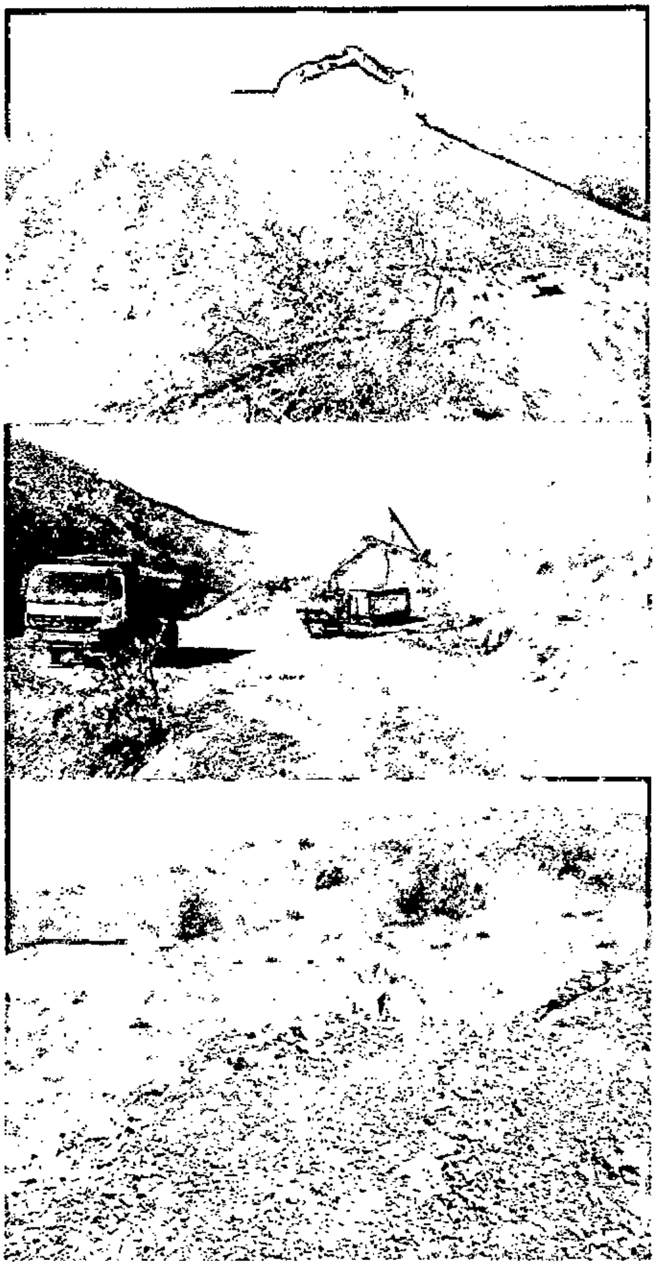


Figura 3: Fiscalización de la orden de no innovar de paralización de faenas, encontrándose que sí estaban trabajando en el sector de la Quebrada de La Plata con un movimiento de maquinarias a tajo abierto. (martes 12 de marzo de 2013, 15:40 hrs).



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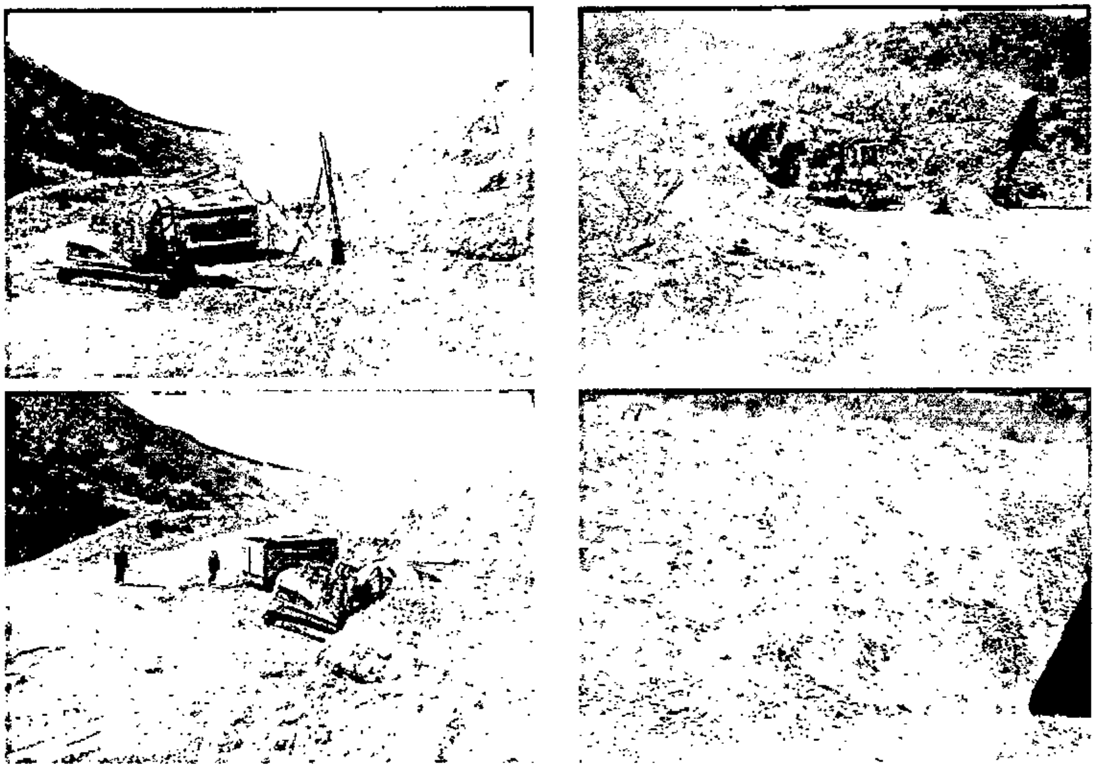

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Bufoubnfouf-!

Estación Experimental Germán Greve Silva ADMINISTRACIÓN

NBSDFMP!BMFKBOESP!PSFMMBOB!SFZFT!
Benjojtusbeps!Hfofsbm
Ftubdj˙o!Fyqfsjnfoubm!Bhspo˙njdb!
Hfsn˙o!Hsfwf!Tjmwb.Sjodpobeb!ef!Nbjqý

Lunes 10 de abril de 2013

ACTA INSPECCIÓN DE CLAUSURA DE ACTIVIDAD MINERA EN QUEBRADA DE LA PLATA CON PERSONAL DEL MUNICIPIO DE MAIPÚ

En marco de una serie de denuncias realizadas por el administrador al municipio de la comuna de Maipú por grave daño al patrimonio y la biodiversidad en el sector denominado QUEBRADA DE LA PLATA, ubicada al interior de la Estación Experimental Agronómica Germán Greve Silva de la Facultad de Ciencias Agronómicas de la Universidad de Chile el día de ayer 10 de abril de 2013 a las 8:30 hrs se procedió a realizar una clausura de las actividades mineras por parte del alcalde de la comuna de Maipú Sr. Christian Vittori **(Fig. 1).**

El día martes 09 de abril se contactó con el administrador de la Estación Experimental, Sr. Marcelo Orellana el Dr. Christian Sepúlveda C. Jefe de la Unidad de Planificación y Fiscalización Medioambiental de la Dirección de Inspección de la Ilustre Municipalidad de Maipú (6776756 csepulveda@maipu.cl) el cual informa que se procederá a realizar a una clausura mediante un DECRETO ALCALDICIO 2099 del 09 de abril de 2013, a la fiscalización se suman reporteros gráficos y prensa (canal 13) junto a todo el aparato administrativo de la alcaldía de Maipú encabezado por su Alcalde, administrador municipal, medio ambiente, departamento de inspección, jurídica y representante de la Universidad de Chile, Sr. Marcelo Orellana en su calidad de administrador de la Estación Experimental Germán Greve Silva.**(Fig. 1, 2 y 3).**

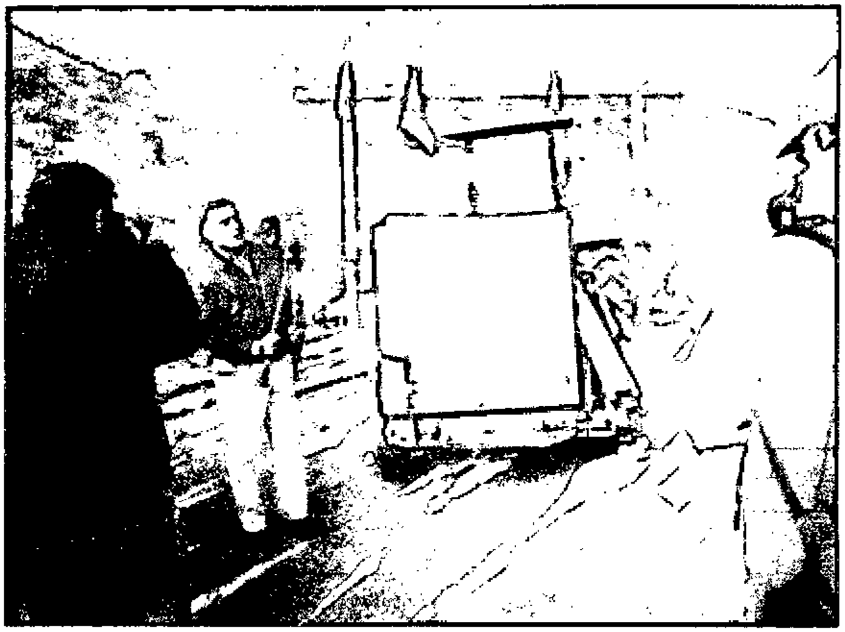


Figura 1: Sector del pórtico, lugar de ingreso a la Quebrada de La Plata con Alcalde Vittori a proceder a la clausura de la actividad minera. (10-03-2013).

Figura 2: Instalación del letrero de clausura en sector de actividad minera en Quebrada de La Plata por inspectores municipales (10-03-2013).

Figura 3: Instalación de barrera metálica con cadenas y letrero de clausura en sector del campamento minero en Quebrada de La Plata por inspectores municipales (10-03-2013).

Para ratificar el cumplimiento de la orden municipal 2099 del 09 de abril de 2013 el cual hace referencia a la clausura del lugar (actividades mineras) el día Jueves 11 de abril de 2013 a las 12:30 hrs se inspecciona el lugar con inspector municipal Sr. Carlos Rivas Ruminot (7640 3686) y se comprueba que los sellos municipales de clausura y letreros que indicaban lo mismo junto con las cadenas de clausura fueron retiradas del lugar y las faenas de explotación estaban activas con maquinaria pesada de minería en pleno proceso de faenas de explotación. **(Fig. 4).**

Cabe dar mención que fuimos increpados verbalmente **(Fig. 5)** y con empujones nos sacaron del lugar aludiendo que eso es propiedad de la minera y no de la Universidad de Chile y fuimos conducidos por personal de la minera a salir del sector, lo cual debimos hacerlos por un lugar no habilitado para el tránsito de a pié en la quebrada dado a que bloquearon el camino de ingreso con aproximadamente 10 a 12 toneladas de material extraído del sector impidiendo la continuidad del sendero natural existente en el lugar **(Fig. 6)**.

En inspección del 03 de diciembre de 2012 con personal del SERNAGEOMÍN **(Fig. 7),** paralizaron las obras por incumplimiento de normativa y los obligaron despejar el sendero natural, sin embargo en el día de hoy nuevamente lo interrumpieron depositando material para impedir el ingreso al sector.

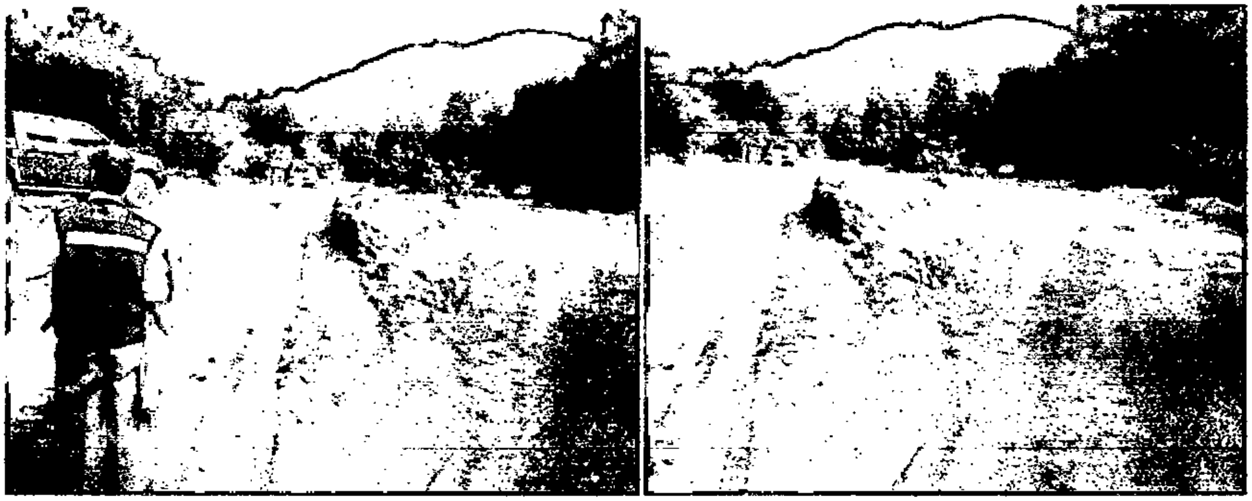
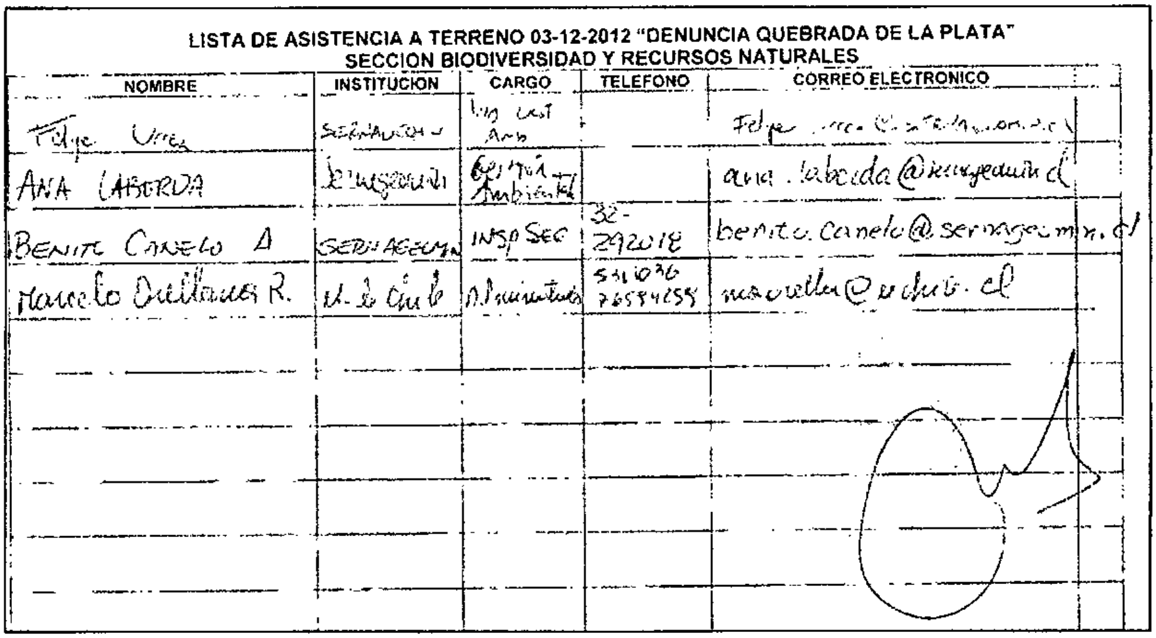


Figura 4: Inspector municipal constatando el rompimiento de sellos, destrucción de cadenas y letreros de clausura instalados en este mismo lugar el día 10 de abril de 2013, tal como se muestra en figura 2 y 3 (11-03-2013).

Figura 5: Trabajadores de la minera nos agreden verbalmente y obligan al inspector municipal Sr. Carlos Rivas y al administrador de la Estación Experimental Sr. Marcelo Orellana a hacer abandono del lugar (11-03-2013).

Figura 6: Depósito de material puesto el día 11 de abril de 2013 para bloquear sendero natural en Quebrada de La Plata (10-03-2013).



LISTA DE ASISTENCIA A TERRENO 03-12-2012 "DENUNCIA QUEBRADA DE LA PLATA"
SECCION BIODIVERSIDAD Y RECURSOS NATURALES

NOMBRE	INSTITUCION	CARGO	TELEFONO	CORREO ELECTRONICO
Felipe Urra	SERNAGEOMIN	Ing. Cont. Amb		[illegible]
ANA LABORDA	Sernageomin	Gestión Ambiental		ana.laborda@sernageomin.cl
BENITO CANELO A	SERNAGEOMIN	INSP SEG	32-292018	benito.canelo@sernageomin.cl
Marcelo Orellana R.	U. de Chile	Administrador	5311036 76584255	maorella@uchile.cl

Figura 7: Lista de asistentes que concurrieron a la inspección en el sector de la Quebrada de La Plata el 03 de diciembre de 2012.

Atentamente,

Estación Experimental Germán Greve Silva ADMINISTRACIÓN

MARCELO ALEJANDRO ORELLANA REYES
Administrador General
Estación Experimental Agronómica
Germán Greve Silva-Rinconada de Maipú

UNIVERSIDAD DE CHILE
FACULTAD DE CIENCIAS AGRONÓMICAS
ESTACIÓN EXPERIMENTAL AGRONÓMICA ***"GERMÁN GREVE SILVA"***
ADMINISTRACIÓN GENERAL

Martes 11 de abril de 2013

QUEBRADA DE LA PLATA (QDP)
RESUMEN DE ANTECEDENTES ECOSISTÉMICOS

La QDP tiene una superficie aproximada de 800 hectáreas y se encuentra situada al interior de la Estación Experimental Agronómica Germán Greve Silva, también conocida como Centro Experimental Rinconada de Maipú, perteneciente a la Universidad de Chile. Está ubicada a 30 km al suroeste de la ciudad de Santiago, inserta en el primer cordón montañoso de la Cordillera de la Costa, en el extremo poniente de la Comuna de Maipú, Región Metropolitana de Chile. Sus coordenadas geográficas son: 33º 29' 26 Latitud Sur y 70º 53' 15" Longitud Oeste. El cordón norte limita con la cuesta Lo Prado y el cordón sur con la cuesta Barriga, mientras que por el oeste limita con la Comuna de Curacaví.

Desde el año 1933 la Quebrada de la Plata ha sido un laboratorio natural para el estudio de investigaciones de alumnos y docentes de diferentes universidades del país, guardan en memorias y publicaciones gran parte del conocimiento de la biodiversidad representativa de la vertiente oriental de la Cordillera de la Costa.

Contexto Geográfico: La Quebrada es de topografía abrupta, aunque es posible encontrar algunos sectores de pequeñas dimensiones relativamente planos. Gran parte del área presenta un relieve muy escarpado, conformado por cordones de una altura media de 450 m y una garganta de apreciable profundidad, en cuyo fondo se juntan las laderas de los cerros en forma de V, encontrándose a menudo pendientes entre un 50 y 70% (Fernández y Seguel, 1947).

Características biogeográficas: De acuerdo con Gajardo (1994), la formación vegetacional de la Quebrada de la Plata corresponde a la del Matorral Espinoso del Secano Costero. La vegetación está compuesta por comunidades de matorrales y bosques esclerófilos que en la Región han sido alteradas fuertemente en el pasado y actualmente amenazadas por la expansión urbana (Tapia, 2005). El área presenta una alta diversidad morfológica en la vegetación, dada por la forma de crecimiento de ésta, ya que es posible encontrar un estrato herbáceo, arbustivo y arbóreo, además de suculentas. De acuerdo con Gallardo (1993), la ladera de exposición norte presenta mayoritariamente especies arbustivas como: colliguay (Colliguaya odorifera) y tevo (Trevoa trinervis); y por especies herbáceas y suculentas, entre las que destacan: chagual (Puya berteroniana) y quisco (Echinopsis chiloensis). El lecho de la Quebrada se caracteriza por presentar vegetación arbórea bien desarrollada en su parte media, y a medida que se asciende por la ladera de exposición sur, la vegetación se presenta cada vez más vigorosa y densa (Schlegel, 1963).

Presencia de formaciones naturales: La mayoría de las cumbres de la zona presentan formas suaves y redondeadas. Sin embargo es posible encontrar, en algunos cerros ubicados en la parte baja de la Quebrada y en la ladera de exposición norte, cumbres que presentan un estado muy avanzado de denudación, con grandes afloramientos rocosos de aspecto dentado (Fernández y Seguel, 1947). Las más altas cumbres de la cuenca corresponden a los cerros "Morros del Fraile" con 1.123 m.s.n.m. y "Las Buitreras" con 1.085 m.s.n.m. (Schlegel, 1963). Debido a la poca altura que alcanzan las cumbres, no es común que en los meses de invierno éstas se encuentren nevadas.

Características hídricas: La presencia de agua en la cuenca se manifiesta mediante escurrimientos estacionales. El escurrimiento máximo se produce en los meses invernales, y se hace prácticamente nulo en los meses del período estival, lo cual condiciona la cantidad de atractivos hidrológicos presentes en el área (López et al., 1998). No obstante, a lo largo de la Quebrada, es común que se formen pequeñas pozas o pozones, debido a que las piedras y rocas existentes en el fondo de la Quebrada, contribuyen a que el agua proveniente de las precipitaciones se acumule. Aún en los meses estivales se puede observar agua en algunas pozas, las que presumiblemente son alimentadas por pequeñas vertientes. Cabe destacar la existencia de una ligera caída de agua denominada comúnmente por los lugareños como "La Cascada". La cantidad de agua que lleva la Quebrada y los otros elementos mencionados anteriormente, está en directa relación con el nivel de precipitaciones caídas durante el invierno.

Importancia del ecosistema: Es uno de los 34 "puntos calientes de biodiversidad" (Hot Spots) del mundo, con cerca del 1% de la biodiversidad mundial, concentrando más de 1.500 especies de flora y fauna endémicas del Bosque Esclerófilo chileno, la mayoría catalogadas por la Unión Internacional para la Conservación de la Naturaleza (UICN) en su Lista Roja como vulnerables y en peligro de extinción. El Estado de Chile en su Estrategia para la Conservación de la Biodiversidad de la Región Metropolitana, lo consigna como Sitio Prioritario (Sitio Prioritario N°2 El Roble). Está catalogado en el Plan Regulador Metropolitano de Santiago (PRMS) como "Zona de Preservación Ecológica" y "Zona de Protección Ecológica con desarrollo Controlado".

Concesiones mineras dentro de la QDP: Existen nueve (9) concesiones mineras otorgadas dentro de la zona de preservación ecológica, de las cuales dos están ya siendo explotadas.

Ecoturísticos: El nombre de la Quebrada de la Plata, se atribuye, por relatos de lugareños, a los acontecimientos acaecidos inmediatamente después de la Batalla de Maipú, el 5 de abril del año 1818. Luego de que Los Patriotas derrotaran a Los Realistas, una de las tropas de éste último, en su huída se perdió, internándose por la Quebrada y para hacer más liviana su carga, enterraron allí sus tesoros y objetos de valor, por lo que esta sería la razón del nombre que hoy en día lleva el lugar. Una segunda interpretación obedece a la presencia de rocas con inserciones de cariz plateado que resplandecen a la luz del sol. Es posible, además, encontrar ornamentos o utensilios mapuches dada su utilización como lugar de tránsito de las comunidades. Se dice que dadas las características de la Quebrada, habría servido como lugar de vigía y puente entre los sectores de Curacaví, María Pinto y Padre Hurtado con el valle de Santiago, utilizado por las huestes de Machimalonco en el asalto a la recién fundada ciudad de Santiago (11 de Septiembre de 1541).

Senderos y Miradores: Existe un Sendero principal, de aproximadamente 4,5 kms. de extensión y 3 mts. de ancho, supuestamente utilizado para la extracción de minerales a inicios del siglo XX. Sirve para acceder al bosque de Peumos y más arriba el bosque viejo de Encinas. Desde este sendero principal se llega a los dos miradores naturales hacia el valle de Maipú y el valle de Curacaví. Se destacan además el Sendero de la Quebrada de los Maquis y el Sendero del Minero, que corresponden a huellas de bajada a la Quebrada principal.

Antigua actividad minera: Sector de los "**Hornos Caleros**" construcciones de piedra, de 7 metros de altura con diferentes niveles de conservación. Su origen data a fines del siglo XIX, construidos para fundir mineral de caliza que se extraía del lugar. Otra historia que se escucha de lugareños, es que fueron construidos por los incas para fundir plata.

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DAÑO PRODUCIDO POR LAS MINERAS AL 11 DE ABRIL DE 2013 EN LA QUEBRADA DE LA PLATA, ASESINATO A LA BIODIVERSIDAD Y ECOSISTEMAS EN LA COMUNA DE MAIPÚ REGIÓN METROPOLITANA

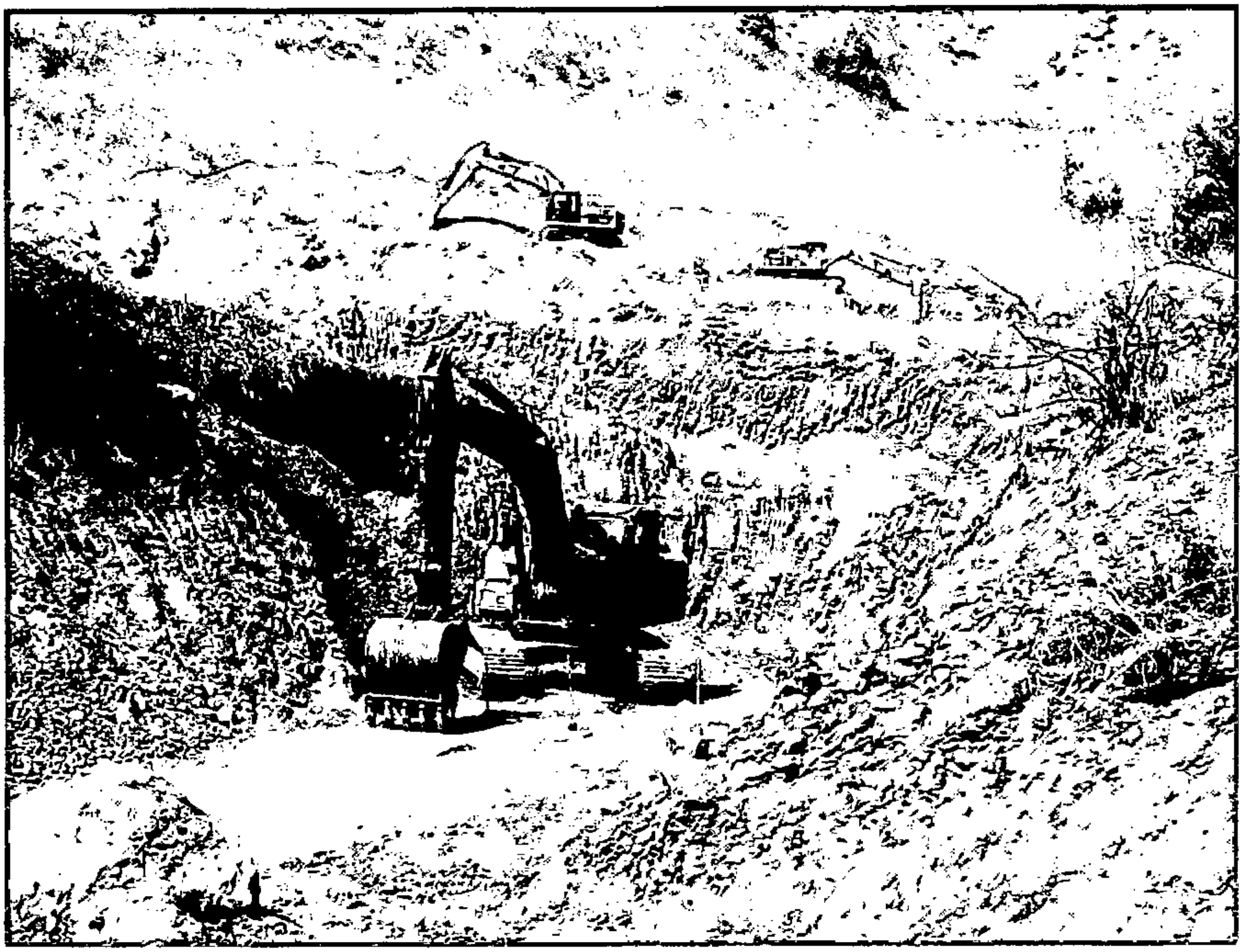
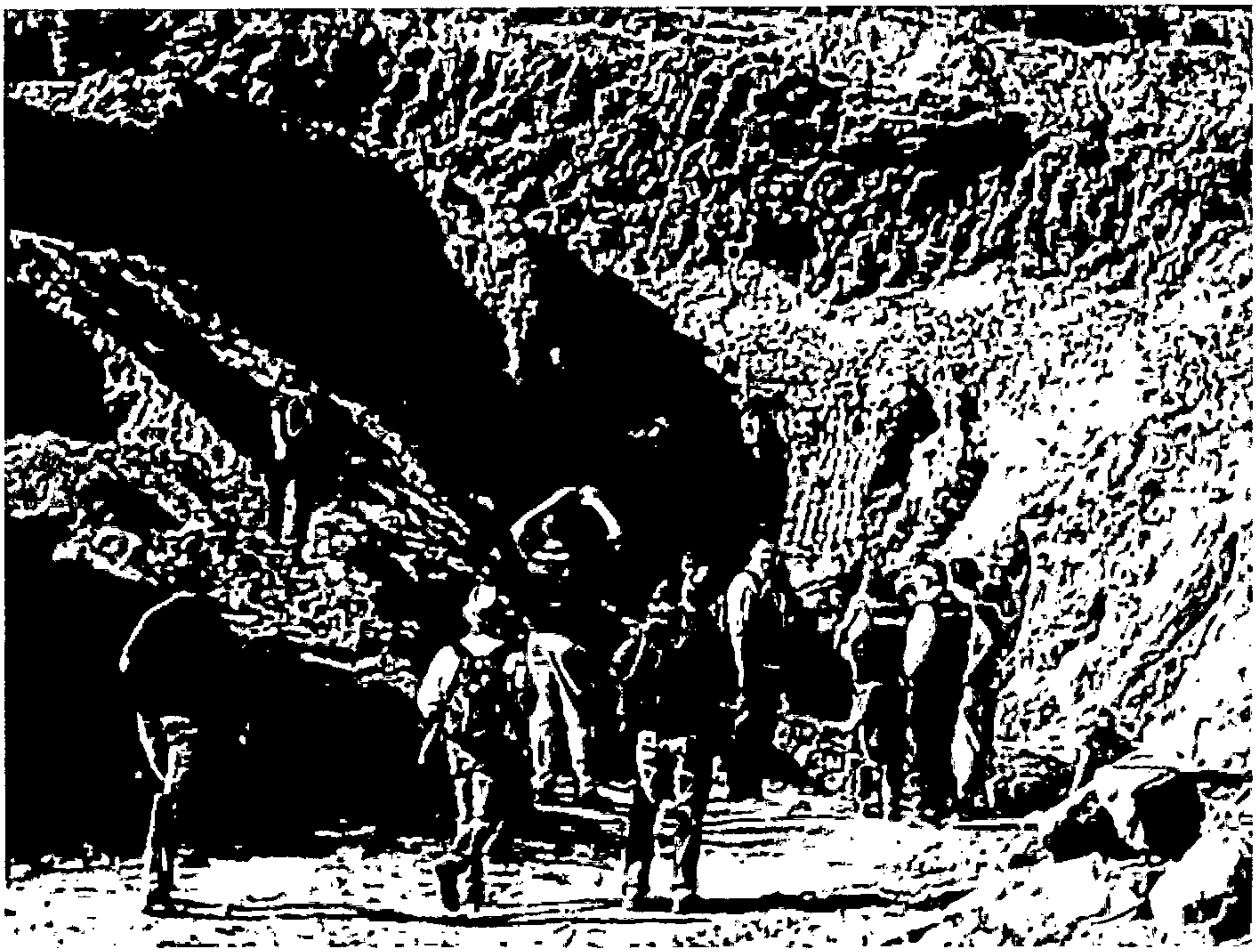


Figura 1: Faena minera de explotación ilegal en Quebrada de la Plata (11-03-2013).



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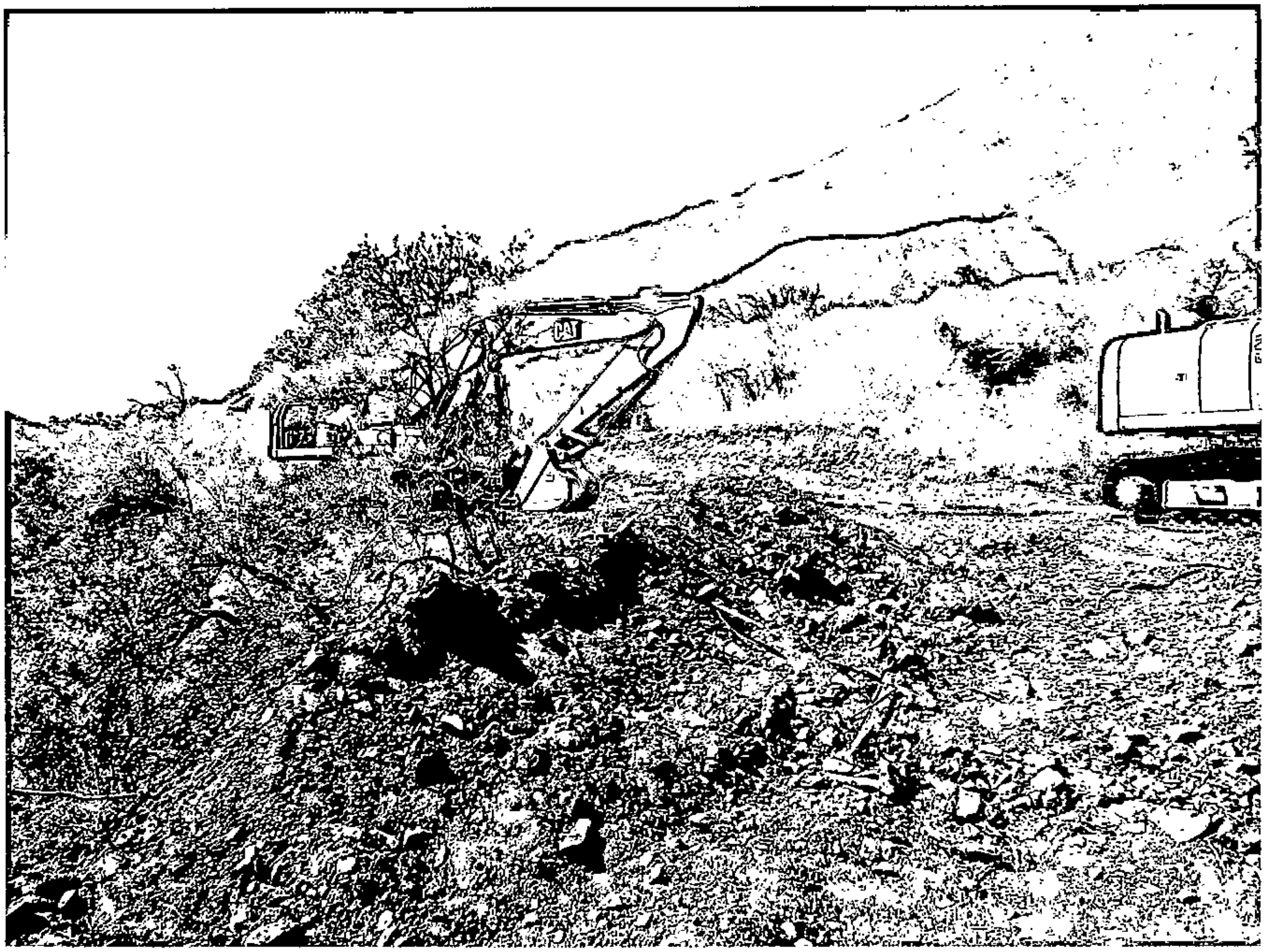

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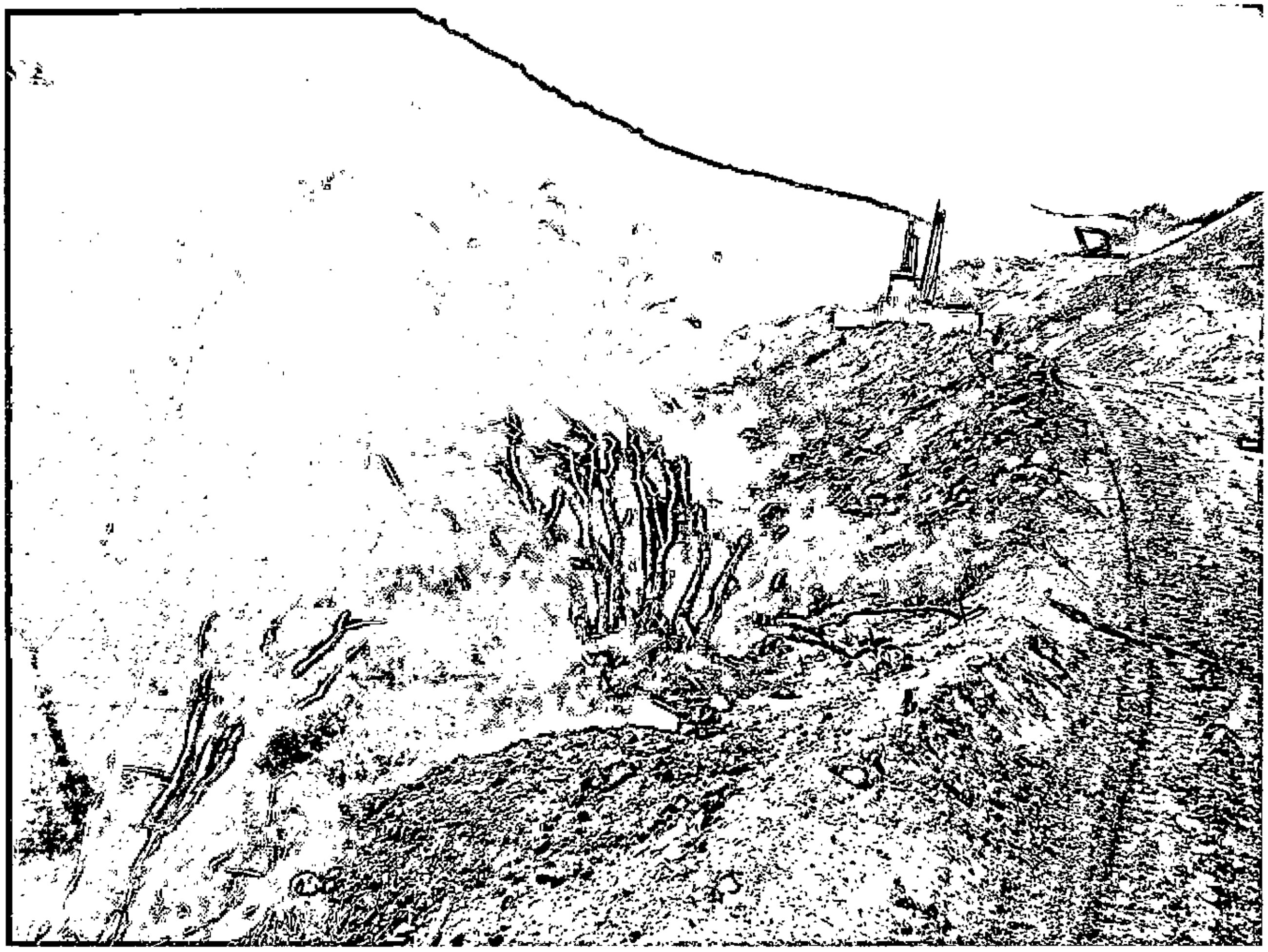

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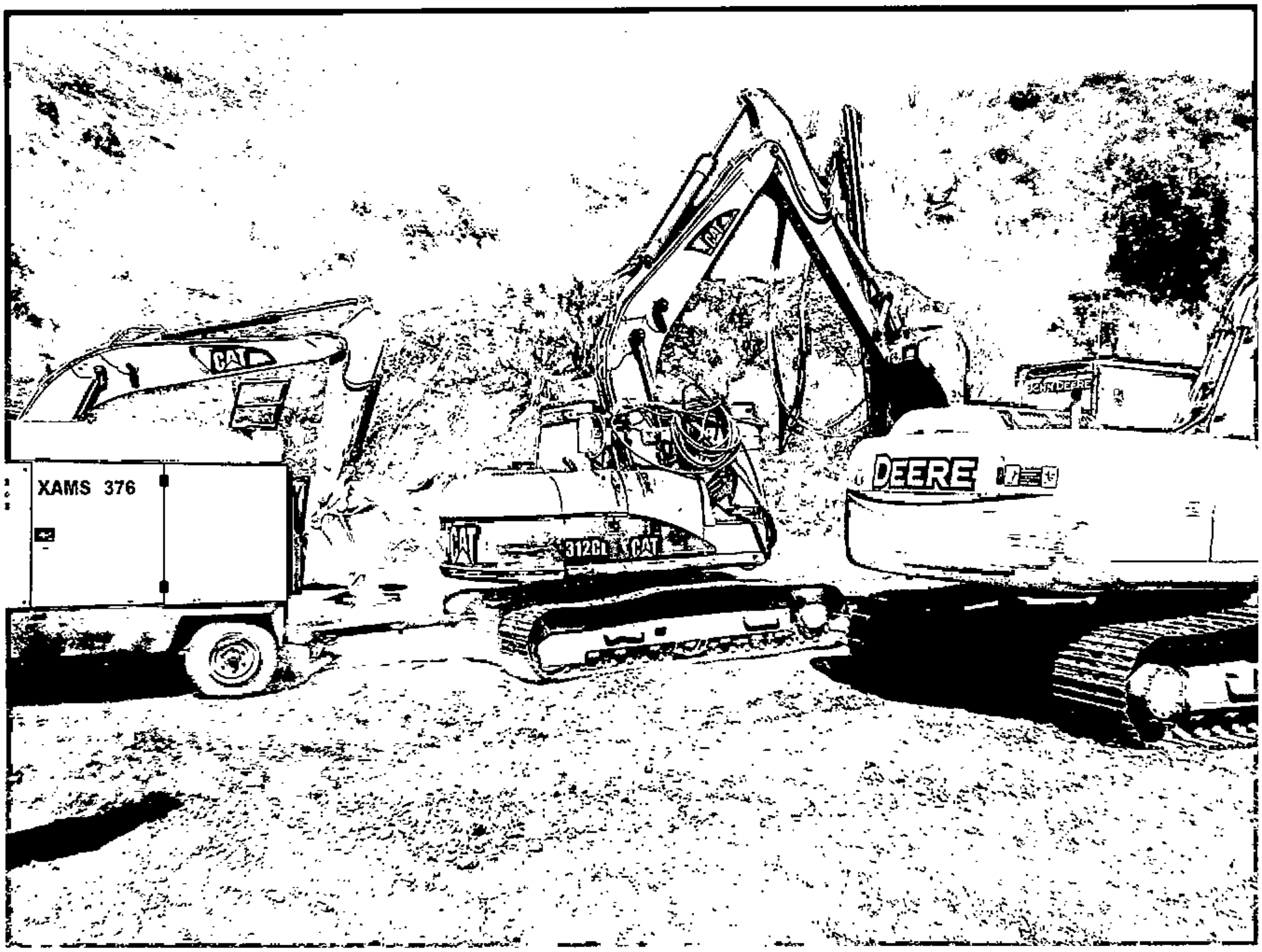

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ESTACIÓN EXPERIMENTAL AGRONÓMICA ***"GERMÁN GREVE SILVA"***
ADMINISTRACIÓN GENERAL

Lunes 8 de Julio de 2013

INFORME TERRENO DE FIZACLIZACIÓN DE REANUDACIÓN DE LA ACTIVIDAD MINERA POR LA SOCIEDAD MINERA ESPAÑOLA CHILE LIMITADA EN EL SECTOR DE LA QUEBRADA DE LA PLATA JUNTO CON PERSONAL DEL MUNICIPIO DE MAIPÚ.

En marco de las ordenes de no innovar de los recursos de protección interpuestos por la Facultad de Ciencias Agronómicas de la Universidad de Chile en contra de la Sociedad Minera Española Chile Limitada por actividad minera en la comuna de Maipú por grave daño al patrimonio y la biodiversidad en el sector denominado QUEBRADA DE LA PLATA, ubicada al interior de la Estación Experimental Agronómica Germán Greve Silva de la Facultad de Ciencias Agronómicas de la Universidad de Chile, el día 04 de abril de 2013 se procedió a realizar una fiscalización en terreno por la reanudación de los trabajos de explotación en un SITIO PRIORITARIO EL ROBLE Nº 2 del cual forma parte la Quebrada de la Plata.

La inspección se realizó con Dr. Christian Sepúlveda C. Jefe de la Unidad de Planificación y Fiscalización Medioambiental de la Dirección de Inspección de la Ilustre Municipalidad de Maipú (6776756 csepulveda@maipu.cl) junto a todo el aparato administrativo de la alcaldía de Maipú encabezado por medio ambiente, unidad de evaluación ambiental, coordinadora del CAM, coordinador saneamiento ambiental, defensor ciudadano, departamento de inspección, jurídica y representante de la Universidad de Chile, Sr. Marcelo Orellana en su calidad de administrador de la Estación Experimental Germán Greve Silva.**(Anexo 1: Acta de inspección).**

Se constata en terreno que las actividades mineras se encontraban en operación con maquinaria pesada de explotación, sectores estacados prohibiendo el ingresos y obstrucción del sendero natural para evitar el ingreso como tambien el ensanchamiento y construcción de caminos para maquinaria de alto tonelaje. **(Anexo 2: Set de Fotografías de Inspección).**

ANEXO 2
SET DE FOTOGRAFÍAS

Figura 1: Inspectores municipales constatando en terreno de la reanudación de la actividad minera en sitio prioritario El Roble N° 2, sector Quebrada de La Plata. (04-07-2013).

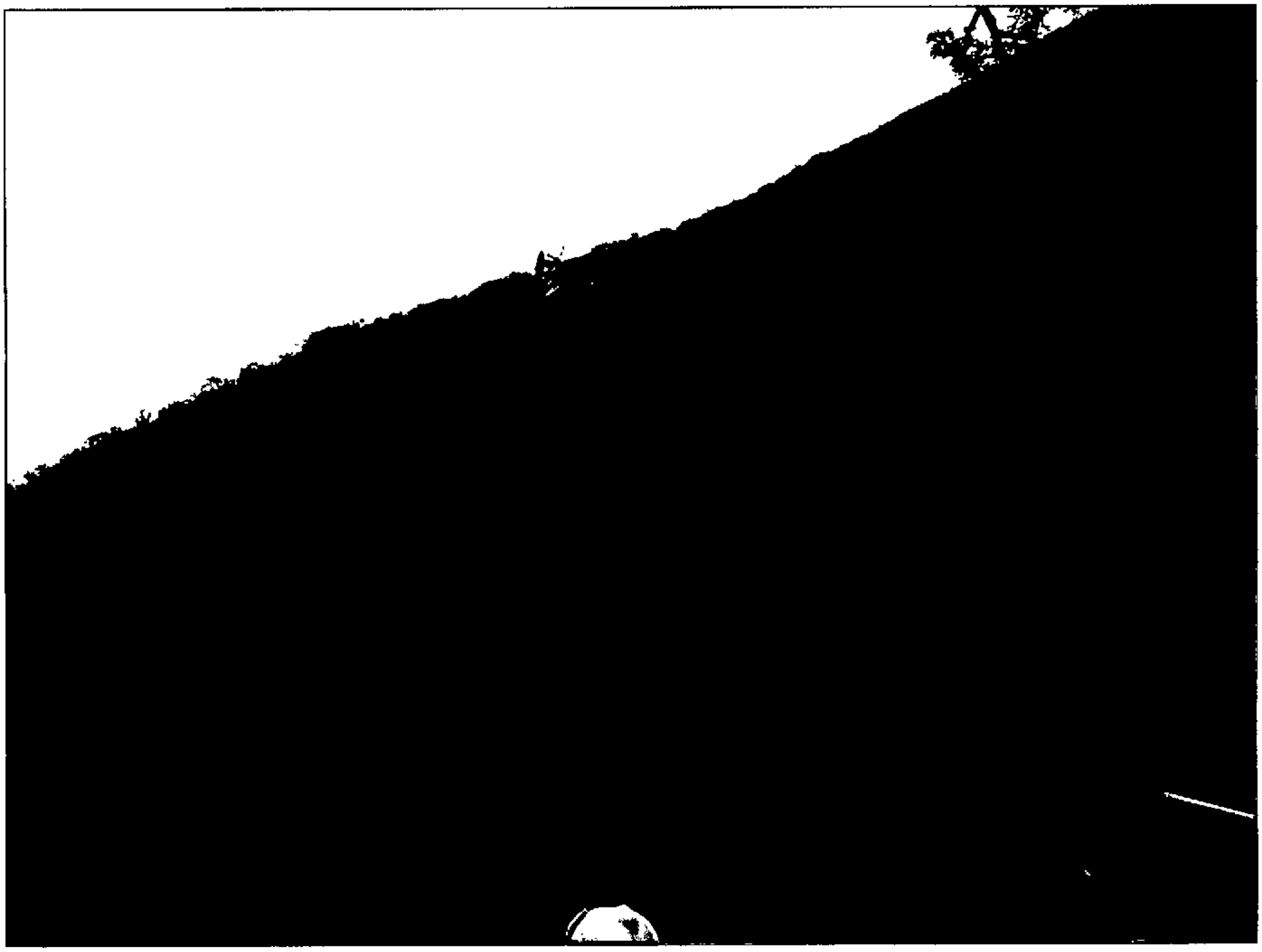

Figura 2: Instalación de estacas y letreros reanudando la actividad minera en Quebrada de La Plata (04-07-2013).

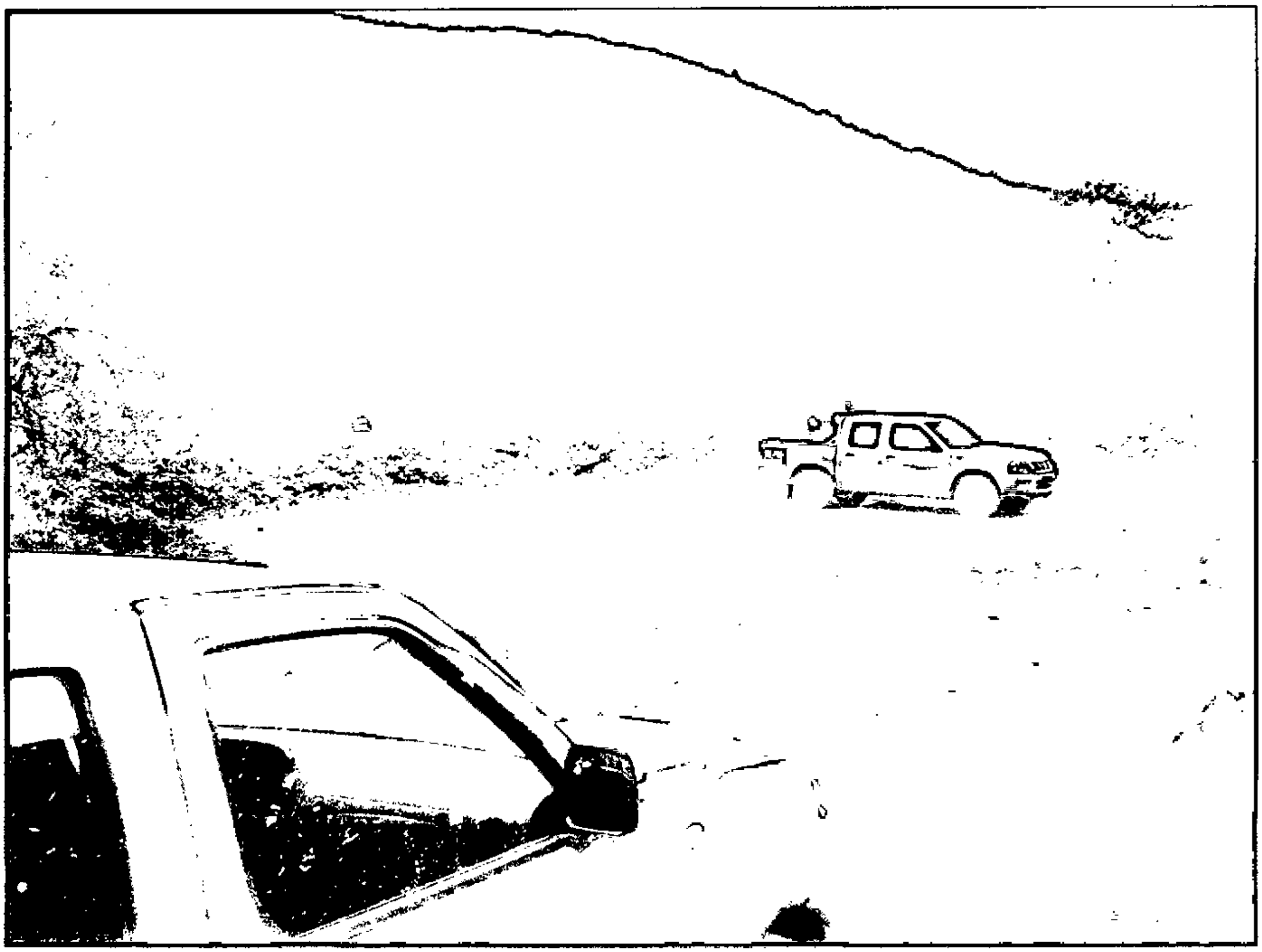

Figura 3: Actividad minera activa en campamento minero en Quebrada de La Plata (04-07-2013).

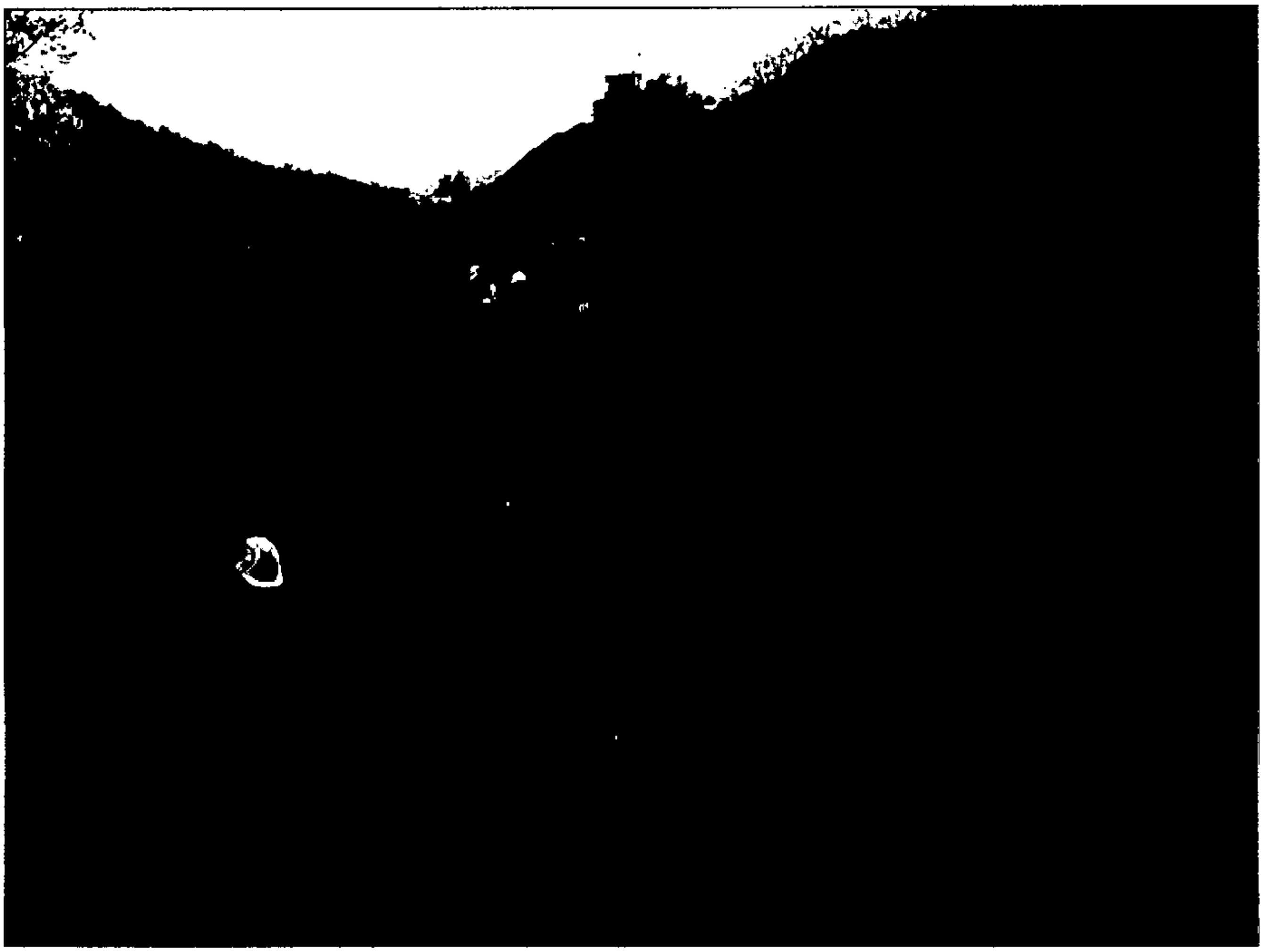

Figura 4: Inspector municipal constatando la actividad minera en terreno apreciando el estacado del sendero para la reanudación de la explotación. (04-07-2013).

Figura 5: Reanudación de actividad minera en La Quebrada de La Plata. (04-07-2013).

Figura 6: Ensanchamiento del sendero para el tránsito de maquinaria pesada en sector de La Quebrada de La Plata, Sitio Prioritario El Roble N° 2. (04-07-2013).

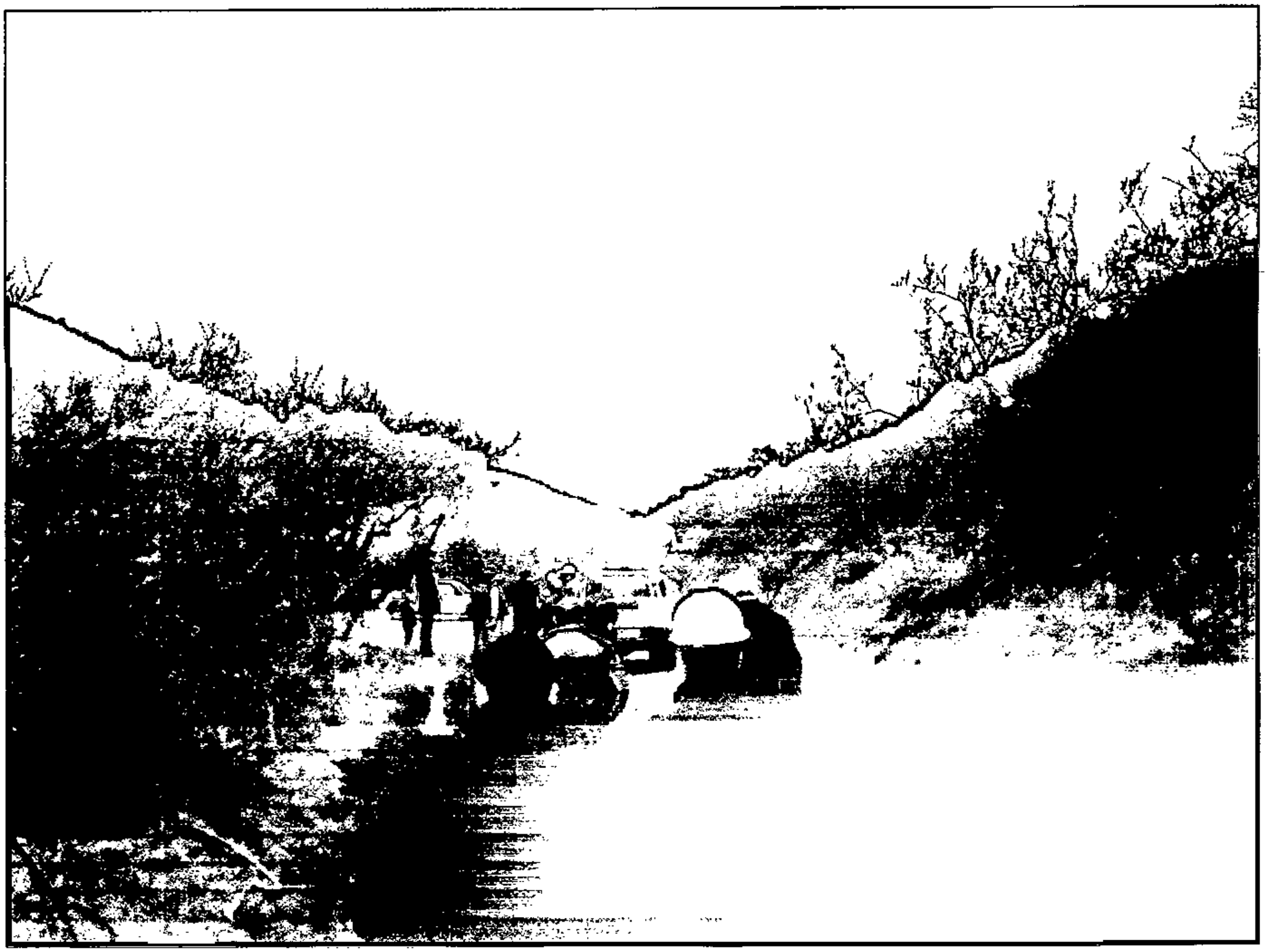

Figura 7: Inspectores municipales y de medio ambiente de la Municipalidad de Maipú constatando la reanudación de la actividad minera en el sector de la Quebrada de La Plata, Sitio Prioritario El Roble N° 2. (04-07-2013).

Atentamente,

MARCELO ALEJANDRO ORELLANA REYES
Administrador General
Estación Experimental Agronómica
Germán Greve Silva-Rinconada de Maipú

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últimas acciones Quebrada de La Plata

Estimado Roberto:

Estas han sido las ultimas acciones de fiscalización en Quebrada de La Plata:

1.- 23 de abril de 2014: fiscalización a la Quebrada de la Plata con personal de CONAF los señores Eduardo Matias Díaz Calderón(eduardo.diaz@conaf.cl) y la señora Marcia Villanueva (marcia.villanueva@conaf.cl). Se comprueba que siguen trabajando. CONAF, de acuerdo a sus mediciones en terreno del daño en el Bosque esclerófilo realizará una nueva denuncia a juzgado de policía local.

2.- 03 de junio de 2014: Fiscalización con personal del SERNAGEOMÍN por no acatar las resoluciones de paralización interpuestas por esta entidad.
Las resoluciones son:
a) Resolución Exenta Nº 0630 del 31 de marzo de 2014.
b) Resolución Exenta Nº 442 del 01 de abril de 2014.
c) Resolución Exenta Nº 0950 del 14 de mayo de 2014.

3.- 27 de Junio de 2014: Fiscalización mediática con periodistas del canal TELESUR (reportaje salió en mismo día en canal 722 en horario de noticias).

4.- 30 de junio de 2014: Fiscalización con personal de la BIDEMA-PDI por causa RUC: Nº 13.100.230.63-6 por desacato de la minera y que lleva la Fiscalía Local de Maipú a cargo del fiscal sr. Juan Gormaz Oliveira.

Roberto, esto es lo último que yo he realizado en terreno con las personas antes mencionadas.

Telefono Fima: 22221670, no tengo el celular.

Saludos

Atentamente,

Estación Experimental Germán Greve Silva
ADMINISTRACIÓN

MARCELO ALEJANDRO ORELLANA REYES
Administrador General
Estación Experimental Agronómica
Germán Greve Silva-Rinconada de Maipú

CAMINO RINCONADA KM. 7 MAIPÚ
FONO 531 1036 – FAX 531 1012
E-mail maorella@uchile.cl

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Martes 3 de Junio de 2014

LISTA DE ASISTENCIA A TERRENO 03-06-2014 PARA FISCALIZACIÓN ACTIVIDAD MINERA EN QUEBRADA DE LA PLAATACON PERSONAL DEL SERNAGEOMÍN ZONA CENTRAL

Nombre	Institución	teléfono	Correo (E-mail)	Firma
Marcelo Orellana	U. de Chile	56-2-25311036	maorella@uchile.cl	
BENITO CANELO A.	SERNAGEOMIN	5632-2820116	~~benito~~ benito.canelo@sernageomin.cl	
Miguel Canales	Sernageomin		Miguel.canales@sernageomin.cl	
Rodrigo Cortés C.	Sernageomin	56-32 2820116	Rodrigo.cortes@sernageomin.cl	

Marcelo Orellana R.

Estación Experimental Germán Greve Silva
ADMINISTRACION

SINTESIS DE LA VISITA REALIZADA A LA ESTACIÓN EXPERIMENTAL AGRONÓMICA GERMAN GREVE.

Profesores: Ing. Agr. MSc. Jaime Rodríguez M.
Ing. Agr. Dr. Máximo Alonso V.

Estudiante: Sebastián Borquez C.

Enero de 2014.

IMPACTO ECOLOGICO PRELIMINAR DE LA INSTALACIÓN DE EMPRESAS MINERAS EN QUEBRADA DE LA PLATA.

El ingreso de camiones por el camino de ingreso a la Quebrada de La Plata, ha ocasionado la destrucción total de la vegetación tanto arbustiva como arbórea en 2 a 3 metros hacia ambos lados del camino. (Fotografías 1, 2 y 3). Hacia el interior de la quebrada principal llegando al inicio de uno de los principales bosques de Peumo *(Cryptocarya alba)*, se pudo observar la destrucción de árboles de más de 80 años de edad (Fotografías 4 y 5).

Por otra parte, en el fondo de la quebrada no hay agua y aparentemente la napa freática ha desaparecido. Cabe preguntarse si la explotación minera es causal de esta disminución en el agua ya que ellos requieren de este vital elemento en el desarrollo de sus labores de explotación.

En relación al daño causado por los incendios se pudo determinar que el principal incendio se propagó hasta el predio de la Facultad desde el predio San Francisco, afectando una parte de la pradera y de cercos de la ovejería y hacia la quebrada afectó levemente a la ladera de exposición norte cuya vegetación en general está adaptada a condiciones de sequía lo que ayuda a resistir fuego de corta duración (estas especies poseen raíces pivotantes, emiten estolones y tienen gran poder de rebrote durante la primavera). (Fotografía 6).

Junto a lo anterior, destaca la presencia de otro incendio ocurrido en la ladera de exposición sur, donde existe una vegetación latifoliada con árboles de mayor valor. El origen de este incendio pudo provenir desde el sector alto del lado derecho de la quebrada, que es donde se encuentra la explotación minera. Este incendio afecto fuertemente a árboles de gran tamaño (por lo menos 30 a 40 individuos de las especies Quillay (*Quillaja saponaria*), Peumo *(Cryptocarya alba)* y Litre (*Lithraea caustica*), de por lo menos 80 años de edad. (Fotografía 7)

Cabe destacar que el impacto de este incendio no sólo afectó a árboles, arbustos y terófitas, sino que su efecto pudo incidir en especies de reptiles de gran interés para la Región Metropolitana, como son: culebras, lagartijas, lagartos e iguanas, que se encuentran en peligro de extinción o en serio retroceso numérico a nivel regional, siendo la Quebrada de La Plata actualmente un importante reservorio de estas especies.

Lamentablemente a este último lugar en la ladera de exposición sur no fue posible acceder debido a que la empresa minera que ocupa parte del predio de la Facultad cerró en forma ilegal el camino de acceso, poniendo alambres de púas, perros enjaulados y dos guardias, además de letreros (Fotografía 8, 9 y 10).

La empresa minera no sólo ha afectado el paisaje al ingreso de la quebrada y notablemente en el sector donde están explotando minerales, sino que además, se ha arrogado la Facultad de impedir el ingreso de los propios académicos y del Sr. Administrador de la Estación Experimental a sectores que son parte del predio que pertenece a la Universidad de Chile.

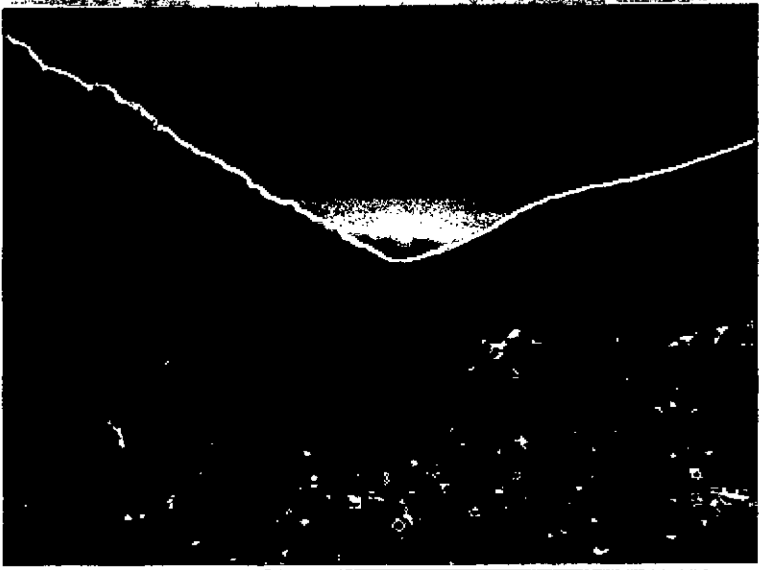
Actualmente nuestra Facultad cuenta con los especialistas necesarios para realizar las investigaciones que dicen relación con los impactos causados, tanto por los incendios, como por la acción de las explotaciones mineras. El eventual ingreso de personal ajeno a la Facultad podría agravar las relaciones con los guardias de la empresa minera y la permanencia de estudiantes no capacitados para reconocer las especies de roedores que habitan en Quebrada de La Plata, puede llevarlos a contraer enfermedades como el Hanta virus, ya que se han detectado especies de roedores positivas a este virus en esta localidad.

En la visita hasta el lugar ocupado por la empresa minera, fuimos acompañados por el señor Marcelo Orellana, Administrador de la Estación Experimental Germán Greve y por cuatro funcionarios de carabineros de una entidad especializada en hacer cumplir las resoluciones de la Corte Suprema a quienes se les permitió acceder a las oficinas de la empresa minera.

Sería fundamental para nuestra Facultad conocer a la brevedad los resultados de la reunión entre estos carabineros y los ejecutivos de la empresa minera.

Fotografia 1.

Fotografia 2.



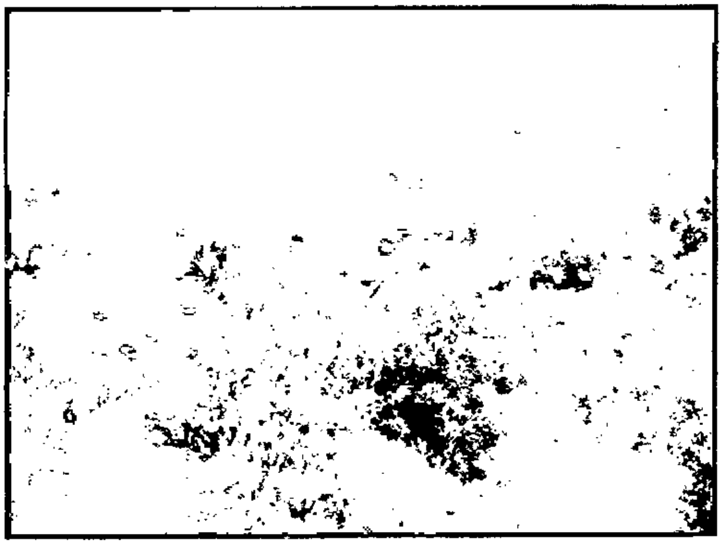
Fotografia 3.

Fotografia 4.

Fotografia 5.

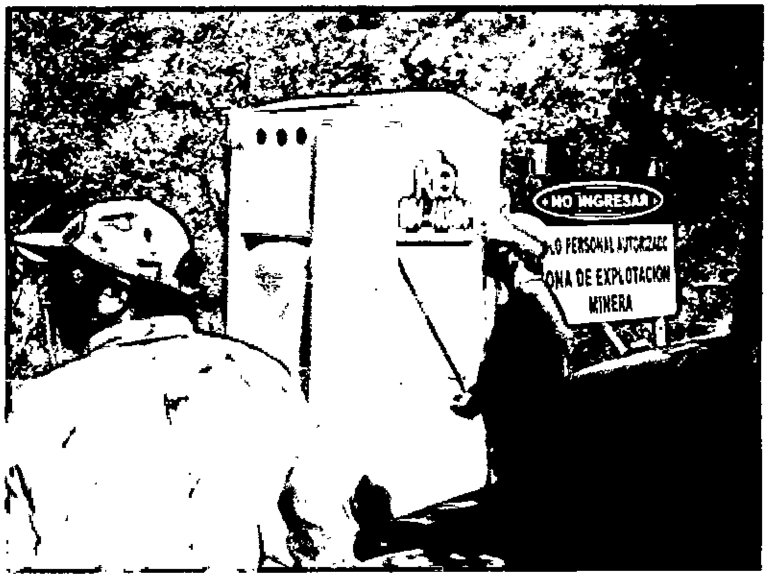
Fotografia 6.

Fotografía 7.



Fotografía 8.

Fotografía 9.



Fotografía 10.

quebrada de la plata

DOCUMENTO FINAL

Proyecto Parque Natural Quebrada de La Plata
Ilustre Municipalidad de Maipú
Enero de 2014

Resumen Ejecutivo

La presente propuesta invita a pensar en grande y a hacer realidad un sueño que es convertir a la cuenca de la Quebrada de la Plata en el parque natural más importante de la región Metropolitana, realzando su vocación tanto en el ámbito paisajístico y de monumento natural, así como también de ser una zona única para el desarrollo de actividades de educación ambiental formal y no formal, un parque natural con estándares en infraestructura y equipamiento a nivel internacional y por sobre todo con un modelo de gestión y de administración eficiente y de alta calidad, permitiendo de esta forma proteger y valorar este lugar, no tan solo pensando en el presente sino más bien en el futuro y en las próximas generaciones.

Para lograr lo anterior, la municipalidad de Maipú y la Universidad de Chile, a través de la Facultad de Ciencias Forestales y Agrarias, quien es propietaria del predio y donde se emplaza la Estación Experimental Agronómica Germán Gravé Silva, están impulsado una serie de gestiones tendientes a generar un Acuerdo Marco que permita, por una parte crear una Corporación Ambiental de derecho privado, y por otra generar los instrumentos de gestión que transformen a la Quebrada de la Plata en el parque natural más importante de la región Metropolitana, cuya vocación será el cuidado y protección de este patrimonio natural, así como también impulsar actividades de educación ambiental, capacitación y docencia, que permitan conciliar los intereses de la Universidad de Chile con los intereses de la comunidad maipucina.

La suscripción de este **Convenio o Acuerdo Marco** entre la Municipalidad de Maipú y la Universidad de Chile (Facultad de Ciencias Agronómicas), permitirá trabajar en conjunto para la creación del parque natural Quebrada de La Plata, el cual debe ser construido desde una visión de cuenca que considera y recoge su estatus legal de protección del área, sus elementos geográficos, derechos de propiedad, caracterización ecológica y paisajística, potencialidades turísticas y de actividades al aire libre en beneficio de la comunidad estudiantil de la Universidad de Chile y otras universidades, así como también de los vecinos de la comuna de Maipú y de otras comunas del Gran Santiago y de la Región Metropolitana.

El Acuerdo propuesto, será el **punto de partida y la gran señal a la comunidad** de la voluntad y responsabilidad de sus propietarios y municipio por la creación del parque natural Quebrada de La Plata.

"Dicho compromiso se debe fundamentar en:

1. Convertir la quebrada de la Plata con sus 1.043 ha., en un parque natural de protección y conservación al servicio de la ciudad y en especial de la comunidad Universitaria y de los vecinos de la comuna de Maipú, cuyo nombre será "Parque Natural Quebrada de La Plata".

2. Crear una entidad (Corporación) de derecho privado sin fines de lucro, que será la que tendrá la administración del parque.

3. Su objeto será desarrollar y promover la conservación y protección de la biodiversidad, la educación ambiental formal y no formal y el geoturismo de naturaleza.

4. Compatibilizar y respetar que los intereses privados y públicos involucrados en las diferentes iniciativas que se desarrollen, lo hagan en armonía con los objetivos del parque.

5. Establecer todos los mecanismos institucionales y prácticos que hagan que el cuidado y desarrollo del parque sea una Responsabilidad Social Compartida (municipio-universidad-vecinos).

6. Plasmar el Interés superior de cuidar el parque para las actuales y futuras generaciones, a través de la elaboración e implementación de instrumentos de gestión territorial y de protección legal.

7. Desarrollar un sistema de gestión y administración que sea eficiente y solidario (integradora de la comunidad).

8. Diseñar e implementar un Sistema de financiamiento diversificado (público – privado) que dé cuenta de las necesidades de desarrollo del parque.

9. Diseñar un sistema de guardaparques que cumpla un servicio de orientar al visitante, cuidar los recursos naturales y prevenir acciones ilegales o de riesgo (vigilancia – seguridad – educación y conciencia).

A través del siguiente documento técnico, se entregan antecedentes históricos y recientes de la Quebrada de La Plata, lineamientos básicos, propuestas y recomendaciones que deben ser el punto de partida para cualquier acción que se tome pensando en la consecución de este sueño, este sueño de muchas personas que se llama "Parque Natural Quebrada de La Plata".

A. Presentación

La Comuna de Maipú se localiza geográficamente al poniente de la provincia de Santiago, en la Región Metropolitana de Chile. Su territorio limita con 4 comunas: Por el Norte la comuna de Pudahuel y Estación Central, por el sur con La comuna de Padre Hurtado, al oriente con la comuna de Cerrillos, y al poniente con las comunas rurales de Curacaví.

Maipú, que en mapudungun *"maipún"* significa *"Lugar Arado"*, es una comuna socialmente heterogénea cuyo desarrollo histórico ha conformado un patrón urbano muy particular, altamente segregado y carente de espacios públicos que se orienten a la integración de los diversos grupos sociales y socioculturales que lo conforman. Cada barrio o entidad geográfico-administrativa de mayor escala, en efecto, contempla espacios públicos, la mayoría de los cuales aún se encuentran en etapa de implementación y consolidación. La Quebrada de la Plata, emplazada en la precordillera de la costa de la región Metropolitana, corresponde al único espacio natural que es utilizado espontáneamente por la población de Maipú a pesar de ser un área privada.

No obstante, la población de la comuna de Maipú (525.229 habitantes, según censo año 2012), producto de la expansión urbana y nuevos proyectos privados durante los últimos 20 años, está perdiendo uno de los principales espacios de esparcimiento, recreación y educación ambiental que tradicionalmente e históricamente había sido aprovechado por familias y vecinos de la comuna de Maipú y otras comunas de la Región Metropolitana, lo anterior se explica entre otras cosas por el crecimiento urbano y la proliferación de proyectos mineros a pequeña y mediana escala emplazados en la precordillera de la costa, impidiendo el libre acceso de las personas a los lugares que habían sido utilizados históricamente para actividades de vida al aire libre, deporte, recreación, educación ambiental, picnic y camping.

Debido a lo anterior, el municipio liderado por su Alcalde Don Cristian Vittorí, se ha planteado un sueño y puesto como gran meta la creación de un parque natural periurbano en los terrenos de la quebrada de la Plata, lo anterior con el objeto de canalizar las necesidades de áreas verdes y espacios naturales que tienen los habitantes de la comuna de Maipú y también de la ciudad de Santiago, así como también la protección y conservación de este patrimonio natural, con el fin de realizar en este parque natural actividades deportivas, recreativas, turísticas y de educación formal y no formal permitiendo mejorar sustancialmente la calidad de vida de las personas y las necesidades de áreas verdes de los ciudadanos de la Región Metropolitana.

Para lograr lo anterior, la municipalidad de Maipú y la Universidad de Chile, a través de la Facultad de Ciencias Forestales y Agrícolas, quien es propietaria del predio y donde se emplaza la Estación Experimental Agronómica Germán Gravé Silva, están impulsado una serie de gestiones tendientes a generar un Acuerdo Marco que permita, por una parte crear una Corporación Ambiental de derecho privado, y por otra generar los instrumentos de gestión que transformen a la Quebrada de la Plata en el parque natural más importante de la región Metropolitana, cuya vocación será el cuidado y protección de este patrimonio natural, así como también impulsar actividades de educación ambiental, capacitación y docencia, que permitan conciliar los intereses de la Universidad de Chile con los intereses de la comunidad maipucina.

B. Localización

La Quebrada de la Plata se ubica en la cordillera de la Costa, en la región Metropolitana de Santiago entre las comunas de Pudahuel y Padre Hurtado. Su cuenca hidrográfica es la primera en importancia en este sector precordillerano, con una superficie aproximada de 1.043 hectáreas correspondiente al 7.6% de la superficie de la comuna de Maipú, de las cuales una parte de ellas es utilizada por la Estación Experimental Agronómica de la Universidad de Chile.

Sus límites son: por el Norte la divisoria de aguas que separa las comunas de Maipú y Pudahuel, por el Este, el predio del Ejército de Chile y la Estación Experimental Agronómica de la Universidad de Chile. Por el sur la línea divisora de aguas que separa las comunas de Padre Hurtado y Maipú, y por el Oeste la cota 950 (msnm) límite de la comuna de Maipú.

Por su localización geográfica, posee pisos altitudinales de vegetación nativa pertenecientes al bosque y matorral esclerófilo de Chile Central que además es un ecosistema de variada fauna nativa. Asimismo, las unidades de paisaje asociadas a estos biotopos permiten configurar un importante patrimonio natural aledaño a la ciudad de Santiago.

Además la quebrada de la Plata se emplaza en una zona catalogada como Sitio Prioritario para la Conservación de la Biodiversidad de la Región Metropolitana denominado "El Roble" Sitio N°2, Incluida en la estrategia de Conservación de la Biodiversidad de la Región Metropolitana.

Por ultimo este ecosistema donde se emplaza la quebrada de la Plata tiene un reconocimiento internacional al ser considerada como uno los 25 sitios de prioridad para la conservación de la biodiversidad mundial (hot spot).

En este contexto se enmarca la quebrada de La Plata como una de las áreas de mayor interés ecológico de este sitio prioritario, donde se conjugan una serie de factores ambientales que la relevan dentro de esta zona de protección. Las "Unidades de Paisaje" predominantes en el área son: quebradas, laderas y laderas altas. La vegetación presente en el área corresponde a la del Matorral y Bosque Esclerófilo de Chile Central cuyas especies características son: arbóreas, el litre (Lithrea caustica), quillay (Quillaja saponaria), maitén (Maytenus boaria); arbustivas, romerillo (Baccharis linearis), colligay (Colliguaja odorifera), crucero (Colletia spinosa); herbáceas de floración anual, alstroemerias (alstroemeria ligtu ssp. Simsii), huilli (Leucocoryne ixioides), placeas (Placea arzae).

De acuerdo a la clasificación de "Formaciones Vegetales" estas corresponden predominantemente a: bosque semidenso, matorral arborescente semidenso, matorral semidenso y pradera altoandina, con presencia de flora en categoría de conservación. Dentro de la fauna característica en el lugar se pueden observar aves, reptiles, y mamíferos de gran importancia para el desarrollo del ecosistema de la cordillera de la costa.

C. Antecedentes Biofísicos

El área natural del territorio de la Quebrada de la Plata es de **1.043 ha** "comprende el territorio emplazado fuera de las áreas urbanizadas y urbanizables, que tienen un interés natural o paisajístico y/o presentan vegetación y fauna silvestre, cursos o vertientes naturales de agua y que constituyen **un patrimonio natural que debe ser protegido o preservado", para los efectos de las normas que le son aplicables el instrumento de planificación territorial metropolitano lo ha definido como "área de preservación ecológica"** que "Son aquellas áreas que serán mantenidas en estado natural, para asegurar y contribuir al equilibrio y calidad del medio ambiente, como asimismo preservar el patrimonio paisajístico" [1].

Desde un punto de vista biofísico, la Quebrada de la Plata es parte del ecosistema montañoso mediterráneos de la zona central de Chile, ecosistema que ha sido catalogado como uno de los cinco de su tipo en el mundo, el único en toda Sudamérica y, desde una mirada conservacionista, como uno de los 25 sitios de prioridad para la biodiversidad mundial. A nivel regional, la precordillera conforma un importante patrimonio ambiental y cultural para la ciudad de Santiago, razón por la cual fue incluida el 2005 dentro de los Sitios Prioritarios para la Conservación de la Biodiversidad de la Región Metropolitana, aprobada por Resolución Exenta N°184/05 de la Corema RMS.

Sólo en la Precordillera de Santiago, los estudios han identificado 398 especies de flora de las cuales 346 son nativas y 52 introducidas, y ocho han sido catalogados como "vulnerables", es decir, en un nivel de conservación bastante comprometido. Y en relación a la fauna se han identificado 82 especies de las cuales 60 corresponden a aves, 10 a mamíferos, 10 a reptiles y 2 a anfibios. De éstas, 17 especies presentan problemas de conservación el halcón peregrino *(Bulteo albigula)*, el zorro culpeo

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4, "Plan Regulador Metropolitano de Santiago" (PRMS), Título VIII.

(Pseudolapex culpaeus), algunas culebras *(Phylodryas) chamissonis* y *Tachymenis chilensis)*, varias especies de lagartija *(Liolaemus chilensis, Liolaemus fuscus, Liolaemus lemniscatus)* y dos especies de anfibios *(Alsodes nodosus* y *Pleurodema thaul)*.

Por otro lado, desde una mirada más social, la Organización Mundial de la Salud (OMS) ha señalado que para tener una alta calidad de vida, se requiere que las ciudades tengan por habitantes 9 m^2 de áreas verdes, lo cual en Santiago, lo mismo para la comuna, las cifras bordean entre un 2,4 m2 a un 4% en promedio. Ante este déficit y la creciente demanda ciudadana para usar espacios al aire libre con fines recreativos, deportivos y educativos, la precordillera de la costa constituye en un gran aporte ambiental a la ciudad y a la calidad de vida de sus habitantes.

En este contexto, se hace imprescindible contar para este patrimonio natural con una línea base biofísica, una zonificación de áreas prioritarias y un plan de ordenamiento y manejo de la cuenca de la quebrada de La Plata, con el objeto de guiar las futuras intervenciones sobre el territorio, y dar consistencia técnica a la valoración y conservación ambiental de este lugar.

UNIVERSIDAD DE CHILE
Facultad de Ciencias Agronómicas

SOLICITUD PARA LA DECLARACIÓN DE SANTUARIO DE LA NATURALEZA A LA 'QUEBRADA DE LA PLATA' DE LA UNIVERSIDAD DE CHILE

Santiago, septiembre de 2013

SOLICITUD DE DECLARACIÓN DE SANTUARIO DE LA NATURALEZA

1.- ANTECEDENTES GENERALES

a.- Carta dirigida a Ministra de Medio Ambiente (hacer carta)

b.- Identificación del solicitante:

Nombre : Universidad de Chile
Rut : 60.910.000-1
Representante legal : Sr. Víctor Pérez Vera, Rector
Fonos : (56)-2-29781003/1004
Correo electrónico : rectoria@uchile.cl
Dirección Postal : Av. Diagonal Paraguay 265, Piso 4, Of. 402, Comuna de Santiago.

c.- Documento que acredite la propiedad sobre el área que se postula

Se adjunta

d.- Documento que acredite la conformidad de el o los propietarios del área para que ésta sea postulada como Santuario de la Naturaleza.

Se adjuntan carta del Sr. Rector de la Universidad de Chile dirigida a la Ministra de Medio Ambiente.

e.- Documentos que de cuenta de los usos actuales o potenciales para el área que se postula y el área adyacente (área de amortiguación o influencia)

f.- Cartas de apoyo u opinión de la declaración por parte de la(s) autoridad(es) competente(es), de los servicios públicos y de la comunidad, cuando procediera.

Se adjuntan diversos documentos que reflejan la preocupación de varios servicios públicos como también de la comunidad. Uno de estos documento el Dictámen del Segundo Juzgado de Policía Local de Maipú, Proceso Rol No. 398-2013 en que se multa a la Minera Española Chile Limitada, con fecha 25 marzo 2013.

Y los siguientes oficios asociados a la causa ROL No. 9206-2010 que dan cuenta de la destrucción del ecosistema debido la actividad minera en la QDP. Estos oficios fueron enviados por el Secretario Regional Ministerial de Medio Ambiente a la Jueza Titular del Tercer Juzgado civil de Santiago el 15 de Enero 2013:

i) Oficio Ord. RRNN No. 1845 del Secretario Regional Ministerial del Medio Ambiente, de 9 Noviembre 2012
ii) Informe Técnico DGA RMS No. 340, de 13 de septiembre 2011
iii) ORD 1185, de 11 agosto 2011 que contiene Pronunciamiento del Servicio Agrícola y Ganadero Región Metropolitana de Santiago, servicio que denuncia faena minera en QDP

iv) ORD. No. 159/2011 de 11 de agosto 2011 de la CONAF, que informa a la SEREMI de Medio Ambiente por la corta de vegetación nativa

2.- IDENTIFICACIÓN DEL ÁREA PROPUESTA

a.- Localización del predio: Región, Provincia, Comuna.

El predio se encuentra localizado al interior de la Estación Experimental Agronómica Germán Greve Silva, perteneciente a la Facultad de Ciencias Agronómicas de la Universidad de Chile, ubicada Comuna de Maipú, provincia de Santiago, Región Metropolitana.

b.- Nombre del área propuesta como Santuario de la Naturaleza

Quebrada de La Plata

c) Superficie en hectáreas del área propuesta como Santuario de la Naturaleza

800 hectáreas, que corresponde al área de la Quebrada dentro de la Estación Experimental Agronómica

d.- Descripción detallada de los límites del área propuesta como Santuario de la Naturaleza, que contenga listado de las coordenadas UTM de los puntos que los definen. De forma complementaria, la delimitación del área propuesta deberá estar representada en un mapa, en él se deben señalar los puntos (coordenadas UTM) que definen el polígono a proteger , así como las principales hitos geográficos (quebradas, elevaciones, etc..)

La Quebrada de La Plata se ubica a 30 km al Suroeste de la ciudad de Santiago, inserta en el primer cordón montañoso de la Cordillera de la Costa, en el extremo poniente de la Comuna de Maipú, Región Metropolitana de Chile. Sus coordenadas geográficas son: 33° 29' 26'' Latitud Sur y 70° 53' 15'' Longitud Oeste. El cordón Norte limita con la Cuesta Lo Prado y el cordón Sur con la Cuesta Barriga, mientras que por el Oeste limita con la Comuna de Curacaví.

Los hitos relevantes se presentan en las figuras 1, 2, 3 y 4 a continuación

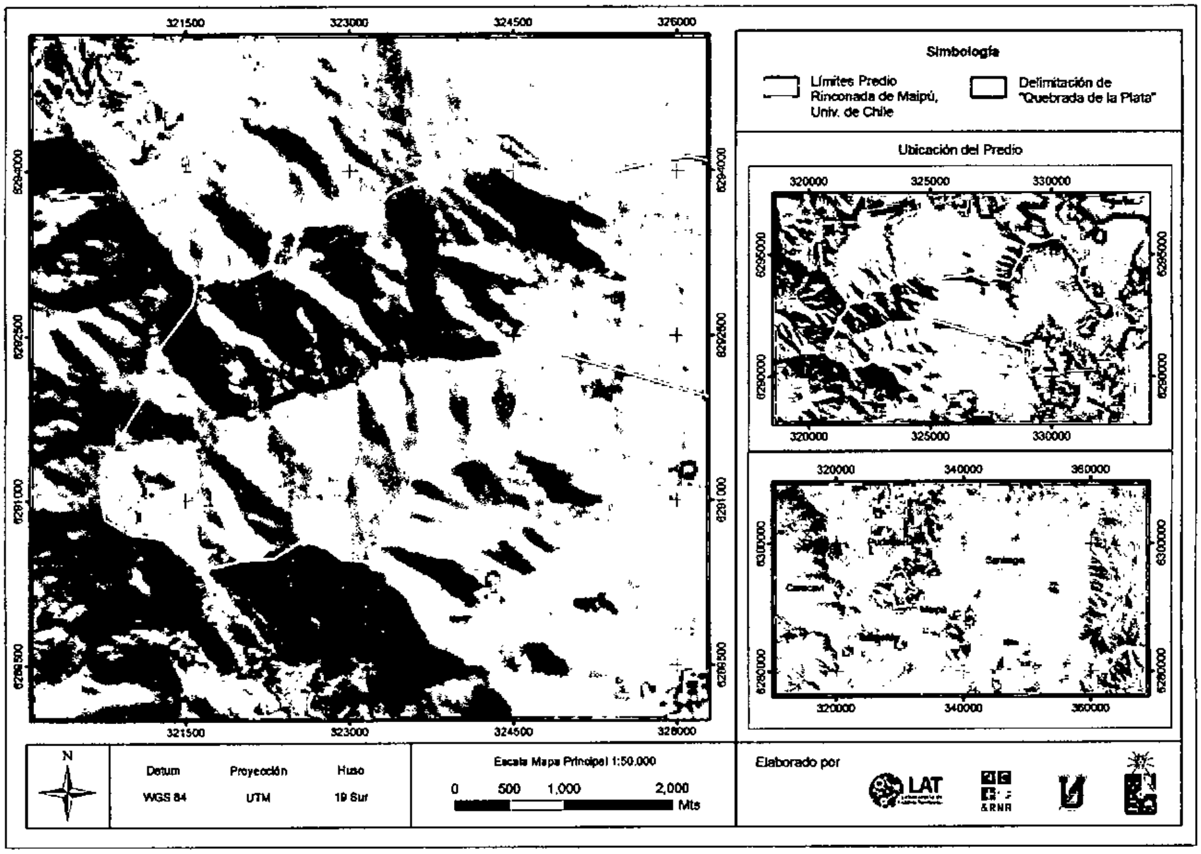

Figura 3: Límites prediales (polígono demarcado amarillo y naranja) y límites de la Quebrada de la Plata para considerar como 'Santuario de la Naturaleza' (polígono naranja y rojo)

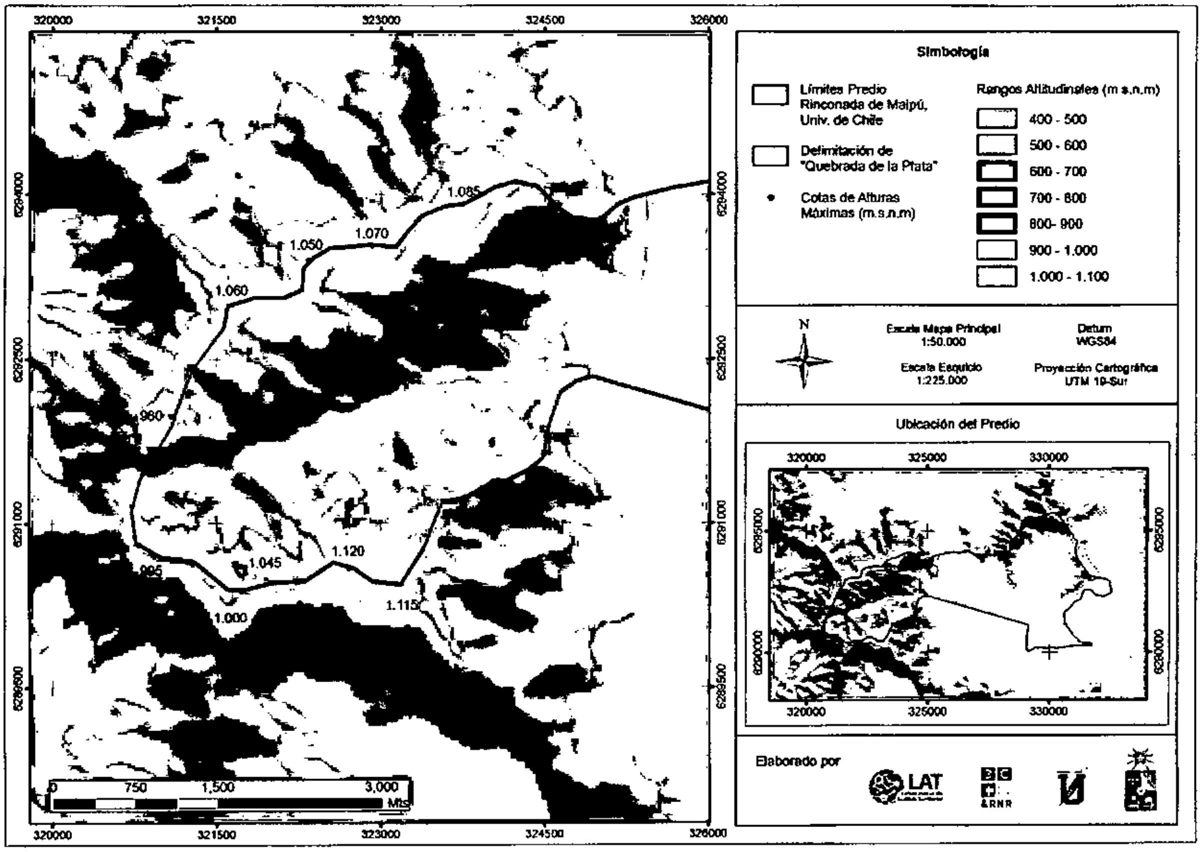

Figura 4: Alturas relevantes de la Quebrada de la Plata

3.- ANTECEDENTES QUE JUSTIFICAN QUE EL ÁREA SEA POSTULADA A SANTUARIO DE LA NATURALEZA (*Se refiere a proporcionar los fundamentos – por parte del proponente – que justifican la solicitud de declaración del Santuario propuesto, de acuerdo a la definición establecida en la Ley Nº 17.288 sobre Monumentos Nacionales, Artículo 31º: " Son Santuarios de las Naturaleza todos aquellos sitios terrestres o marinos que ofrezcan posibilidades especiales para estudios e investigaciones geológicas, paleontológicas, zoológicas, botánicas o de ecología, o que posean formaciones naturales, cuyas conservaciones sea de interés para la ciencia o para el Estado"*)

La Quebrada de La Plata está dentro de uno de los 34 *hot spots de la biodiversidad* del mundo, con cerca del 1% de la biodiversidad mundial. En el caso de Chile, se trata del *Bosque Esclerófilo,* que concentra más de 1.500 especies de flora y fauna endémicas. La mayoría de estas especies han sido catalogadas por la Unión Internacional para la Conservación de la Naturaleza (UICN) en su Lista Roja como 'vulnerables' y 'en peligro de extinción'.

Por otra parte, en el marco de la Estrategia para la Conservación de la Biodiversidad de la Región Metropolitana de Santiago, la Comisión Nacional del Medio Ambiente (CONAMA) en 2004 propuso 27 zonas como 'sitios prioritarios' para la conservación. Uno de ellos es el sitio denominado "El Roble", que incluye la Quebrada de la Plata, que corresponde al acceso sur del Sitio. También la Quebrada de La Plata está catalogada, en el Plan Regulador Metropolitano de Santiago (PRMS), como 'Zona de preservación ecológica'.

Finalmente, desde 1933 la Quebrada de la Plata ha sido un laboratorio natural para el estudio e investigaciones científicas de alumnos de pre y posgrado y académicos de diferentes universidades del país, que guardan en memorias, tesis y publicaciones (muchas de ellas indexadas), tanto nacionales como internacionales, gran parte del conocimiento de la biodiversidad representativa de la vertiente oriental de la Cordillera de la Costa.

Por estas razones, tanto ecológicas, científicas y sociales—dado el interés demostrado por la comunidad de la comuna de Maipú de preservar el área—es que declarar la Quebrada de la Plata es de interés para el Estado de Chile.

4.- DESCRIPCIÓN DEL ÁREA PROPUESTA

a.- Descripción detallada del área propuesta como Santuario de la Naturaleza: situación geográfica, caracterización de ecosistemas, presencia de flora y/o fauna nativa y en estado de conservación, formaciones naturales, geológicas, paleontológicas, entre otros aspectos.

El área propuesta como Santuario de la Naturaleza presenta una alta diversidad en la vegetación, ya que es posible encontrar un estrato herbáceo, arbustivo y arbóreo, además de especies suculentas. Los principales tipos de vegetación presentes en la Quebrada de la Plata corresponden a bosque esclerófilo y matorral espinoso. En el área existen un total de 315 taxas, de las cuales 245 corresponden a especies nativas (77,8%) y 70 a especies exóticas (22,2%). Del total de especies presentes 254 especies (80,6%) son herbáceas, 47 (14,9%) son arbustivas y 5 (1,6%) son arbóreas. Las familias que reúnen mayor número de especies son: Asteraceae (18,7%), Poaceae (9,2%), Fabaceae (6,7%), Scrophulariaceae (5,7%) y Apiaceae (4,4%) (Schlegel, 1963).

De acuerdo con Gallardo (1993), la Quebrada es relevante porque presenta mayoritariamente especies arbustivas (Tabla 1) como colliguay (*Colliguaya odorifera*) y tevo (*Trevoa trinervis*), y especies herbáceas y suculentas, entre las que destacan el chagual (*Puya berteroniana*) y el quisco (*Echinopsis chiloensis*). Por otra parte, el lecho de la Quebrada de La Plata se caracteriza por presentar vegetación arbórea bien desarrollada en su parte media, y a medida que se asciende por la ladera de exposición Sur, la vegetación se presenta cada vez más vigorosa y densa (Schlegel, 1963). De acuerdo con estos mismos autores existen también numerosas especies animales autóctonas (Tabla 1).

TABLA 1: Flora y Fauna presente en el sector Quebrada de la Plata

A) Especies Vegetales Focales:

Nombre Científico	Nombre Común	Principales características	Principales usos
Cryptocarya alba	Peumo	Árbol siempre verde con follaje denso y muy aromático, puede alcanzar hasta 20 m de altura. Hojas blanquecinas por el envés y verde brillante en su cara superior. El fruto es una drupa de color rojo o rosado de forma ovalada. Endémica. Floración: noviembre a enero.	Leña y carbón, alimento (fruto), Ornamental, medicinal (antirreumático y enfermedades del hígado) y artesanal.

Quillaja saponaria	Quillay	Árbol o arbusto siempre verde de hasta 15 m de altura. Hojas brillantes debido a la gruesa capa de cera que las cubre, de color verde claro y bordes ligeramente dentados. El fruto es un penta folículo estrellado. La corteza contiene saponina. Endémica. Floración: noviembre a enero.	Cosmética (detergentes y champú), medicinal, (corteza repelente de polillas y zancudos), artesanal y ornamental.
Lithraea caustica	Litre	Árbol siempre verde, crece hasta los 6 m de altura. Sus hojas se reconocen por el contraste entre la nervadura amarilla y el color verde intenso de sus otros tejidos foliares. Posee un efecto irritante, ya que sus hojas desprenden litreol, sustancia volátil, que provoca inflamaciones cutáneas en las personas. Endémica. Floración: septiembre a diciembre.	Se explota para producir leña, carbón y tierra de hojas. Artesanal (madera dura, apta para fabricar mazas de carreta, instrumentos de labranza y partes de embarcaciones) y ornamental.
Cassia clossiana	Quebracho	Endémica. Mide de 2 a 6 mts. Árbol de follaje globoso muy ornamental debido a su abundante floración amarilla. Floración: de agosto a febrero.	Ornamental
Maytenus boaria	Maitén	Árbol o arbusto siempre verde. Mide entre 3 a 15 m de alto, con ramas colgantes. Hojas alternas, simples, pecioladas, lanceoladas a elípticas, con bordes aserrados y nervadura marcada. Flores solitarias o en fascículos de 3 a 10 unidades, de coloración roja. Floración: septiembre a diciembre.	Forrajera, fruto era utilizado como sucedáneo del óleo, medicinal (cura la fiebre, inflamaciones producidas por el litre, caída del cabello, cicatrizador de heridas),

			artesanal (carpintería) y Jardinería.
Porlieria chilensis	Guayacán o Palo Santo	Endémico de la zona central de Chile donde se encuentra en un estado de conservación vulnerable. Es un arbusto siempre verde o decíduo facultativo que puede alcanzar hasta los 4 metros de altura. El fruto es una cápsula de color violeta oscuro cuando madura. Floración: agosto a marzo.	Medicinales (dolores reumáticos y de gota, estimulante y calmante), artesanal (utensilios como peinetas, cucharas y adornos varios), ornamental.
Echinopsis chiloensis	Quisco	Es una suculenta, endémica de la IV a la VII Región de Chile, crece por lo general en laderas de exposición norte, alcanzando hasta los 7 metros de altura. Su estado de conservación es vulnerable. Floración: octubre a noviembre.	Alimenticio (su fruto), medicinal (refrescante y emoliente), ornamental y artesanal (cerco vivo, objetos de adorno).
Puya berteroniana	Chagual o puya	Planta perenne que se encuentra generalmente en las laderas de exposición norte entre la IV y VII Región de Chile, es de origen endémica y no tiene problemas de conservación. Posee un tallo floral alto, cuyas flores están dispuestas en espigas compuestas. Floración: octubre a noviembre.	Apícola, alimentario (ensaladas), medicinal (emoliente y astringente) y artesanal (cestería fina)
Alstroemeria spp.	Alstroemeria o Lirio del Campo	Hierbas perennes, provistas de rizomas y raíces suberificadas. Hojas sésiles y alternas, presentan una torsión de 180° de manera que el haz corresponde en realidad al envés. Floración: noviembre a	Flores muy apreciadas en primavera por sus hermosos colores. Han sido muy explotadas como flores de

		diciembre.	corta (para florero).
Leucocoryne ixiodes	Huilli	Hierba perenne, bulbosa, con tallo florífero de hasta 25 cm. Flores blancas o violáceas y poseen un suave aroma a vainilla. Crece en cerros asoleados de la zona central, originaria de Chile. Floración: octubre a noviembre.	Flores muy apreciadas en primavera por sus hermosos colores. Han sido muy explotadas como flores de corta (para florero).
hycella bicolor	Añañuca de fuego	Hierba perenne, provista de bulbo. Especie endémica de Chile. Relativamente común en las áreas bien conservadas de bosque esclerófilo costero e interior, crece preferentemente bajo dosel, pero se puede observar creciendo expuestas al sol incluso en exposiciones norte. Floración: agosto a septiembre	Flores muy apreciadas en primavera por sus hermosos colores. Han sido muy explotadas como flores de corte.

Fuente: Elaboración adaptado de Manual de Práctica Ecología, Facultad de Ciencias Agronómicas, Universidad de Chile, 2006.

B) **Faunas Silvestres y focales:** Listado de las especies posibles de encontrar en el área, su estado de conservación (EC) y las especies consideradas focales (F).

Nombre Científico	Nombre Común	EC	F	Fuente
Artrópodos				
Castnia psittachus	Mariposa del chagual		*	
Battus polydamas	Mariposa negra		*	
Grammostola mollicoma	Araña pollito		*	
Reptiles				
Liolaemus fuscus	Lagartija oscura	Fuera de peligro		1-3
Liolaemus lemniscatus	Lagartija lemniscata	Vulnerable		1-3
Liolaemus monticola	Lagartija de los Montes	Vulnerable		1-3
Liolaemus nitidus	Lagarto nítido	Vulnerable		1-3
Liolaemus tenuis	Lagartija esbelta	Vulnerable		1-3
Tachymenis chilensis	Culebra de cola corta	Vulnerable		3
Philodryas chamissonis	Culebra de	Vulnerable		3

	cola larga			
Callopistes palluma	Iguana	Vulnerable	*	3
Anfibios				
Bufo chilensis	Sapo de rulo	Vulnerable	*	2-3
Aves				
Nothoprocta predicaria	Perdiz chilena		*	1-3-4
Bubulcus ibis	Garza boyera			1-3-4
Coragyps atratus	Jote cabeza negra			3
Falco peregrinus	Halcón peregrino	Vulnerable		2-3
Elanus leucurus	Bailarín			1-3
Geranoaestus melanoleucos	Águila		*	1-3
Buteo polyosoma	Aguilucho			3-4
Parabuteo unicinctus	Peuco			1-3-4
Milvago chimango	Tiuque			1-3-4
Falco femoralis pichinchae	Halcón perdiguero			3
Falco sparveri	Cernícalo			1-3-4
Callipepla californica	Codorniz			1-3-4
Vanellus chilensis	Queltehue			1-3-4
Columba livia	Paloma			1-3-4
Columba araucana	Torcaza	Vulnerable	*	2
Zenaida auriculata	Tórtola			1-3-4
Columbina picui	Tórtolita cuyana			1-3-4
Glacidium nanum	Chuncho			1-3
Atiene cunicularia	Pequén			1-3
Caprimulgus logirostris	Gallina ciega			1-3
Sephanoides galeritus	Picaflor chico			1-3-4
Patagona gigas	Picaflor gigante			1-3
Caloptes pitius	Pitío			1-3
Picoides lignarus	Carpinterito			3
Sylviorthorhynchus desmursii	Colilarga			1-3
Aphrastura spinicauda	Rayadito			1-3
Leptasthenura	Tijeral			1-3-4
Satenes humicola	Canastero			1-3
Pteroptochos megapodius	Turca		*	1-3-4
Scelorchilus albicollis	Tapaculo			1-3
Scytalopus magallanicus	Churrín			1-3
Pyrope pyrope	Diucón			1-3
Elaenia albiceps	Fío-fío			1-3
Anairetes parulus	Cachudito			1
Colorhamphus parvirostris	Viudita			1-3
Phytotoma rara	Rara			1-3
Tachycineta leucopyga	Golondrina chilena			1-3-4
Troglodytes aedon	Chercán			1-3-4
Turdus falcklandii	Zorzal			1-3-4
Mimus tenca	Tenca		*	1-3-4
Sicalis luteiventris	Chirihue			1-3-4
Zonotrichia capensis	Chincol			1-3-4
Molothrus bonariensis	Tordo			1-3

Sturnella loyca	Loica		*	1-3-4
Phrygilus patagonicus	Cometocino patagónico			1-3
Phrygilus fruticeti	Yal			1-3
Phrygilus alaudinus	Platero			3
Diuca diuca	Diuca			1-3-4
Carduelos barbatus	Jilguero			1-3-4
Passer domesticus	Gorrión			1-3
Mamíferos				
Tadarida brasiliensis	Murciélago común			3
Histiotus macrotus	Murciélago orejón			3
Histiotus montanus	Murciélago orejudo			3
Lasiurus borealis	Murciélago colorado			3
Lasiurus cinereus	Murciélago gris			3
Myotis chiloensis	Murciélago oreja de ratón			3
Octodon degus	Degú común	Inadecuadamente conocido	*	1
Abrocoma bennetti	Ratón chinchilla común	Amenaza Indeterminada		
Spalacopus cyanus	Cururo			3
Abrothrix longipilis	Ratón lanudo común			3
Abrothrix olivaceus	Ratón oliváceo			3
Oligoryzomis longicaudatus	Ratón de cola larga			3
Chelemys megalonyx	Ratón topo del matorral			3
Phillotis darwini	Ratón orejudo de Darwin			3
Lepus capensis	Liebre			1
Oryctolagus cuniculus	Conejo			1
Thylamys elegans	Llaca	Rara	*	3
Pseudalopex culpaeus	Zorro culpeo	Inadecuadamente conocido	*	2-3
Pseudalopex griseus	Zorro chilla	Inadecuadamente conocido	*	2-3
Galictis cuja	Quique	Vulnerable		2-3
Conepatus chinga	Chingue	Fuera de peligro		2-3

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[1] Glade, 1993.

[1] Para la determinación de las especies focales se consultó a las siguientes personas: Alberto Carvacho Bravo, Ingeniero Agrónomo, Facultad de Ciencias Agronómicas de la Universidad de Chile, Profesor de Zoología, 2006 (Comunicación personal); Matilde López Muñoz, Profesora de Biología y Ciencias, Facultad de Ciencias Forestales de la Universidad de Chile, Profesora de Biología Forestal, 2006 (Comunicación personal) y Jorge Pérez Quezada, Ingeniero Agrónomo, Facultad de Ciencias Agronómicas de la Universidad de Chile, Profesor de la Cátedra de Ecología, 2006 (Comunicación personal).

[1] Para el caso de los artrópodos se mencionan sólo aquellos considerados focales por el estudio de Memoria para obtener el título de Ingeniero en Recursos Naturales Renovables, realizado por Mariana Orellana Miquel "Bases para el desarrollo ecoturístico de la Quebrada de la Plata, Región Metropolitana".

b.- Descripción del valor ecológico del área, que da origen a su propuesta de declaración como Santuario de la Naturaleza.

En el contexto geográfico el terreno ubicado inmediatamente antes de ingresar a la Quebrada de La Plata es bastante plano, presentando sólo algunas pequeñas colinas de pendientes y alturas moderadas. Hacia el interior de la Quebrada, la topografía se vuelve abrupta. Gran parte del área presenta un relieve muy escarpado, conformado por cordones de una altura media de 450 m y una garganta central de apreciable profundidad, en cuyo fondo se juntan las laderas de los cerros en forma de V, encontrándose a menudo pendientes entre un 50 y 70% (Fernández y Seguel, 1947).

Dentro de las características biogeográficas, la formación vegetacional de la Quebrada de la Plata corresponde a la de Matorral Espinoso del Secano Costero (Gajardo, 1994) y está compuesta por comunidades de matorrales y bosques esclerófilos alteradas fuertemente en el pasado y actualmente amenazadas por la expansión urbana (Tapia, 2005).

La diversidad cromática de la vegetación se hace más evidente en los meses primaverales, debido a los variados colores aportados por la floración de muchas especies. Las laderas de exposición Norte y exposición Sur presentan un marcado contraste, dado por la composición de especies y, por tanto, los distintos tonos cromáticos de la vegetación. Por lo anterior se podría decir que, la mayor belleza escénica del paisaje se evidencia durante la primavera.

Respecto de la presencia de formaciones naturales la mayoría de las cumbres de la zona presentan formas suaves y redondeadas. Sin embargo es posible encontrar, en algunos cerros ubicados en la parte baja de la Quebrada y en la ladera de exposición Norte, cumbres que presentan un estado muy avanzado de denudación, con grandes afloramientos rocosos de aspecto dentado (Fernández y Seguel, 1947).

Las más altas cumbres de la cuenca corresponden a los cerros “Morros del Fraile” con 1.123 m.s.n.m. y “Las Buitreras” con 1.085 m.s.n.m. (Schlegel, 1963). Debido a la poca altura que alcanzan las cumbres, no es común que en los meses de invierno éstas se encuentren nevadas.

En cuanto a la disponibilidad de agua, la QDP se surte sólo mediante escurrimientos estacionales. El escurrimiento máximo se produce en los meses invernales, y se hace prácticamente nulo en los meses del período estival, lo que limita el flujo hídrico del área (López *et al.*, 1998). No obstante, a lo largo de la Quebrada, es común que se formen pequeñas pozas o pozones, debido a que las piedras y rocas existentes en el fondo de la Quebrada, contribuyen a que el agua proveniente de las precipitaciones se acumule. Aún en los meses estivales se puede observar agua en algunas pozas, las que presumiblemente son alimentadas por pequeñas vertientes. Cabe destacar la existencia de una ligera caída de agua denominada comúnmente por los lugareños como ‘La Cascada’. La cantidad de agua que lleva la Quebrada está en directa relación con el nivel de precipitaciones caídas durante el invierno.

c) Descripción de los valores complementarios asociados al área, si correspondiera (naturales, culturales, sociales, turísticos, etc...)

Ecoturísticos: El nombre de la Quebrada de la Plata se atribuye, por relatos de lugareños, a los acontecimientos acaecidos inmediatamente después de la Batalla de Maipú, el 5 de abril de 1818. Luego de que Los Patriotas derrotaran a Los Realistas, estos huyeron. En su huída, una unidad se perdió, internándose por la Quebrada. Para hacer más liviana su carga, enterraron allí algunos objetos de valor. De ahí el nombre que hoy lleva el lugar. Una segunda interpretación obedece a la presencia de rocas con inserciones de cariz plateado que resplandecen a la luz del sol.

También es posible encontrar ornamentos o utensilios mapuches dada su utilización como lugar de tránsito de las comunidades. Dadas las características de la Quebrada, se cree que habría servido como lugar de vigía y puente entre los sectores de Curacaví, María Pinto y Padre Hurtado con el valle de Santiago, utilizado por las huestes de Machimalonco en el asalto (11 de Septiembre de 1541) a la recién fundada ciudad de Santiago.

Senderos y Miradores: Existe un Sendero principal, de aproximadamente 4,5 kms. de extensión y 2 mts. de ancho, supuestamente utilizado para la extracción de minerales a inicios del siglo XX. Sirve para acceder al bosque de peumos y más arriba a un bosque de encinas. Desde este sendero principal se llega a los dos miradores naturales hacia el valle de Maipú y el valle de Curacaví. Destacan además el Sendero de la Quebrada de los Maquis y el Sendero del Minero, que corresponden a huellas de bajada a la Quebrada principal.

Antigua actividad minera: En el sector conocido como 'Hornos Caleros' existen construcciones de piedra de 7 metros de altura, que presentan diferentes niveles de conservación. Su origen es de fines del siglo XIX, y fueron construidos para fundir mineral de caliza que se extraía del lugar. Otra historia que se escucha de lugareños, es que fueron construidos por los incas para fundir plata.

Actividad Militar: Se desarrolló en el sector 'Polvorines', ubicado a unos 700 m antes del ingreso principal al Sendero de La Plata, en donde hoy existe infraestructura militar abandonada. Las construcciones más notorias corresponden a los seis polvorines construidos e insertos en la base de los cerros, de concreto armado estilo bunker, donde hasta hace algunas décadas se almacenaba material bélico.

d) Descripción detallada del objeto de protección.

La Quebrada de la Plata, dada su topografía, al clima mediterráneo, su ubicación, además del grado de aislamiento que otorgan sus características orográficas, posee una flora y fauna representativa de la zona mediterránea de Chile, con una alta riqueza (número de especies) y abundancia en su fauna (número de individuos), incluyendo endemismo en especies de aves y mamíferos. Este componente biótico, presenta dependiendo de la especie, variaciones en su ciclo anual, relacionado a la alta estacionalidad climática (Di Castri & Hajek 1976). Reflejo de esta particular biodiversidad es la intensa realización de investigación y docencia que se desarrolla este lugar. En las siguientes tablas se enumeran las especies vegetales y animales documentadas en la zona, incluyendo su estado de conservación.

Tabla 1. Especies animales presentes en la estación Germán Greve Silva (Quebrada de la Plata), asociadas al matorral espinoso, bosque esclerófilo y tranques de riego.

Nombre científico	Nombre común	Endemismo	Estado de conservación	Fuente
Artrópodos				
Castnia psittachus	Mariposa del chagual			7
Battus polydamas	Mariposa negra			7
Grammostola mollicoma	Araña pollito			7
Reptiles				
Liolaemus fuscus	Lagartija oscura			
Liolaemus lemniscatus	Lagartija lemniscata		Vulnerable	1 3
Liolaemus monticola	Lagartija de los montes		Vulnerable	1 3
Liolaemus nitidus	Lagarto nítido		Vulnerable	1 3
Liolaemus tenuis	Lagartija esbelta		Vulnerable	1 3
Tachymenis chilensis	Culebra de cola corta		Vulnerable	3

Philodryas chamissonis	Culebra de cola larga		Vulnerable	3
Callopistes palluma	Iguana Vulnerable		Vulnerable	4
Anfibios				
Rhinella arunco	Sapo de rulo	X	Vulnerable	2 3
Aves				
Nothoprocta predicaria	Perdiz chilena	X		1 3 4
Bubulcus ibis	Garza boyera			2 3 4
Coragyps atratus	Jote cabeza negra			3
Falco peregrinus	Halcón peregrino			2 3
Elanus leucurus	Bailarín			3
Geranoaetus melanoleucus	Águila chilena			1 3
Geranoaetus polyosoma	Aguilucho			3 4
Parabuteo unicinctus	Peuco			1 3 4
Milvago chimango	Tiuque			1 3 4
Falco femoralis pichinchae	Halcón perdiguero			3
Falco sparverius	Cernícalo			1 3 4
Callipepla californica	Codorniz			1 3 4
Vanellus chilensis	Queltehue			1 3 4
Columba livia	Paloma			1 3 4
Patagioenas araucana	Torcaza			2
Zenaida auriculata	Tortola			1 3 4
Columbina picui	Tortolita cuyana			1 3 4
Glaucidium nanum	Chuncho			1 3
Athene cunicularia	Pequén			1 3
Caprimulgus logirostris	Gallina ciega			1 3
Sephanoides sephaniodes	Picaflor chico			1 3 4
Patagona gigas	Picaflor gigante			1 3
Colaptes pitius	Pitío			1 3
Picoides lignarus	Carpinterito			3
Sylviorthorhynchus desmursii	Colilarga	X*		1 3
Aphrastura spinicauda	Rayadito			1 3
Leptasthenura aegithaloides	Tijeral			1 3 4
Satenes humicola	Canastero			1 3
Pteroptochos megapodius	Turca	X		1 3 4
Scelorchilus albicollis	Tapaculo	X		1 3
Scytalopus fuscus	Churrín	X		1 3
Xolmis pyrope	Diucón			1 3
Elaenia albiceps	Fío-fío			1 3
Anairetes parulus 1	Cachudito			1
Colorhamphus parvirostris	Viudita			1 3
Phytotoma rara	Rara			1 3
Tachycineta meyeni	Golondrina chilena			1 3 4

Troglodytes aedon	Chercán			1 3 4
Turdus falcklandii	Zorzal			1 3 4
Mimus thenca Tenca	Tenca	X*		1 3 4
Sicalis luteiventris	Chirihue			1 3 4
Zonotrichia capensis	Chincol			1 3 4
Molothrus bonariensis Tordo	Tordo argentino o mirlo			1 3
Curaeus curaeus	Tordo			5
Sturnella loyca	Loica			1 3 4
Phrygilus patagonicus	Cometocino patagónico			1 3
Phrygilus fruticeti	Yal			1 3
Phrygilus alaudinus	Platero			3
Diuca diuca	Diuca			1 3 4
Carduelos barbatus	Jilguero			1 3 4
Passer domesticus	Gorrión			1 3
Rollandia rollans	Pimpollo			6
Podiceps occidentalis	Blanquillo			6
Podilymbus podiceps	Picurio			6
Ardea alba	Garza grande			6
Egretta thula	Garza chica			6
Bubulcus ibis	Garza boyera			6
Plegadis chihi	Cuervo de pantano			6
Anas geórgica	Pato Jergón grande			6
Anas bahamensis	Pato gargantillo			6
Anas sibilatrix	Pato real			6
Anas cyanoptera	Pato colorado			6
Anas platalea	Pato cuchara			6
Heteronetta atricapilla	Pato rinconero			6
Oxyura vittata	Pato rana de pico delgado			6
Porphyriops melanops	Tagüita			6
Fulica armillata	Tagua			6
Himantopus melanurus	Perrito			6
Larus dominicanus	Gaviota dominicana			6
Larus maculipennis	Gaviota Cahuil			6
Tringa flavipes	Pitotoy chico			6
Phalacrocorax brasilianus	Cormorán negro (Yeco)			6
Nycticorax nycticorax	Huairavo			6
Pardirallus sanguinolentus	Pidén			6
Fulica rufifrons	Tagua de frente roja			6
Tyto alba	Lechuza			5
Myiopsitta monachus	Cotorra argentina			5
Bubo magellanicus	Tucúquere			5
Mamíferos				
Tadarida brasiliensis	Murciélago común			3
Histiotus macrotus	Murciélago orejón			3

Histiotus montanus	Murciélago orejudo			3
Lasiurus borealis	Murciélago colorado			3
Lasiurus cinereus	Murciélago gris			3
Myotis chiloensis	Murciélago oreja de ratón			3
Octodon degus	Degú			1
Abrocoma bennetti	Ratón chinchilla común	X	Inadecuadamente conocido	1
Spalacopus cyanus	Cururo	X	En Peligro	3
Abrothrix longipilis	Ratón lanudo común			3
Abrothrix olivaceus	Ratón oliváceo			3
Oligoryzomis longicaudatus	Ratón de cola larga			3
Chelemys megalonyx	Ratón topo del matorral			3
Phillotis darwini	Ratón orejudo de Darwin	X		3
Lepus capensis	Liebre			1
Oryctolagus cuniculus	Conejo			1
Thylamys elegans	Llaca		rara	3
Pseudalopex culpaeus	Zorro culpeo		Inadecuadamente conocido	2 3
Pseudalopex griseus	Zorro chilla		Inadecuadamente conocido	2 3
Galictis cuja	Quique		Vulnerable	2 3
Conepatus chinga	Chingue			2 3

X* = Especie cuasi endémica, es decir con mayores poblaciones en Chile.
Fuentes: 1, López et al. (1998); 2, GORE RMS (2001); 3, Coinca (2001); 4, Agroindustrial Pullihue (2005). 5, Peña-Villalobos comunicación personal; 6, Peña-Villalobos et al. (2012); 7, Orellana 2006.

e) Estado actual de conservación del área propuesta.

En términos biológicos y cualitativos, a pesar del grado de intervención antrópica que presenta el área propuesta y las amenazas de origen antrópico, evidenciadas por la existencia de senderos para vehículos motorizados y el hallazgo eventual de desperdicios o cartuchos que sugieren presión de caza en la zona o el ingreso de ganado vacuno, este lugar presenta óptimas condiciones para el desarrollo de especies *sensibles* a la contaminación y alteraciones antrópicas, favoreciendo (como se presentó en la tabla 1) la existencia de especies de vertebrados endémicos y en peligro de conservación (e.g. *Spalacopus cyanus*) en toda su superficie. Así, y antes del inicio de la faena de explotación minera durante el pimer semestre 2013, era posible observar en la zona la presencia de líquenes desde el ingreso de la estación agronómica experimental, forma de vida que requiere bajos niveles de toxicidad en el aire para su desarrollo. Del mismo modo, la presencia de al menos 78 especies de aves de diversos gremios (17 % del total de especies presente en Chile), desde granívoras estrictas (e.g. *Diuca diuca*) a depredadores tope (e.g. *Geranoaetus melanoleucus*), sugieren la existencia de tramas tróficas completas y de complejas interacciones ecológicas con integrantes mayoritariamente nativos, que a excepción de un par de especies migrantes invernales, se reproducen en esta área. Más interesante, pero menos evidente, es el nivel de conservación medioambiental de esta zona, reflejado por la existencia de murciélagos (ver tabla 1), ya que Quebrada de la Plata contendría cerca del 50% de las especies de Quirópteros insectívoros presentes en Chile, orden de mamíferos cuyos ambientes requieren de especial cuidado, conociéndose que algunas especies son altamente específicas en la selección de sus hábitats y especialmente sensibles a la alteración antrópica (Aguirre 2002, Canals & Cattan 2008). Esta gran diversidad faunística presentada, no tendría sustrato estructural ni base trófica, si no fuera por el ensamble vegetal de esta zona, compuesta en su mayoría por flora endémica representativa de la zona mediterránea.

f) Presiones y/o amenazas sobre el área propuesta y el objeto de protección (caracterización de las acciones o actividades que afectan o pudieren afectar al objeto de protección o procesos ecológicos que se pretenden proteger).

En Quebrada de la Plata es posible observar tramas tróficas completas (desde productores primarios hasta depredadores tope) y además el ensamble de especies animales de cada tipo vegetacional o tipo de paisaje, es altamente representativo y compuesto por especies de baja movilidad espacial. Razones por las cuales, el efecto de una amenaza es predecible *a priori*.

Tabla 3. Presiones y/o amenazas sobre el área propuesta y el objeto de protección.

Presiones y/o amenazas	Objeto de protección
	Fauna endémica (destrucción de nidos)
Destrucción de suelo por: Erosión Actividad ganadera (pisadas) Destrucción de laderas (vehículos motorizados) Creación de senderos	Tapaculo Turca Cururo Degú Sapo de rulo
	Fauna de bosque esclerófilo (destrucción de hábitat)
Destrucción de vegetación por: Tala de bosque Quema de bosque	Tucúquere Pitío Murciélago común Murciélago orejón Murciélago colorado Murciélago gris Murciélago oreja de ratón
	Fauna de matorral espinoso (destrucción de hábitat)
Destrucción de vegetación por: Tala de matorral Quema de matorral	Roedores zorros (culpeo y chilla) Passeriformes (aves, e.g. chincol, diuca) Gallina ciega Lechuza Pequén Reptiles
Caza ilegal	Zorro culpeo Zorro Chilla
Extracción minera	Afecta la totalidad del ecosistema

En este momento (Septiembre 2013) la principal amenaza que afecta a la Quebrada de la Plata es la actividad minera, que ha destruido parte importante del área de la cabecera de la Quebrada.

Observaciones no científicas indican que una parte relevante de la fauna autóctona ha migrado debido a las detonaciones y al constante tráfico de camiones y maquinaria pesada.

5. GESTION DEL ÁREA PROPUESTA

a. Propietario(s).

La Hacienda La Rinconada fue adquirida por la Universidad de Chile en el año 1933 (Decreto Nº 1158 del 29 de Abril de 1933, firmándose la escritura de compraventa en la notaría Abraham del Río el 6 de Mayo de 1933) para el bien de la enseñanza durante la presidencia de don Arturo Alessandri Palma, siendo ministro de instrucción don Domingo Durán Morales y rector de la Universidad de Chile don Juvenal Hernández Jaque y Decano de la Facultad de Agronomía y Veterinaria don Germán Greve Silva.

La Estación Experimental Agronómica de la Facultad de Ciencias Agrarias y Forestales de la Universidad de Chile pasó a llamarse "Estación Experimental Agronómica Germán Greve Silva, Rinconada de Maipú, el 20 de Mayo de 1994, nombre con el cual se conoce actualmente. La encargada de su administración en la actualidad es la Facultad de Ciencias Agronómicas.

b. Persona(s), Institución(es) responsables(s) de la gestión y Administración.

La institución a cargo de la gestión y administración de la Quebrada de la Plata es la Universidad de Chile, a través de la Facultad de Ciencias Agronómicas y, más específicamente, del personal técnico a cargo de la Estación Experimental Germán Greve.

En el futuro inmediato, mediante proyecto que pretende incorporarla a un Tramo del Sendero de Chile, tendrá una administración compartida mediante convenio entre la Fundación Sendero de Chile, la Facultad de Ciencias Agronómicas titular del predio y la Ilustre Municipalidad de Maipú.??

c. Uso actual del suelo en el área propuesta y adyacente.

El uso actual del suelo en la Quebrada de la Plata es de conservación de flora y fauna, proceso que ha sido afectado por la explotación minera.

El área adyacente corresponde, hacia el norte, sur y poniente a zonas de bosque esclerófilo de las mismas características que las señaladas para la Quebrada de la Plata.

Hacia el oriente de la Quebrada, es decir en el sector de suelos planos y de aptitud agropecuaria, se extiende la Estación Experimental propiamente tal, que se destina principalmente a los siguientes rubros de producción silvo-agrícola-ganadera:

- Producción de 28 ha de ciruelas D'Agen para secado
- Producción de 10 ha de viñas para elaboración de alcoholes
- Producción de 37,5 ha de hortalizas consumo fresco
- Producción de 66,9 ha de semilleros de hortalizas y cereales
- Producción de miel y propagación de abejas melíferas
- Producción de ganado menores caprinos y ovinos
- Producción de viveros forestal
- Producción de engorda de animales vacunos y equinos (talajes)
- Bodegas para la producción de 15.000 botellas de licores anuales

d. Descripción de la zonificación establecida por los instrumentos de planificación territorial vigentes.

De acuerdo a la planificación territorial vigente, la Quebrada de la Plata está incluida en los siguientes instrumentos vigentes:

1. Estrategia Regional de Preservación de la Biodiversidad
2. Plan Regulador Metropolitano de Santiago
3. Plan Regulador Comunal

e. Otras categorías de protección existentes al interior del área propuesta y zona adyacente.

1. Sitio Prioritario N° 2 "El Roble"
2. Zona de Preservación Ecológica (PRMS)
3. Zona de Protección Ecológica con desarrollo Controlado (PRMS)

f. Plan de Manejo preliminar, que considere objetivos, lineamientos estratégicos, metodología y medidas afines a los objetos de protección definidos para el área propuesta, así como la zonificación preliminar que establezca normas de uso a fin de cumplir los objetivos planteados para el área.

Objetivos:

Conservar el área de la Quebrada de la Plata (800 há), evitando que actividades antrópicas continúen afectando negativamente el ecosistema

Lineamientos Estratégicos:

Promoción para el incremento de la investigación científica
Rehabilitación de la vegetación autóctona en zonas dañadas
Participación de la comunidad, a través de una mesa de diálogo
Incorporar la QDP al programa 'Senderos de Chile'

Métodos:

La investigación científica se ha desarrollado en la QDP desde hace décadas. Sin embargo, debido a las actividades actuales de extracción minera partes significativas del área han sido destruidas. Una vez que cesen estas actividades extractivas, serán necesarios nuevos estudios científico-técnicos que determinen impactos y los pasos a seguir en el corto, mediando y largo plazo con el propósito de recuperar el ecosistema.

Para recuperar la vegetación destruida, será necesario recurrir al vivero de especies autóctonas que la Universidad de Chile mantiene en la Facultad de Ciencias Forestales

Señalética: actualmente los senderos de la QDP son utilizados por deportistas en moto, bicicleta y peatones. Será necesario demarcar estos senderos de manera de sensibilizar a los usuarios para evitar el uso de senderos no habilitados

Programas de educación ambiental: con la participación de la comunidad académica y científica, se diseñarán programas de educación ambiental dirigidos a la comunidad local (Maipú) con el propósito de sociabilizar resultados científicos, participar en actividades como plantación de especies, observación de flora y fauna. En este mismo sentido, se organizarán visitas guiadas con las escuelas locales.

g. **Propuesta de Plan de Infraestructura a implementar, si fuera pertinente, para cumplir los objetivos de protección planteados para él área.**

Puesto que se trata de un lugar orientado a la conservación de suelo, flora y fauna no se requiere de infraestructura.

h. **Plan de Financiamiento Preliminar (compromisos específicos demostrables en el ámbito financiero, que den cuenta de los recursos con los que se contará para implementar infraestructura a fin a la conservación, actividades de educación , investigación y difusión, entre otras). (falta este punto a completar por el decano)**

i. **Carta compromiso del potencial administrador respecto de las acciones de protección sobre el área que se pretende declarar y de la elaboración y aplicación del Plan de Manejo para el sitio. (falta este punto)**

6. DOCUMENTACION A PRESENTAR

a. Respecto de los antecedentes legales y otros, se deberán proporcionar:
    - Copia autorizada de la inscripción de dominio con certificado de vigencia de una antigüedad no superior a 60 días, respecto de cada uno de los predios involucrados.
    - Fotocopia de la escritura pública de compraventa (u otro título de dominio del(los) inmuebles(s) correspondiente(s), respecto de cada uno de los predios involucrados.
    - Carta de compromiso de cada uno de los propietarios involucrados.
    - Copia de la escritura pública de constitución y copia autorizada de la inscripción social correspondiente, con certificado de vigencia de una antigüedad no superior a 60 días-tratándose de dueños que sean personas jurídicas.
    - Certificado de vigencia emitido por Ministerio de Justicia, en el caso de fundaciones o corporaciones sin fines de lucro.
    - Carta del Ministerio de Bienes Nacionales que demuestre su acuerdo con la iniciativa, en caso de que el área propuesta sea de propiedad fiscal.

b. Antecedentes planimétricos (plano de ubicación y emplazamiento, plantas de arquitectura tipo, cortes, elevaciones si corresponde).
c. Antecedentes fotográficos (generales y en detalles reverlantes, en formato gif o jepg, de alta resolución).
d. Antecedentes bibliográficos.
e. La cartografía presentada en la solicitud deberá estar conforme los siguientes criterios:
    - Datum: World Geodetic System 1984 (WGS84).
    - Proyección: Universal Transversal de Mercator (UTM)
    - Escala: (según la escala requerida para el proyecto)
    - Huso: 19 sur, o bien en 18 sur para proyectos locales de la regiones del Sur de Chile.
    - Formato de Coberturas: Formato shape para coberturas vectoriales; Formato Img para cobertura raster
    - Proyecto SIG: Debe ser leódp en plataforma ArcGis 9.x
    - Metadatos: Creación de metadatos para cada cobertura generada.

<u>Nota</u>: La información deberá ser proporcionada en formato impreso (3 copias) y digital en un CD/DVD claramente identificado.

INFORME DE DESARROLLO DEL TOUR TREKKING ECOTURÍSTICO QUEBRADA DE LA PLATA

2004 – 2009

DIRECCIÓN DE DESARROLLO COMUNITARIO
OFICINA DE TURISMO
JUNIO, 2008

WWW.MAIPU.CL

Pasaje Jardín 3 N °2235
Maipú, Santiago de Chile
Tel. 5312344 – 5320448
turismo@maipu.cl

INFORME DE DESARROLLO DEL TOUR TREKKING ECOTURÍSTICO QUEBRADA DE LA PLATA 2004 - 2009

Génesis del Proyecto

Este proyecto nace en el Departamento de Higiene y Control del ambiente, específicamente en la Unidad de Educación y Gestión Ambiental, destinado a implementar un sendero de trekking en el sector de Quebrada de la Plata, en Rinconada de Maipú. Los objetivos planteados inicialmente estaban enfocados a aprovechar este lugar en la actividad del Trekking, junto con acercar a la población de Maipú a espacios naturales e incentivar así su valoración. Posteriormente, surge la idea de explotar la Quebrada de la Plata como locación para realizar educación ambiental, actividad destinada principalmente a establecimientos educacionales.

El monto inicial del proyecto debió reducirse debido al momento complejo vivido durante el año 2004 entre el municipio y la U. de Chile. Tal situación llevó a trabajar el proyecto solo 5 de los 12 meses que habían sido contemplados en una primera instancia.

Estos cinco meses se dividieron en dos etapas durante el año 2004. La primera de ellas estuvo comprendida entre el 31 de Enero hasta el día 14 de Marzo, con 520 visitas, y la segunda entre el 30 de Septiembre y el 31 de Diciembre del año 2004, con un número que alcanzó las 580 visitas entre instituciones y público en general.

Con respecto al personal destinado para trabajar en el sendero, en esta primera etapa se contrató a tres guarda-senderos, todos con estudios profesionales; un Geógrafo titulado de la PUC, un Ingeniero Civil egresado de la USACH, un ingeniero agrónomo egresado de la UCh y un Paisajista, quienes tenían la misión de impartir las charlas a los visitantes además existía un Ingeniero en Minas, destinado a las labores logísticas de la actividad del sendero, además de labores de guía, inscripción de la gente y coordinación de las actividades de Quebrada de la Plata. El modo de contratación de de ellos fue de media jornada y en calidad de honorarios.

Infraestructura de Quebrada de la Plata

En el transcurso del proyecto se desarrollaron múltiples obras con el objetivo de implementar este sendero y así poder hacerlo mas atractivo y seguro para los visitantes. Sin embargo, la escasa seguridad que existe en dicho sector ha obligado a este Departamento a limitar los recursos destinados a este tipo de iniciativas.

A la fecha en la Quebrada de la Plata se han realizado las siguientes obras:

- **Pórtico (1)**: Esta obra, construida en base a rollizos, se ubica al ingreso del sendero, con un alto y un ancho de 3 y 4 mts. respectivamente y marca el inicio del trekking. Es además el lugar donde el bus deja y recoge al público visitante. En la actualidad sólo existe el pórtico, sin el letrero.

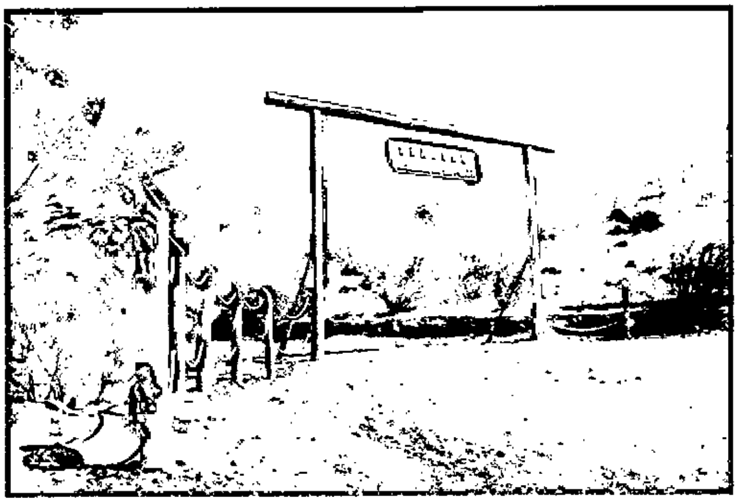

Foto n°1: Pórtico Quebrada de la Plata

- **Letreros Informativos (2)** : Estos se ubican al ingreso del sendero y tienen como finalidad informar las normas básicas que debe adoptar el visitante en el trayecto del sendero. Estos letreros metálicos miden 1,10 X 1,80 Metros.(Estos letreros fueron destruidos)

SENDERO QUEBRADA DE LA PLATA
RESPETE LAS SIGUIENTES NORMAS:
- CONSERVE Y CUIDE EL ENTORNO
- REGÍSTRESE EN EL INGRESO AL SENDERO
- NO BOTE BASURA EN EL CAMINO; VUELVA CON ELLA
- CAMINE SOLO POR LA RUTA HABILITADA
- PROGRAME BIEN SU RECORRIDO
- PROHIBIDO ACAMPAR Y HACER FOGATAS

DISFRUTE LA NATURALEZA
SENDERO QUEBRADA DE MAIPÚ

Foto n°2: Letreros informativos

- **Señaletica (17):** Estos letreros construidos metálicos se encuentran ubicados en el trayecto del sendero y tienen como finalidad guiar al visitante, además de evitar que se abran nuevas rutas. Las dimensiones de este tipo de letreros es de 0,80 X 0,40 Metros. (esta señaletica fue destruida)

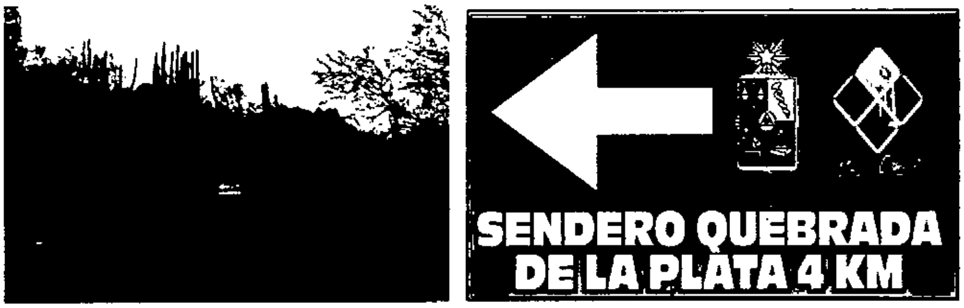

Foto n°3: Señal ética localizada en la ruta del sendero

- **Letreros colgantes (14):** Estos letreritos, de 13 x 27 cm., fueron diseñados para el reconocimiento de especies nativas, por lo que cada uno de ellos fue rotulado con información referente al nombre común y científico de la especie. Su instalación obedeció a dos requisitos fundamentales: por un lado, ser una especie representativa del lugar y por otro, ubicarse en la ruta del visitante.

Las especies consideradas fueron las siguientes:

TABLA 1

	Nombre común	**N° letreros instalados por especie**	**Especie**
1	Quillay	3	Árbol
2	Peumo	2	Árbol
3	Litre	2	Árbol

4	Maitén	1	Árbol
5	Espino	2	Árbol
6	Tevo	2	Arbusto
7	Quisco	2	Cactácea

Implementos adquiridos durante el proyecto

Para el desarrollo del proyecto se adquirieron una serie de implementos destinados tanto al equipamiento de los guarda-senderos como para el apoyo de las actividades allí desarrolladas.

Indumentaria: Con el objetivo de equipar y uniformar a los guarda-senderos, se adquirió el siguiente material:

- Poleras (color amarillo y verde) con logo municipal.
- Pantalones cargo
- Cinturones militares
- Cantimploras
- Gorros
- Brújulas
- Guantes de bicicleta
-

Implementos complementarios: Este material se adquirió con el fin de dar apoyo a las actividades desarrolladas por los guarda-senderos.

- Equipos de comunicación: Se adquirieron 3 equipos de comunicación marca Alinco, modelo DJ- 193, VHF, con el objetivo de mantener una comunicación constante entre los guarda-senderos y las respectivas

Centrales de Radios de la Municipalidad de Maipú y del Departamento de Seguridad Ciudadana, brindando así mayor seguridad a los visitantes de Quebrada de la Plata.

- Bicicletas: Para lograr movilización por parte de los guarda-senderos en el sector, se adquirieron 4 bicicletas Mountain Bike, aro 26, modelo Bianchi "*Progresive*" 1800 sx, además de sus respectivos cascos y guantes a fin de dar un uso adecuado al material señalado. En la primera fase del proyecto, se trabajó con dos bicicletas las que eran trasladadas en vehículos destinados para tales efectos. En la segunda etapa, su uso vio restringido dada la escasez de medios de transporte hacia el sector.

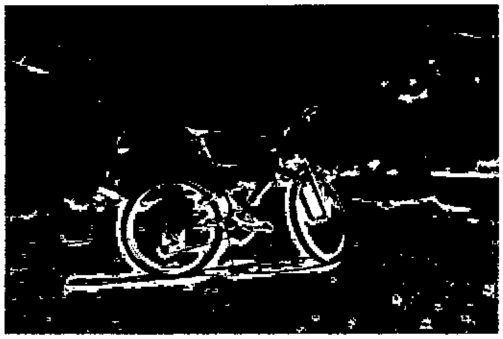

Foto n°4: Bicicleta Mountain-Bike adquirida para el desplazamiento en el sendero

- Bidones de Agua: El agua es un recurso escaso en la Quebrada de la Plata, sobre todo en la época estival. Con el objeto de satisfacer la demanda de este vital elemento por parte de los visitantes, se decidió comprar 2 bidones para el transporte de agua, de 50 litros cada uno. Hoy en día se solicita a cada visitante que lleve al menos 1 litro de agua.

- Botiquines: Las lesiones menores (cortes por caídas, etc) son común en una actividad desarrollada en un ambiente natural. Es por ello que se decidió adquirir 3 botiquines de primeros auxilios a fin de dar una atención básica frente a eventuales lesiones que pudiesen sufrir los visitantes.

Detalle de insumos adquiridos durante el año 2004

TABLA 2.

Insumos	Cantidad	Precio Unidad	Precio Total
Pórtico	1	380.443	380.443
Cerca	1	87.231	87.231
Letrero Pórtico	1	180.000	180.000
Lienzos	3	58.900	210.273
Letreritos identificación especies	14		120.000
Bicicletas	4	115.990	463.960
Cascos	4	8.800	35.200
Guantes	4	4.200	16.800
Bombines	2	8.990	17.980
Set de Herramientas	2	5.990	11.980
Parches	4	1.490	5.960
Candados	4	3.490	13.960
Equipos de Comunicación	3	112.502	401.632
Poleras	20	5.900	118.000
Pantalones	5	7.800	46.800
Gorros	5	1.512,61	7.563
Cantimploras	5	3.865	19.328
Cinturones	5	1.890,77	9.454
Brújulas	4		27.600
Botiquines	3		20.080
Bidones	3		42.126
Mesas	3		43.161

Arriendo Bus			1.910.000
Sueldos	15	180000(mes)	2.700.000
Insumos Ceremonia Clausura			39.211
Total			**6.928.742**

Cambio de Unidad Responsable

El año 2005 el *Tour Trekking Ecoturístico Quebrada de la Plata* cambia de unidad Municipal a cargo de operarlo, siendo la Oficina de Turismo la nueva unidad responsable. El guía y responsable del proyecto hasta la actualidad es el Señor Leopoldo Sánchez A. (Geógrafo UC). El objetivo definido por esta unidad para este proyecto es desarrollar conciencia ambiental a través de charlas educativas in situ durante la caminata, por otro lado promover el cuidado de espacios naturales de excepción como Quebrada de la Plata y su entorno.

La Oficina de Turismo municipal registra hasta la actualidad a todas las personas naturales o de organizaciones sociales que son participantes del proyecto, mediante listado de participantes con entrega de una copia, después de cada actividad, al administrador de la Estación Experimental German Greve Silva.

La Oficina de Turismo ha beneficiado, hasta el año 2009, a 6867 personas de las cuales el 78% corresponde a personas pertenecientes a diferentes tipos de centros educacionales de la comuna, ratificando el compromiso educativo y concientizador de esta actividad. A continuación un detalle anual de los beneficiarios del *Tour Trekking Ecoturístico Quebrada de la Plata.*

Según la Tabla 3 y el grafico 1, el año 2008 y 2009 presentan una tendencia a la disminución de beneficiarios. Este problema se debe a un ajuste presupuestario para estos años.

TABLA 3

AÑO	BENEFICIARIOS
2004	1100 PERSONAS
2005	515 PERSONAS
2006	1380 PERSONAS
2007	1685 PERSONAS
2008	1283 PERSONAS
2009	904 PERSONAS

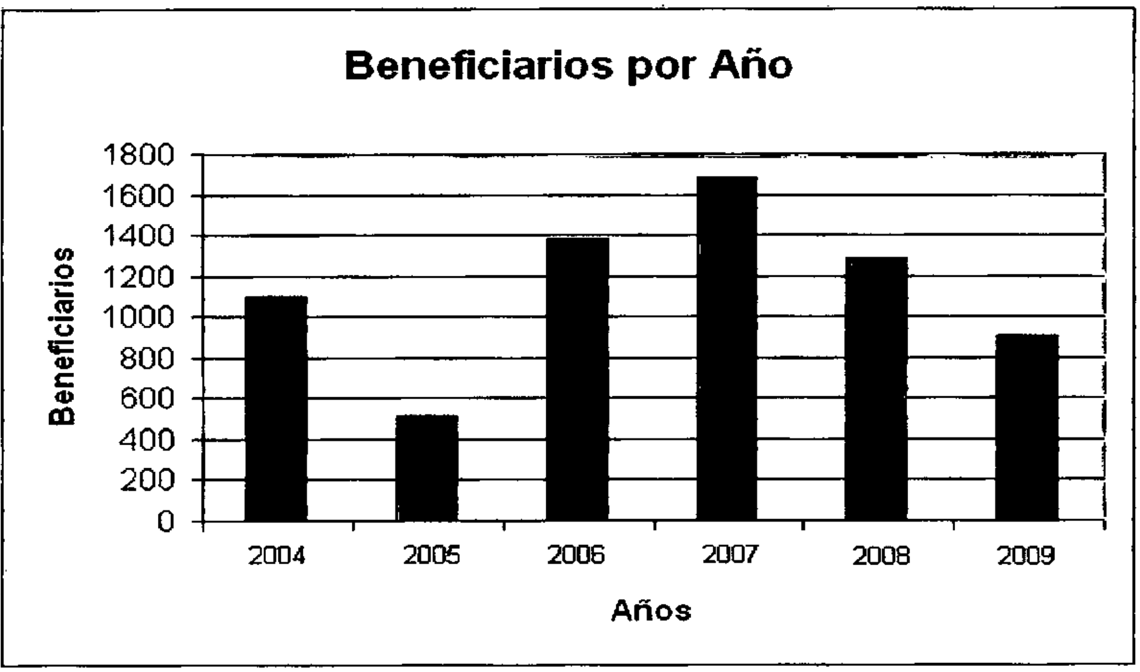

GRAFICO 1

Limitantes e Inconvenientes

Este proyecto se ha visto enfrentado a una serie de limitantes y problemas desde su inicio.

Uno de los principales a los cuales se ha visto enfrentado este proyecto se relaciona con la escasa seguridad y control que existe en este lugar (Flujos espontáneos de personas). Dicha situación está generando, por una parte, la pérdida de especies tanto faunísticas como florísticas, y por otra, la destrucción y robo de bienes materiales adquiridos y ejecutados por el municipio.

Un ejemplo de lo anteriormente descrito se traduce en los destrozos que han sufrido las obras que se han instalado. Se tienen los siguientes casos:

- Robo de la totalidad de los letreros colgantes instalados en especies nativas en la segunda etapa del proyecto.
- Rayado de los letreros ubicados en el acceso del sendero.
- Desmantelación y rayado de señalética.

Con respecto a los problemas relacionados con la flora y fauna del lugar, se cuenta la quema y caza ilegal respectivamente. En relación a esto último, en varias oportunidades se ha sorprendido a cazadores ilegales, situación que sin duda pone en serio peligro el ecosistema del lugar. Es importante mencionar además que la Quebrada de la Plata es hábitat del Zorro Chilla y Culpeo, ambas especies con estado de conservación inadecuadamente conocida.

Foto n°5: Zorro Chilla muerto por la acción de cazadores ilegales

La basura es otro problema que afecta principalmente la imagen estética del sendero y que está muy relacionado con la escasa cultura medioambiental de los visitantes ilegales. En varias oportunidades se han realizado acciones tendientes a extraer la basura del lugar, sin embargo, la situación se vuelve a repetir.

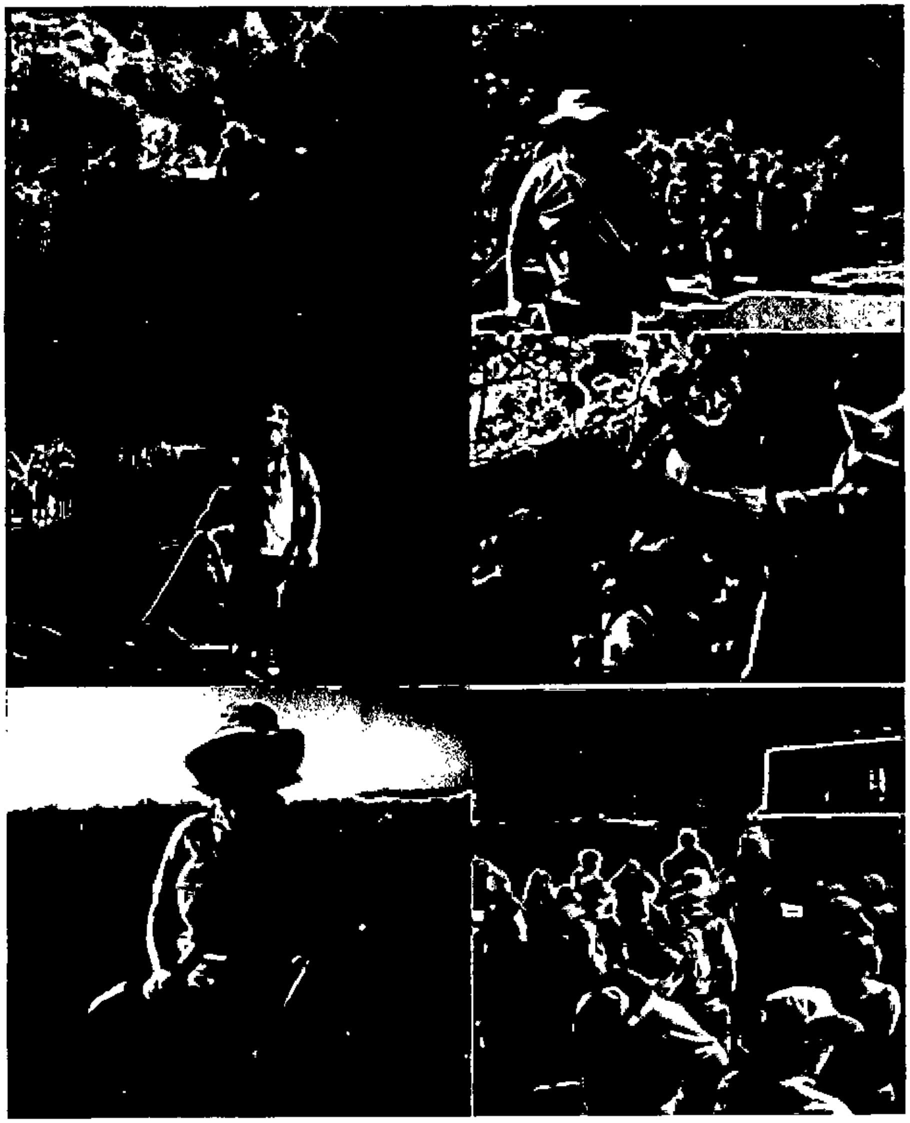

Foto n°6: La basura es un problema constante del sendero debido a la acción de personas sin conciencia ambiental

Por ultimo, para mejorar el cuidado ambiental de Quebrada de la Plata se acordó, en Mayo del 2008, en reunión donde participo por parte de la Universidad de Chile el Decano de la Faculta de Ciencias Agronómicas Don Antonio Lizana y la Directora Económica y Administrativa Doña Claudia Padilla y por parte de la Oficina de Turismo Municipal Don Claudio Yañez encargado de la Oficina de Turismo y Don Leopoldo Sánchez encargado del proyecto Trekking Quebrada de la Plata, que se implementara una mesa técnica de trabajo constituidas por ambas instituciones y que tendrá como propósito generar las condiciones de protección y conservación de Quebrada de la Plata y su entorno y así mejorar el convenio ya suscrito por amabas instituciones.

FACULTAD DE CIENCIAS
UNIVERSIDAD DE CHILE

CONSULTORÍA PARA ESTABLECER UNA LÍNEA BASE Y ZONIFICACIÓN PARA LA CONSERVACIÓN DE LA BIODIVERSIDAD EN EL SITIO PRIORITARIO N°2, "EL ROBLE" DE LA REGIÓN METROPOLITANA DE SANTIAGO

Informe Final

Unarte

Informe elaborado para:

GOBIERNO DE CHILE
CONAMA
METROPOLITANA
DE SANTIAGO

Unarte

UNIVERSIDAD DE CHILE
FACULTAD DE CIENCIAS

INFORME FINAL

CONSULTORÍA PARA ESTABLECER UNA LÍNEA BASE Y ZONIFICACIÓN PARA LA CONSERVACIÓN DE LA BIODIVERSIDAD EN EL SITIO PRIORITARIO N°2, "EL ROBLE", DE LA REGIÓN METROPOLITANA DE SANTIAGO

Jefe de Proyecto	Dr. Orion Aramayo
Asesor Técnico	Dr. Italo Serey
Coordinador de proyecto	Sergio Moraga
Staff Técnico	Michael Lukas Gonzalo Sepúlveda Sebastián Barahona Jaime Villanueva

Diciembre, 2006

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acentuada en la parte central del sitio, donde se expande al punto de generar una discontinuidad en otras formaciones presentes en la zona y en el sitio.

Tanto en el sector norte como en el sector sur, destaca la presencia de secuencias volcánicas del tipo cretácico inferior ubicadas en la medianía del área de estudio. La formación central presenta secuencias y complejos volcánicos continentales formados por lavas y brechas basálticas a andesíticas, además de rocas piroclásticas andesíticas a riolíticas, con escasas intercalaciones sedimentarias (Kla3). La formación más periférica, por su parte, presenta secuencias volcánicas y sedimentarias marinas, con lavas andesíticas y basálticas, tobas y brechas volcánicas y sedimentarias, areniscas y calizas fosilíferas (Kl2m).

En puntos específicos del área de estudio, y que tendrían relación con sectores del sitio prioritario, es posible identificar formaciones de menor superficie correspondientes a secuencias volcánicas del tipo Jurásico y del Pleistoceno. Las primeras se caracterizan por la presencia de secuencias volcánicas y sedimentarias marinas, con lavas y brechas, andesíticas y basálticas, además de calizas y areniscas marinas fosilíferas (J2m), ubicándose en el extremo más occidental del sitio, cercano a Curacaví. Por su parte, la segunda formación se ubicaría próxima al sector de Quebrada de la Plata, caracterizándose por la presencia de depósitos piroclásticos principalmente riolíticos, asociados a calderas de colapso (Pl3t).

4.1.1.2 *Geomorfología*

El sitio prioritario El Roble se emplaza sobre la cordillera de la costa, extendiéndose en su mayoría por el borde occidental de la cuenca del río Mapocho. Su paisaje de montaña alcanza sus mayores alturas en el cerro El Roble (2.222 m.s.n.m) descendiendo hacia el límite sur en el sector de Quebrada de la Plata, donde las mayores alturas se encuentran en "Morros del Fraile" (1.123 m.s.n.m.) y "Buitreras" (1.085 m.s.n.m.)

El principal registro de información geomorfológica del área de estudio corresponde al trabajo desarrollado por Araya (1985). En este trabajo, la Cordillera de la Costa, borde occidental de la cuenca del río Mapocho y lugar de emplazamiento de parte del sitio El Roble, se describe como una formación situada sobre 2 tipos de regiones estructurales: la cobertura detrítico-volcánica y el batolito. La primera región sobreyace a la segunda en un estilo monoclinal, de modo que las vertientes residuales pueden aparecer como flancos de valle pasivo. Las formas de excavación sobre la gran vertiente generan vertientes de flanco de valle activo y que también pueden ser discordantes indiferenciadas.

sector, puesto que actúan como reguladores de crecidas y corredores biológicos para muchas especies de fauna.

Vegetación del sector Chicauma.

Un estudio de flora realizado en este sector, entre los 550 y 2.200 m.s.n.m, centrado en la vertiente oriental y en las altas cumbres de la cordillera, distinguió tres unidades vegetacionales segregadas altitudinal y exposicionalmente: bosque y matorral esclerofilo, bosque caducifolio de *Nothofagus macrocarpa* y matorral estepario de altura (García & Arroyo 2003). En este estudio se registraron 560 taxa, de los cuales un 86% corresponde a entidades autóctonas de Chile. La Familia más numerosa resultó ser Asteraceae, que representó un 18% de la flora registrada, y el género con más especies fue *Calceolaria* (14). Un 46% de la flora autóctona registrada correspondió a taxa endémicos de Chile continental. Además, se destaca el buen estado de conservación del sector (García & Arroyo 2003).

Vegetación del sector Altos del Puangue.

González (2004), basada en una descripción de la flora de la Provincia de Melipilla, describe la posible presencia de un bosque esclerofilo mezclado con especies caducifolias, dominado por *Cryptocarya alba* y *Nothofagus macrocarpa*. Este bosque crecería sobre los 1.500 m.s.n.m, en sectores del extremo noreste de la comuna de Curacaví. En las partes más bajas de su distribución, este bosque presentaría especies esclerofilas como *Cryptocarya alba* y *Quillaja saponaria*, mientras que en sectores de mayor altitud, aparecerían *Azara petiolaris* y *Schinus montanus*. En base a Gajardo (1994), en el sector poniente del sitio El Roble existirían formaciones como matorrales que van desde muy abiertos hasta densos, frecuentemente dominados por elementos de l bosque esclerofilo, como *Peumus boldus*, *Cryptocarya alba* y *Quillaja saponaria*. También es posible encontrar matorrales abiertos de *Acacia caven*, y matorrales abiertos y semidensos de *Trevoa trinervis*, hacia el extremo poniente del sitio.

Vegetación del sector Quebrada de la Plata.

En el sector Quebrada de la Plata, en el extremo sur del sitio prioritario El Roble, se identifican 11 agrupaciones vegetacionales diferenciadas en cuanto a su estructura, especies dominantes y ambiente en el que se desarrollan (Tapia 2005). Estas agrupaciones corresponden a *Puya berteroniana-Echinopsis chiloensis*, donde la primera es la especie más representativa, en la que también se desarrollan *Proustia cinerea* y *Colliguaja odorifera* en el nivel arbustivo; *Baccharis linearis*; *Cryptocarya alba*, donde también frecuentemente se presentan ejemplares de *Quillaja saponaria*; *Quillaja saponaria-Lithraea caustica*, donde la segunda especie se presenta como matorrales, en los que se puede encontrar ejemplares de *Retanilla trinervia* y *Acacia caven*;

Peumus boldus-Lithraea caustica, donde estas dos son las especies más representativas, acompañadas por *Quillaja saponaria*, *Colliguaja odorifera* y *Retanilla trinervia*; *Acacia caven*, desarrollándose en los sectores más bajos, en laderas de exposición norte; *Flourensia thurifera*, a veces acompañada por la presencia de *Puya berteroniana* cuando se presentan suculentas en la agrupación; *Proustia cinerea*, que suele estar acompañada por *Colliguaja odorifera*, *Baccharis paniculata* o *Retanilla trinervia*; *Proustia cuneifolia*; *Retanilla trinervia-Colliguaja odorifera*; y *Senna candolleana*, donde aisladamente se puede observar individuos de *Retanilla trinervia* y *Colliguaja odorifera*. Para ver en forma detallada las características de las agrupaciones vegetacionales de Quebrada de la Plata, ver anexo 7.3.

4.1.2.2 *Flora*

Según González (2004), no existen estudios particulares de flora en el sitio prioritario El Roble. Sin embargo, pueden encontrarse algunos registros generados por estudios no de naturaleza florística directamente, como es el caso de una Declaración de Impacto Ambiental para el sector de Cuesta La Dormida y otros estudios publicados (Ravenna 2005, Tapia 2005) que indican la presencia de determinadas especies al interior del área de estudio. En lo que respecta a la riqueza florística en el área de estudio según los registros que pudieron encontrarse, se observan 172 especies pertenecientes a 129 géneros y a 56 familias. El estado de conservación, para algunas especies, fue obtenido del Libro rojo de la flora terrestre de Chile (Benoit 1989).

Tabla 17. Especies vegetales que es posible encontrar en el sitio prioritario El Roble. Las especies listadas a continuación fueron registradas, en su mayoría, en el sector Cuesta La Dormida.

Familia	Nombre científico	Nombre común	Origen
Fabaceae	*Acacia caven*	Espino	Nativa
Euphorbiaceae	*Adenopeltis serrata*	Lechón	Nativa
Fabaceae	*Adesmia conferta*		Endémica
Fabaceae	*Adesmia confusa*	Espinillo	Nativa
Fabaceae	*Adesmia radicifolia*	Arvejilla	Nativa
Fabaceae	*Adesmia resinosa*	Paramela de Tiltil	Endémica
Adiantaceae	*Adiantum gertrudis*		Endémica
Adiantaceae	*Adiantum glanduliferum*	Culantrillo	Nativa
Adiantaceae	*Adiantum scabrum*		Nativa
Adiantaceae	*Adiantum sulphureum*		Nativa
Poaceae	*Aira caryophyllea*		Alóctono
Scrophulariaceae	*Alonsoa meridionalis*	Ajicillo	Nativa
Amaryllidaceae	*Alstroemeria angustifolia*		Endémica
Amaryllidaceae	*Alstroemeria garaventae*		Endémica
Amaryllidaceae	*Alstroemeria zoellneri*		Endémica
Asteraceae	*Anthemis cotula*	Manzanillón	Alóctona
Apiaceae	*Anthriscus caucalis*		Alóctona
Elaeocarpaceae	*Aristotelia chilensis*	Maqui	Nativa
Asteraceae	*Artemisia abrotanum*	Éter	Alóctona
Fabaceae	*Astragalus pisissii*	Yerba loca	Nativa

Tabla 17. (Continuación)

Familia	Nombre científico	Nombre común	Origen
Asclepiadaceae	*Tweedia obliquifolia*	Zahumerio	Nativa
Valerianaceae	*Valeriana sp.*		Nativa
Vivianiaceae	*Viviania crenata*		Nativa
Vivianiaceae	*Viviania marifolia*		Nativa
Poaceae	*Vulpia myurus*	Pasto sedilla	Alóctona

Es importante destacar la presencia de *Solaria curacavina*, especie, al parecer, endémica de los alrededores de Curacaví (Ravenna 2005).

De las especies listadas anteriormente, en su mayoría pertenecientes a Cuesta La Dormida, se muestran a continuación las que estaban incluidas en estudios sobre Quebrada de La Plata (tabla 18).

Tabla 18. Especies de plantas registradas en Quebrada de La Plata.

Familia	Nombre científico	Nombre común	Origen
Fabaceae	*Acacia caven*	Espino	Nativa
Elaeocarpaceae	*Aristotelia chilensis*	Maqui	Nativa
Poaceae	*Avena barbata*	Teatina	Alóctona
Asteraceae	*Baccharis linearis*	Romerillo	Nativa
Asteraceae	*Baccharis paniculata*	Falso romerillo	Nativa
Euphorbiaceae	*Colliguaja odorifera*	Colliguay	Nativa
Lauraceae	*Cryptocarya alba*	Peumo	Nativa
Cactaceae	*Echinopsis chiloensis*	Quisco	Nativa
Geraniaceae	*Erodium cicutarium*	Yerba del platero	Alóctona
Saxifragaceae	*Escallonia illinita*	Barraco	Nativa
Asteraceae	*Eupatorium salvia*		Nativa
Asteraceae	*Flourensia thurifera*	Incienso	Endémica
Rosaceae	*Kageneckia oblonga*	Huallo, Boyén	Endémica
Anacardiaceae	*Lithrea caustica*	Litre	Nativa
Celastraceae	*Maytenus boaria*	Maitén	Nativa
Monimiaceae	*Peumus boldus*	Boldo	Nativa
Asteraceae	*Podanthus mitiqui*	Mitiqui	Nativa
Asteraceae	*Proustia cuneifolia*	Huañil blanco	Endémica
Bromeliaceae	*Puya berteroniana*	Chagual	Nativa
Rosaceae	*Quillaja saponaria*	Quillay	Nativa
Rhamnaceae	*Retanilla trinervis*	Tebo	Nativa
Asteraceae	*Senecio adenotrichius*	Senecio	Nativa
Fabaceae	*Senna candolleana*	Quebracho	Nativa

Respecto de la flora leñosa en categorías de conservación, se ha citado para el sitio a *Nothofagus obliqua* spp. *macrocarpa*, roble de Santiago, vulnerable a nivel regional; *Cryptocarya alba*, peumo, vulnerable también a nivel regional (Riscal et al, 2000); *Beilschmiedia miersii* (Belloto del norte), *Jubaea chilensis* (Palma chilena) y *Porlieria chilensis* (Guayacán), vulnerable tanto a nivel regional como nacional según el Libro Rojo de la Flora Terrestre de Chile (Benoit 1989). Un registro interesante corresponde a *Adesmia resinosa*, una especie arbustiva considerada como "Rara", conocida solamente para el sector de Cuesta La Dormida, en las cercanías de Tiltil (Muñoz et al, 1996). Entre las especies herbáceas, se ha citado la presencia del helecho *Adiantum gertrudis* y las bulbosas *Alstroemeria garaventae*, *Placea germainii* y *Rhodophiala tiltilensis* (Muñoz et al. 1996).

En relación a su origen geográfico, de las 172 especies, 14 corresponden a especies alóctonas (8,14%), 33 a especies endémicas (19,41%) y 125 a especies nativas (72,67%) (figura 19).

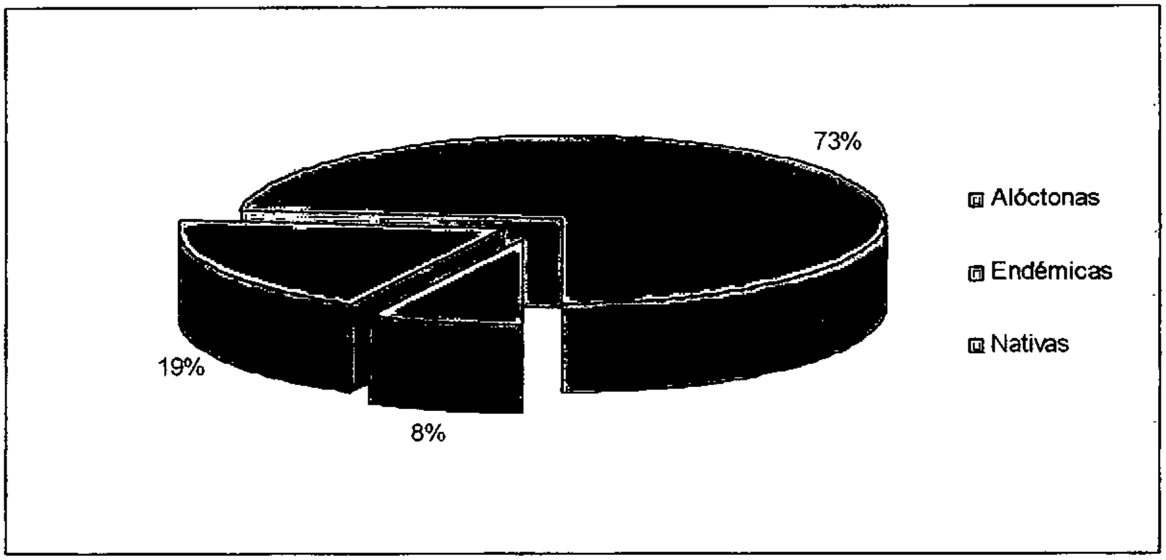

Figura 19. Proporción de especies vegetales con respecto a su origen.

En el sector de Cuesta La Dormida, los estudios y declaraciones de impacto ambiental generados indican que se habría encontrado un escaso número de especies alóctonas, pudiendo esto indicar un buen estado de conservación debido a la poca invasión de especies foráneas que ha habido en el lugar (Geotécnica Consultores 1999).

Las especies registradas en este estudio, para la totalidad del área del sitio El Roble, se agrupan en 56 familias. De éstas, se puede decir que las mejor representadas en el sitio El Roble son las Asteraceae, con 33 especies (19,41%), seguidas de las Fagaceae, con 12 especies (7,06%) y las Poaceae, con 10 especies (5,88%) (Tabla 19). Es importante recordar que la información sobre flora en el sitio se encuentra altamente concentrada en la zona de Cuesta La Dormida.

Tabla 19. Número de familias presentes y porcentaje que representan en el área de estudio

Familia	N°	%
Adiantaceae	5	2,94
Amaryllidaceae	6	3,53
Anacardiaceae	4	2,35
Apiaceae	7	4,12
Arecaceae	1	0,59
Asclepiadaceae	2	1,18
Asteraceae	33	19,41
Berberidaceae	1	0,59
Blechnaceae	2	1,18
Boraginaceae	2	1,18
Bromeliaceae	3	1,76
Cactaceae	3	1,76
Campanulaceae	1	0,59
Caryophyllaceae	2	1,18
Celastraceae	1	0,59
Convolvulaceae	1	0,59
Dennstaedtiaceae	1	0,59
Dioscoreaceae	1	0,59
Elaeocarpaceae	1	0,59
Ephedraceae	1	0,59
Equisetaceae	1	0,59
Euphorbiaceae	4	2,35
Fagaceae	12	7,06
Flacourtiaceae	1	0,59
Geraniaceae	3	1,76
Hydrophyllaceae	2	1,18
Icacinaceae	1	0,59
Iridaceae	2	1,18
Lauraceae	7	4,12
Liliaceae	2	1,18
Loasaceae	1	0,59
Monimiaceae	1	0,59
Myrtaceae	1	0,59
Onagraceae	2	1,18
Orchidaceae	1	0,59
Plantaginaceae	1	0,59
Poaceae	10	5,88
Polygonaceae	3	1,76
Portulacaceae	1	0,59
Proteaceae	1	0,59
Rhamnaceae	4	2,35
Rosaceae	4	2,35
Rubiaceae	2	1,18
Rutaceae	1	0,59
Salicaceae	1	0,59
Santalaceae	1	0,59
Sapindaceae	1	0,59
Saxifragaceae	4	2,35
Scrophulariaceae	7	4,12
Solanaceae	2	1,18
Valerianaceae	1	0,59
Verbenaceae	2	1,18
Vitaceae	1	0,59
Vivianiaceae	2	1,18
Winteraceae	1	0,59
Zygophyllaceae	1	0,59

La presencia de una no menor cantidad de especies vegetales endémicas y de importancia, tales como *Nothofagus macrocarpa, Beilschmiedia miersii* y *Solaria curacavina*, aumenta la importante necesidad de sumar mecanismos de acción que tiendan a la protección y conservación del sitio prioritario El Roble.

4.1.2.3 *Fauna*

Con respecto a la diversidad de su fauna, la Región Metropolitana es una de las mejores conocidas del país. En referencia a los mamíferos, Muñoz & Yánez (2000) describen cerca de 30 especies potencialmente presentes en el área de estudio; entre ellas carnívoros como los zorros chilla (*Pseudalopex griseus*) y culpeo (*Pseudalopex culpaeus*), el gato colocolo (*Lynchailurus colocolo*), mustélidos como el quique (*Galictis cuja*), varias especies de micromamíferos, como la yaca (*Thyllamys elegans*), y roedores como el degu (*Octodon degus*), el lauchón orejudo de Darwin (*Phyllotys darwini*), la rata chinchilla (*Abrocoma benetti*), la lauchita de los espinos (*Oligoryzomys longicaudatus*), la laucha de pelo largo (*Abrothrix longipilis*) y la laucha olivácea (*Abrothrix olivaceus*), entre otros.

La presencia de avifauna terrestre descrita para la zona norte del sitio El Roble (Araya & Millie, 1996) está dominada por especies del orden Passeriformes, siendo comunes la tenca (*Mimus thenca*), el chincol (*Zonotrichia capensis*), el tordo (*Curaeus curaeus*) y la diuca (*Diuca diuca*). En general, este ensamble está dominado por pocas especies. De las que son menos frecuentes y abundantes, se registran ejemplares de canastero (*Asthenes humicola*), rara (*Phytotoma rara*), churrín (*Scytalopus magellanicus*) y rayadito (*Aphrastura spinicauda*). Entre las aves migratorias de invierno, son características algunas como el picaflor (*Sephanoides sephaniodes*) y el diucón (*Xolmis pyrope*), en tanto que entre las aves migratorias de verano son características especies como el fio-fio (*Elaenia albiceps*), el picaflor gigante (*Patagonas gigas*) y el mirlo (*Molothrus bonariensis*). De las rapaces diurnas se pueden mencionar al aguilucho (*Buteo polyosoma*), el bailarín (*Elanus leucurus*), el tiuque (*Milvago chimango*) y el cernícalo (*Falco sparverius*).

En tanto los anfibios potencialmente presentes en el área, están descritos por Veloso & Navarro (1988), mencionándose ejemplares de *Bufo chilensis*, y *Pleurodema thaul*, entre otros. En el caso de los reptiles, Mella (2006) indica que una gran cantidad de ellos presentan distribución continua, abarcando la Región Metropolitana. Esto hace probable la presencia de ejemplares como *Liolaemus fuscus, Liolaemus lemniscatus* y *Tachymenis chilensis*, entre otros , al interior del sitio El Roble.

A continuación se presentan los registros existentes de fauna presente en el sitio prioritario El Roble:

Tabla 20. Especies de vertebrados terrestres no voladores registradas en el área de estudio

Clase mamíferos (12 especies)

Familia	Nombre científico	Nombre común	Origen
Cricetidae	*Abrothrix longipilis*	Ratoncito lanudo	Nativo
Mustelidae	*Conepatus chinga*	Chingue	Nativo
Mustelidae	*Galictis cuja*	Quique	Nativo
Felidae	*Lynchailurus colocolo*	Colocolo	Nativo
Felidae	*Oncifelis guigna*	Guiña	Nativo
Canidae	*Pseudalopex culpaeus*	Zorro culpeo	Nativo
Canidae	*Pseudalopex griseus*	Zorro chilla	Nativo
Felidae	*Puma concolor*	Puma	Nativo
Didelphidae	*Thylamys elegans*	Yaca	Nativo
Leporidae	*Oryctolagus cuniculus*	Conejo	Introducido
Octodonidae	*Octodon degus*	Degu	Endémico
Cricetidae	*Phyllotis darwini*	Lauchón orejudo de Darwin	Nativo

Clase anfibios (4 especies)

Familia	Nombre científico	Nombre común	Origen
Leptodactylidae	*Alsodes nodosus*	Sapo arriero	Nativo
Bufonidae	*Bufo chilensis*	Sapo de rulo	Endémico
Leptodactylidae	*Caudiverbera caudiverbera*	Rana chilena	Endémico
Leptodactylidae	*Pleurodema thaul*	Sapito de cuatro ojos	Nativo

Clase reptiles (12 especies)

Familia	Nombre científico	Nombre común	Origen
Teiidae	*Callopistes palluma*	Iguana	Endémico
Tropiduridae	*Liolaemus chiliensis*	Lagarto llorón	Nativo
Tropiduridae	*Liolaemus fuscus*	Lagartija oscura	Endémico
Tropiduridae	*Liolaemus lemniscatus*	Lagartija lemniscata	Nativo
Tropiduridae	*Liolaemus monticola*	Lagartija del monte	Endémico
Tropiduridae	*Liolaemus nigroviridis*	Lagartija verde	Endémico
Tropiduridae	*Liolaemus nitidus*	Lagartija nítida	Endémico
Tropiduridae	*Liolaemus schroederi*	Lagartija de Schroeder	Endémico
Tropiduridae	*Liolaemus tenuis*	Lagartija pintada	Endémico
Colubridae	*Philodryas chamissonis*	Culebra de cola larga	Endémico
Polychridae	*Pristidactylus alvaroi*	Lagarto gruñidor	Endémico
Colubridae	*Tachymenis chilensis*	Culebra de cola corta	Endémico

Tabla 21. Especies de aves registradas en la zona de Cuesta La Dormida (36 especies)

Orden	Nombre científico	Nombre común
APODIFORMES	*Patagona gigas*	Picaflor gigante
	Sephanoides sephaniodes	Picaflor
CICONIFORMES	*Cathartes aura*	Jote de cabeza colorada
	Vultur gryphus	Cóndor
COLUMBIFORMES	*Columba araucana*	Paloma araucana
	Columbina picui	Tortolita cuyana
	Zenaida auriculata	Tórtola
FALCONIFORMES	*Accipiter bicolor*	Peuquito
	Buteo polyosoma	Aguilucho
	Elanus leucurus	Bailarín
	Falco peregrinus	Halcón peregrino
FALCONIFORMES	*Falco sparverius*	Cernícalo
	Milvago chimango	Tiuque
GALLIFORMES	*Callipepla californica*	Codorniz
PASSERIFORMES	*Anairetes parulus*	Cachudito
	Aphrastura spinicauda	Rayadito
PASSERIFORMES	*Asthenes humicola*	Canastero
	Carduelis barbatus	Jilguero
	Curaeus curaeus	Tordo
	Diuca diuca	Diuca
	Elaenia albiceps	Fío-fío
	Leptasthenura aegithaloides	Tijeral
	Mimus thenca	Tenca
	Molothrus bonariensis	Mirlo
	Phrygilus alaudinus	Platero
	Phytotoma rara	Rara
	Pteroptochos megapodius	Turca
	Scytalopus magellanicus	Churrín
	Sturnella loyca	Loica
	Tachycineta meyeni	Golondrina chilena
	Troglodytes aedon	Chercán
	Turdus falcklandii	Zorzal
	Xolmis pyrope	Diucón
	Zonotrichia capensis	Chincol
PICIFORMES	*Colaptes pitius*	Pitío
TINAMIFORMES	*Nothoprocta perdicaria*	Perdiz

Tabla 22. Especies de aves registradas en la zona de Quebrada de La Plata.

Orden	Nombre científico	Nombre común
TINAMIFORMES	*Nothoprocta perdicaria*	Perdiz
FALCONIFORMES	*Geranoaetus meloanoleucus*	Águila
	Buteo polysoma	Aguilucho
	Parabuteo unicinctus	Peuco
	Milvago chimango	Tiuque
	Falco sparverius	Cernícalo
GALLIFORMES	*Callipepla californica*	Codorniz
COLUMBIFORMES	*Columbina pucui*	Tortolita cuyana
	Metriopelia melanoptera	Tórtola cordillerana
STRIGIFORMES	*Tyto alba*	Lechuza
	Bubo virginianus	Tucúquere
	Glaucidium nanum	Chuncho
	Athene cunicularia	Pequén
CAPRIMULGIFORMES	*Caprimulgus longirostris*	Gallina ciega
APODIFORMES	*Patagona gigas*	Picaflor gigante
	Sephanoides galeritus	Picaflor
PICIFORMES	*Colaptes pitius*	Pitío
	Picoides lignarius	Carpinterito
PASSERIFORMES	*Upurcerthia dumetaria*	Bandurrilla
	Aphrastura spinicauda	Rayadito
	Leptasthenura aegithaloides	Tijeral
	Thripophaga humicola	Canastero
	Pteroptochos megapodius	Turca
	Scelorchilus albicollis	Tapaculo
	Scytalopus magellanicus	Churrín
	Xolmis pyrope	Diucón
	Elaenia albiceps	Fío-fío
	Colorhamphus parvirostris	Viudita
	Phytotoma rara	Rara
	Tachycineta leucopyga	Golondrina chilena
	Hirundo rustica	Golondrina bermeja
	Troglodytes aedon	Chercán
	Turdus falcklandii	Zorzal
	Mimus thenca	Tenca
	Sicalis luteola	Chirigüe
	Zonotrichia capensis	Chincol
	Sturnella loyca	Loica
	Curaeus curaeus	Tordo
	Phrygilus gayi	Cometosino de Gay
	Phrygilus fruticeti	Yal
	Phrygilus alaudinus	Platero
	Phrygilus unicolor	Pájaro plomo
	Diuca diuca	Diuca
	Cardelius barbatus	Jilguero

A continuación se muestra el listado de las especies catalogadas en alguna categoría de conservación (tabla 23). Para cada uno de los taxa identificados, se verificó el estado de conservación de acuerdo con la Ley de Caza N' 19.473 (considerando el estado definido para la zona central, que incluye de la IV a la VII Regiones, SAG 2005), y con información del Libro rojo de vertebrados terrestres (CONAF, 1993).

Tabla 23. Vertebrados terrestres catalogados en su estado de conservación.

Clase mamíferos

Nombre científico	Nombre común	Estado de conservación
Abrothrix longipilis	Ratoncito lanudo	Inad. Conocido
Conepatus chinga	Chingue	Rara
Galictis cuja	Quique	Vulnerable
Lynchailurus colocolo	Colocolo	En peligro
Oncifelis guigna	Guiña	Vulnerable
Pseudalopex culpaeus	Zorro culpeo	Inad. Conocido
Pseudalopex griseus	Zorro chilla	Inad. Conocido
Puma concolor	Puma	En peligro
Thylamys elegans	Yaca	Rara
Phyllotys darwini	Lauchón orejudo de Darwin	Fuera de peligro

Clase anfibios

Nombre científico	Nombre común	Estado de conservación
Alsodes nodosus	Sapo arriero	En peligro
Bufo chilensis	Sapo de rulo	Vulnerable
Caudiverbera caudiverbera	Rana chilena	En peligro
Pleurodema thaul	Sapito de cuatro ojos	Vulnerable

Clase reptiles

Nombre científico	Nombre común	Estado de conservación
Callopistes palluma	Iguana	Vulnerable
Liolaemus chiliensis	Lagarto llorón	Inad. Conocida
Liolaemus fuscus	Lagartija oscura	Fuera de peligro
Liolaemus lemniscatus	Lagartija lemniscata	Vulnerable
Liolaemus monticola	Lagartija del monte	Vulnerable
Liolaemus nigroviridis	Lagartija verde	Vulnerable
Liolaemus nitidus	Lagartija nítida	Vulnerable
Liolaemus schroederi	Lagartija de Schroeder	Inad. Conocida
Liolaemus tenuis	Lagartija pintada	Vulnerable
Philodryas chamissonis	Culebra de cola larga	Vulnerable
Pristidactylus alvaroi	Lagarto gruñidor	En peligro
Tachymenis chilensis	Culebra de cola corta	Vulnerable

Clase aves

Nombre científico	Nombre común	Estado de conservación
Vultur gryphus	Cóndor	Vulnerable
Accipiter bicolor	Peuquito	Rara
Falco peregrinus	Halcón peregrino	En peligro

En total, de los registros existentes se contabilizaron 64 especies de vertebrados terrestres, con 4 especies de anfibios, 12 especies de reptiles, 12 especies de mamíferos y 36 especies de aves. Del total de especies, 29 cuentan con problemas de conservación (45,3%). Con respecto a estos datos, donde más información existe es en lo referente a anfibios, reptiles y mamíferos, siendo las aves las más difíciles de catalogar. Del total de especies de aves registradas en el sitio de estudio, sólo 3 especies cuentan con categoría de conservación (1,08%).

Las 36 especies de aves registradas en Cuesta La Dormida se agrupan en 8 órdenes, de los cuales los más dominantes numéricamente son los Passeriformes, con 20 especies, seguidos de los Falconiformes (6 especies) y Columbiformes (3 especies). El resto de los órdenes consta sólo de una o dos especies (tabla 24).

Tabla 24. Número de especies de aves por orden taxonómico y porcentaje que representan (Cuesta La Dormida)

Orden	N° de especies	%
APODIFORMES	2	5,56
CICONIFORMES	2	5,56
COLUMBIFORMES	3	8,33
FALCONIFORMES	6	16,67
GALLIFORMES	1	2,78
PASSERIFORMES	20	55,56
PICIFORMES	1	2,78
TINAMIFORMES	1	2,78

La proporción descrita en la tabla anterior puede observarse gráficamente en la siguiente figura:

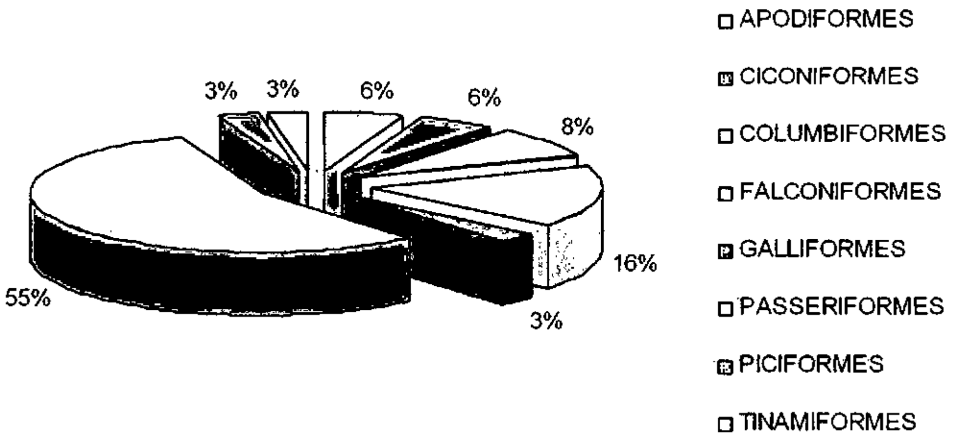

Figura 20. Número de especies de aves de Cuesta La Dormida y proporción de ellas en relación al total registrado en dicha zona.

De las 44 especies de aves registradas en Quebrada de La Plata, pueden distinguirse 11 órdenes, siendo el de los Passeriformes el más abundante (26 especies), seguido por el de los Falconiformes (5 especies) y el de los Strigiformes (4 especies). El resto de los órdenes sólo consta de una o dos especies (tabla 25).

Tabla 25. Número de especies de aves por orden taxonómico y porcentaje que representan (Cuesta La Dormida)

Orden	Nº de especies	%
TINAMIFORMES	1	2,27
FALCONIFORMES	5	11,36
GALLIFORMES	1	2,27
COLUMBIFORMES	2	4,55
STRIGIFORMES	4	9,09
CAPRIMULGIFORMES	1	2,27
APODIFORMES	2	4,55
PICIFORMES	2	4,55
PASSERIFORMES	26	59,09

La proporción descrita en la tabla anterior puede observarse gráficamente en la figura 21:

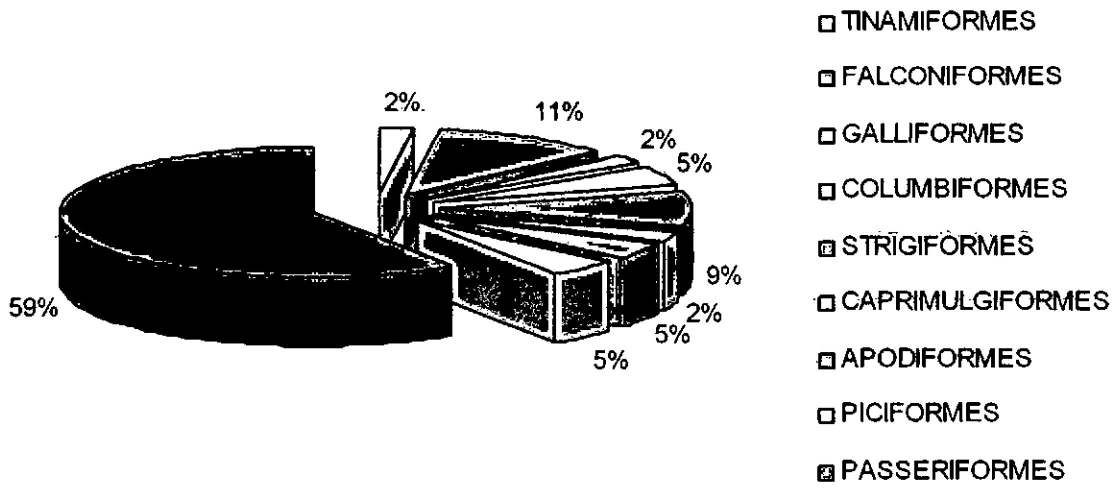

Figura 21. Número de especies de aves de Quebrada de La Plata y proporción de ellas en relación al total registrado en dicha zona.

Es importante destacar que los anfibios nativos y reptiles registrados se consideran amenazados, destacando la importancia de poner en funcionamiento medidas adecuadas que contribuyan con su conservación.

A pesar de no haber registros para este estudio, si se toma en cuenta los hábitat que existen en el sitio prioritario El Roble, debería considerarse también la posible presencia de los roedores introducidos *Rattus rattus* (rata), *Rattus norvegicus* (guarén) y *Mus musculus* (laucha). Además de ellos, podrían estar también presentes las especies *Abrothrix olivaceus, Abrocoma benneti,* y los murciélagos *Myotis chiloensis* y *Tadarida brasiliensis.*

4.1.2.4 *Paisaje*

Si bien no fue posible encontrar estudios que permitan hacer una descripción del paisaje del sitio prioritario El Roble, una reseña global de los paisajes de Chile central permite obtener un acercamiento a la descripción paisajística del área de estudio. No obstante lo anterior, el Plan de Manejo del Santuario de la Naturaleza cerro El Roble (CONAF 2005) realiza una descripción paisajística exclusiva de ese sector, la que se agrega al final de esta sección.

En Chile central, son dos características fundamentales las que diferencian los paisajes de la zona: clima de tipo mediterráneo y relieve altamente accidentado. La primera característica se refiere a aquellos climas en que las precipitaciones ocurren mayoritariamente en invierno, y los veranos son secos y calurosos. Sin embargo, estas condiciones imperan sólo en las zonas entre cero y 1500 metros sobre el nivel del mar. Los paisajes que se encuentran por sobre esa altitud tienen derivaciones del tipo mediterráneo hacia condiciones de bajas temperaturas y altas precipitaciones, frecuentemente en forma de nieve (Fuentes 1998). Este fenómeno puede observarse, por ejemplo, en la cumbre del cerro El Roble, habitualmente cubierta de nieve en los meses más fríos del año.

En esta zona del país, la cantidad de precipitaciones tiende a ser baja, encontrándose en un rango que va de los 200 milímetros a los 900 milímetros al año. Específicamente en la zona de Cuesta La Dormida, los antecedentes climáticos de Santibáñez y Uribe (1991) indican que la temperatura máxima media anual es de 19,2°C, alcanzando los 26,9°C en el mes de enero. La temperatura mínima media anual es de 6,7°C, registrándose en Agosto la más baja (4°C). Así, la temperatura media anual es de 12,3°C. Por su parte, la precipitación media anual en esta zona alcanza los 656 mm (Santibáñez y Uribe 1991).

El área de estudio se encuentra emplazada en parte de la llamada Cordillera de La Costa, predominando en el sitio un relieve de tipo montañoso. Según fuentes (1998), este cordón montañoso, por su discontinuidad geográfica y baja altitud (2000 m.s.n.m.), merecería ser llamada serranía costera. Estos montes son por lo general redondeados, húmedos y

Resumen de actividades en Estación Experimental German Greve

Desde el año 2008 a la fecha se han realizado diversos estudios en el marco del proyecto Fondecyt 1080077 a cargo del Dr. Pablo Sabat, Profesor Titular de la Facultad de Ciencias, Universidad de Chile. Dentro de las actividades desarrolladas bajo este proyecto se encuentran:

Determinación de gasto energético de especies de paseriformes endémicos de Chile

Determinación de la fisiología osmorregulatoria (función renal y tasas de pérdida de agua evaporativa) en especies de paseriformes endémicos de Chile.

Determinación de la dieta natural de de especies de paseriformes endémicos de Chile

Determinación de parámetros digestivos (morfología y enzimología) de especies de paseriformes endémicos de Chile

Todos estos estudios cuentan con el permiso del Servicio Agrícola y Ganadero (SAG) y cumplen con las mormas aprobadas por el comité de Bioética de la Facultad de Ciencias de la Universidad.

Sin otro particular se despide atentamente,

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INVESTIGACIONES REALIZADAS POR EL DR. Pablo Sabat Kirkwood EN LA ZONA DE QUEBRADA DE LA PLATA DESDE EL AÑO 1993 A LA FECHA.

1.- Proyecto asociado a su investigación (Innova, fondecyt, conicyt, corfo etc con su respectivo número)

a) Animal personalities and the underlying roles of behavioral innovation and decision-making. Fondecyt 1090794.

b) Compromisos entre la regulación hidrica y el gasto de energía en la araña migalomorfa Paraphisa parvula. Fondecyt 10800038.

c) Estrategias nutricionales e integración fisiológica: procesos de adquisición, uso y gasto de energía en aves paseriformes FONDECYT 1080077.

d) Economía Hídrica y Energética de Aves Pequeñas: variación fenotípica y flexibilidad fisiológica en Zonotrichia capensis a lo largo dc un gradiente latitudinal FONDECYT 1050196.

2.- Nombre de la investigación:

2002 Unidad de Investigación: Digestión y preferencias de alimentación en Turdus flaklandii. Alumno: Carolina Gatica. Programa de Doctorado en Fisiología, Facultad de Ciencias Biológicas, Pontificia Universidad Católica de Chile.

2003 Unidad de investigación: "Integración fenotípica, fisiología renal y digestiva en paseriformes: efecto de la dieta y tamaño corporal". Alumna Maritza Sepúlveda, Doctorante Programa de Doctorado en Ecología y Biología Evolutiva (EBE), Facultad dc Ciencias Universidad de Chile.

Unidad de investigación: "Efecto de la Proteína dietaria en la composición de la orina en Zonotrichia capensis. Alumno: Esteban Sepúlveda, Licenciatura en Ciencias con mención en Biología, Facultad de Ciencias Universidad de Chile.

3.-Publicaciones asociadas a las investigaciones:

1. Maldonado K, G Cavieres, C Veloso, M Canals & P Sabat*. 2009. Physiological responses in Rufous-collared Sparrows to thermal acclimation and seasonal acclimatization. Journal of Comparative Physiology B. 179:335-343.

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7. DANIEL E. NAYA, LUIS A. EBENSPERGER, PABLO SABAT & FRANCISCO BOZINOVIC 2008. Digestive and metabolic flexibility allows female degus to cope with lactation costs. Physiological and Biochemical Zoology. 81(2):186–194.
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10. JOHN C. WINGFIELD, IGNACIO T. MOORE, RODRIGO VASQUEZ, PABLO SABAT, Shallin Busch, Aaron Clark, Elizabeth Addis, Federico Prado, and Haruka Wada. 2008. Modulation of the adrenocortical responses to acute stress in northern and southern populations of Zonotrichia. Ornitología Neotropical.19: 241-251.
11. Cavieres G, Sabat, P*. 2008. Geographic variation in the response to thermal acclimation in Rufous-collared Sparrows: are physiological flexibility and environmental heterogeneity correlated? Functional Ecology. 22, 509-515.
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4.- Tesis de grado:

Pregrado:

2009 Efecto de la dieta sobre capacidades osmorregulatorias en aves paseriformes. Alumno: Gonzalo Barceló, Licenciatura en Biología Ambiental, Facultad de Ciencias Universidad de Chile. Proyecto en desarrollo

Doctorado:

2009 Variabilidad intra-poblacional en la utilización del nicho trófico: flexibilidad fisiológica y especialización individual en zonotrichia capensis". Alumna: Karin Maldonado. Programa de Doctorado EBE, Facultad de Ciencias Universidad de Chile. "Tesis finalizada.

2010 Flexibilidad fenotípica y plasticidad del desarrollo de las tasas de gasto de energía y parámetros osmorregulatoris en Phyllotis darwini: efecto de la variabliddad climática a lo largo de un gradiente latitudinal. Alumna Grisel Cavieres, Programa de Doctorado EBE, Facultad de Ciencias Universidad de Chile. Proyecto en desarrollo

Magíster:

2006 "Flexibilidad fisiológica de la función renal en el paseriforme omnívoro Zonotrichia capensis (Emberiziidae): efecto de la dieta y de la disponibilidad hídrica". Alumna: Patricia Aldea. Programa de Magíster en Ciencias Biológicas con mención en Ecologia y Biología Evolutiva, Facultad de Ciencias Universidad de Chile. Tesis finalizada. Responsabilidad: Tutor.

2006 "Heterogeneidad ambiental y variabilidad de la respuesta plástica en los rasgos energéticos y osmorregulatorios de Zonotrichia capensis a lo largo de un gradiente latitudinal". Alumna: Grisel Cavieres. Programa de Magíster en Ciencias Biológicas con mención en Ecologia y Biología Evolutiva, Facultad de Ciencias Universidad de Chile. Tesis finalizada. Responsabilidad: Tutor

2008- 2010 Análisis del efecto de las transiciones dietarias sobre la capacidad hidrolítica de disacaridasas (maltasa y sacarasa) y aminopeptidasa-N en aves
Natalia Ramirez. Programa de Magíster, Facultad de Ciencias Universidad de Chile. Tesis terminada. Responsabilidad: Tutor

5.- Años de investigación:

El Dr Pablo Sabat Kirkwood ha desarrollado investigaciones en la zona de Quebrada de la Plata desde el año 1993 a la fecha.

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ADMINISTRACIÓN GENERAL

PROYECTOS DE INVESTIGACIÓN REALIZADOS EN MARCO DEL PROGRAMA DE COOPERACIÓN ENTRE LA FACULTAD DE CIENCIAS AGRONÓMICAS CON LA FA CULTAD DE CIENCIAS DE LA UNIVERSIDAD DE CHILE.

Proyectos realizados en investigación en Rinconada por el Dr. El Dr Pablo Sabat Kirkwood, quien ha desarrollado investigaciones en la zona de Quebrada de la Platas desde el año 1993 a la fecha.

1.- Fondecyt 1090794

Animal personalities and the underlying roles of behavioral innovation and decision-making.

2.- Fondecyt 10800038

Compromisos entre la regulación hídrica y el gasto de energía en la araña migalomorfa Paraphisa parvula.

3.- FONDECYT 1080077

Estrategias nutricionales e integración fisiológica: procesos de adquisición, uso y gasto de energía en aves paseriformes

4.- FONDECYT 1050196

Economía Hídrica y Energética de Aves Pequeñas: variación fenotípica y flexibilidad fisiológica en Zonotrichia capensis a lo largo de un gradiente latitudinal

UNIDADES DE INVESTIGACIÓN

AñO 2002:

Título: Digestión y preferencias de alimentación en Turdus flaklandii. Alumno: Carolina Gatica. Programa de Doctorado en Fisiología, Facultad de Ciencias Biológicas, Pontificia Universidad Católica de Chile.

Año 2003

Título: "Integración fenotípica, fisiología renal y digestiva en paseriformes: efecto de la dieta y tamaño corporal". Alumna Maritza Sepúlveda, Doctorante Programa de Doctorado en Ecología y Biología Evolutiva (EBE), Facultad de Ciencias Universidad de Chile.

Título: "Efecto de la Proteína dietaria en la composición de la orina en Zonotrichia capensis. Alumno: Esteban Sepúlveda, Licenciatura en Ciencias con mención en Biologia, Facultad de Ciencias Universidad de Chile.

PUBLICACIONES

1. Maldonado K, G Cavieres, C Veloso, M Canals & P Sabat*. 2009. Physiological responses in Rufous-collared Sparrows to thermal acclimation and seasonal acclimatization. Journal of Comparative Physiology B. 179:335-343.

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13. SABAT P*, Cavieres g, veloso c & canasl M 2006 Water and energy economy of an omnivorous bird: population differences in the rufous-collared sparrow. Comparative Biochemistry and Physiology. A 144: 485-490.

14. GATICA, CDL, SP GONZALEZ, RA VASQUEZ & P SABAT* 2006 On the relationship between sugar digestion and diet preference in two Chilean avian species belonging to the muscicapoidea superfamily. Revista Chilena de Historia Natural. 79: 287-294.

15. Novoa F, A Rivera-hutinel, M rosenmann & P Sabat* 2005 Intraspecific differences in metabolic rate in Chroeomys olivaceus (Rodentia: Muridae): effect of thermal acclimation in arid and mesic habitats. Revista Chilena de historia Natural: 78: 207-214.

16. SABAT P*, Sepúlveda-Kattan E & Maldonado K. 2004 . Physiological and biochemical responses to dietary protein in the omnivore passerine Zonotrichia capensis (Emberizidae) Comparative Biochemistry and Physiology A. 137: 391-396.

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AÑOS 2008- 2010

" Análisis del efecto de las transiciones dietarias sobre la capacidad hidrolítica de disacaridasas (maltasa y sacarasa) y aminopeptidasa-N en aves
Natalia Ramirez. Programa de Magíster, Facultad de Ciencias Universidad de Chile. Tesis terminada. Responsabilidad: Tutor

Doctorado

AÑO 2009

" Variabilidad intra-poblacional en la utilización del nicho trófico: flexibilidad fisiológica y especialización individual en zonotrichia capensis". Alumna: Karin Maldonado. Programa de Doctorado EBE, Facultad de Ciencias Universidad de Chile. "Tesis finalizada".

AñO 2010

"Flexibilidad fenotípica y plasticidad del desarrollo de las tasas de gasto de energía y parámetros osmorregulatoris en Phyllotis darwini: efecto de la variabliddad climática a lo largo de un gradiente latitudinal. Alumna Grisel Cavieres, Programa de Doctorado EBE, Facultad de Ciencias Universidad de Chile. Proyecto en desarrollo

UNIVERSIDAD DE CHILE
FACULTAD DE CIENCIAS AGRONÓMICAS
ESTACIÓN EXPERIMENTAL AGRONÓMICA ***"GERMÁN GREVE SILVA"***
ADMINISTRACIÓN GENERAL

PROYECTOS DE INVESTIGACIÓN REALIZADOS EN MARCO DEL PROGRAMA DE COOPERACIÓN ENTRE LA FACULTAD DE CIENCIAS AGRONÓMICAS CON LA FA CULTAD DE CIENCIAS DE LA UNIVERSIDAD CATOLICA DE CHILE.

Dr. Luis Ebensperger, Associate Professor, Departamento de Ecología, P. Universidad Católica de Chile, Alameda 340, Santiago 8331150

1.- Received 13 October 1999; revised 5 April 2001; accepted 14 May 2001.
2002 International Society for Behavioral Ecology

The influence of habitat on travel speed, intermittent locomotion, and vigilance in a diurnal rodent. Rodrigo A. Va´squez,a Luis A. Ebensperger,b and Francisco Bozinovicb
Departamento de Ciencias Ecológicas, Facultad de Ciencias, Universidad de Chile, Santiago, Chile, and Departamento de Ecología, Facultad de Ciencias Biológicas, P. Universidad Católica de Chile, Santiago, Chile. **Behavioral Ecology Vol. 13 No. 2: 182–187**

2.- Accepted 6 March 2002, Copyright © OIKOS 2002, ISSN 0030-1299

Grouping increases the ability of the social rodent, Octodon degus, to detect predators when using exposed microhabitats. Ebensperger, L. A. and Wallem, P. K. 2002. Grouping increases the ability of the social rodent, Octodon degus, to detect predators when using exposed microhabitats.
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3.- Received: 8 March 2004 / Accepted: 2 June 2004 / Published online: 15 July 2004, Springer-Verlag 2004.

L. A. Ebensperger ()) · M. J. Hurtado · M. Soto-Gamboa Centro de Estudios Avanzados en Ecología y Biodiversidad, Departamento de Ecología, Facultad de Ciencias Biológicas, Pontificia Universidad Católica de Chile, Casilla 114-D, Santiago, Chile e-mail: lebenspe@bio.puc.cl,
Tel.: +56-2-6862733
Fax: +56-2-6862621

E. A. Lacey · A. T. Chang, Museum of Vertebrate Zoology, Department of Integrative Biology, University of California, Berkeley, CA, 94720, USA

Communal nesting and kinship in degus (Octodon degus). Luis A. Ebensperger · Mar□a Jos□ Hurtado, Mauricio Soto-Gamboa · Eileen A. Lacey Ann T. Chang. **Naturwissenschaften (2004) 91:391–395 DOI 10.1007/s00114-004-0545-5**

4.- Accepted: 26 January 2005

"Seasonal changes in the time budget of degus", Octodon degus. Luis A. Ebensperger & María José Hurtado (Centro de Estudios Avanzados en Ecología & Biodiversidad, and Departamento de Ecología, Facultad de Ciencias Biológicas, Pontificia Universidad Católica de Chile. **Behaviour 142, 91-112.**

5.- "On the Relationship between Herbaceous Cover and Vigilance Activity of Degus (Octodon degus)" Luis A. Ebensperger & María J. Hurtado. **Ethology 111, 593—608 (2005)**
2005 Blackwell Verlag, Berlin

6.- Ethology 112 (2006) 879–887 ª 2006 The Authors
Journal compilation ª 2006 Blackwell Verlag, Berlin

" Vigilance and Collective Detection of Predators in Degus (Octodon degus)" Luis A. Ebensperger*, Manía Jose´ Hurtado & Rodrigo Ramos-Jiliberto. Centro de Estudios Avanzados en Ecología and Biodiversidad, and Departamento de Ecologıía, Facultad de Ciencias Biológicas, Pontificia Universidad Católica de Chile, Santiago, Chile Departamento de Ciencias Ecolólogicas, Facultad de Ciencias, Universidad de Chile, Santiago, Chile. .- **Ethology 112 (2006) 879–887 ª 2006**

7.- Received: July 11, 2006 Initial acceptance: August 3, 2006. Final acceptance: August 11, 2006 S. K. Sakaluk), doi: 10.1111/j.1439-0310.2006.01305

Ecological Predictors of Range Areas and Use of Burrow Systems in the Diurnal Rodent, Octodon degus. Loren D. Hayes, Adrian S. Chesh* & Luis A. Ebensperger. Department of Biology, University of Louisiana at Monroe, Monroe, LA, USA. Centro de Estudios Avanzados en Ecologıía & Biodiversidad, and Facultad de Ciencias Biológicas, Pontificia Universidad Católica de Chile. **Ethology 113 (2007) 155–165 ª 2007.**

Unidad de investigación:

Cambios estaciónales en la avifauna de la Quebrada de la plata, Región Metropolitana.

Profesor asesor: Dr. Michel Sallaberry Ayerza.
Alumno: Isaac Peña Villalobos
Carrera: Licenciatura en Ciencias con Mención en Biología.

Laboratorio de Zoología de Vertebrados, Departamento de Ciencias Ecológicas, Facultad de Ciencias, Universidad de Chile, Las Palmeras 3425, Ñuñoa, Santiago, Chile.

Objetivo:

Identificar las variaciones estacionales en la composición de la avifauna (anexo 1), presente en el sector Quebrada De la plata, así también determinar índices comunitarios, en los diferentes ambientes presentes en la zona (anexo 2), comprendidos por:

1.- Sector tranques artificiales (avifauna acuática)

2.- Sectores de vegetación matorral espinoso.

3.- Sectores de vegetación bosque esclerófilo.

Método:

Se realizaran excursiones mensuales desde enero a diciembre de 2010, en las cuales, con ayuda de guías de identificación y binoculares se identificaran y cuantificaran las aves presentes en cada zona previamente definida. Además, se consideraran para efectos de distribución en los diferentes sectores propuestos la presencia de plumas, restos de aves muertas y egagrópilas. También se observará eventos tales como nidificación en el caso de las lagunas artificiales y se recopilaran datos climáticos (temperaturas, lluvias, etc.) para relacionar posteriormente, posibles cambios en la composición de la avifauna, con variables climáticas.

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Anexo 1

Lista avifauna de Quebrada de la plata, incluye especies descritas (50), tentativas (54), y observadas sin describir (30).

Descritas[1]		
N. común	N. científico	N. inglés
Perdiz Chilena	*Nothoprocta perdicaria*	Chilean Tinamou
Garza boyera	*Bubulcus ibis*	Cattle Egret
Jote	*Coragyps atratus*	Black Vulture
Bailarín	*Elanus leucurus*	White-tailed Kite
Águila	*Geranoaetus melanoleucus*	Black-chested Buzzard- Eagle
Aguilucho	*Buteo polyosoma*	Red-backed (Variable) Hawk
Peuco	*Parabuteo unicinctus*	Harris' Hawk
Tiuque	*Milvago chimango*	Chimango Caracara
Halcón perdiguero	*Falco femoralis*	Aplomado Falcon
Cernícalo	*Falco sparverius*	American Kestrel
Halcón peregrino	*Falco peregrinus*	Peregrine falcon
Codorniz	*Callipepla californica*	California Quail
Queltehue	*Vanellus chilensis*	Southern Lapwing
Paloma	*Columba livia*	Rock Dove
Torcaza	*Patagioenas (Columba) araucana*	Chilean Pigeon
Tórtola	*Zenaida auriculata*	Eared Dove
Tortolita cuyana	*Columbina picui*	Picui Ground Dove
Chuncho	*Glaucidium nanum*	Austral Pygmy-Owl
Pequén	*Athene cunicularia*	Burrowing Owl
Gallina ciega (Plasta)	*Caprimulgus longirostris*	Band-winged Nightjard
Picaflor chico	*Sephanoides sephanoides*	Green-backed Firecrown
Picaflor gigante	*Patagonas gigas*	Giant Hummingbird
Pitío	*Colaptes pitius*	Chilean Fliker
Carpinterito	*Picoides lignarus*	Striped Woodpecker
Colilarga	*Sylviorthohynchus desmursii*	Des Murs´ Wiretail
Rayadito	*Aphrastura spinicauda*	Thorn-tailed Rayadito
Tijeral	*Leptasthenura aegithaloides*	Plain-mantled Tit-Spinetail
Canastero	*Asthenes humicola*	Dusky-tailed Canastero
Turca	*Pteroptochos megapodius*	Moustached Turca
Tapaculo	*Scelorchilus albicollis*	White-throated Tapaculo
Churrín del norte	*Scytalopus fuscus*	Dusky Tapaculo
Diucón	*Xolmis pyrope*	Fire-eyed Diucon
Cachudito (Torito)	*Anairetes parulus*	Tufted Tit-Tyrant
Fío-fío	*Elaenia albiceps*	White-crested Elaenia
viudita	*Colorhanfus parvirostris*	patagonian Tyrant
Rara	*Phytotoma rara*	Rufous-tailed Plantcutter
Golondrina chilena	*Tachycineta meyeni*	Chilean Swallow
Chercán	*Troglodytes musculus*	Southern House Wren
Zorzal	*Turdus falklandii*	Austral Thrush
Tenca	*Mimus tenca*	Chilean Mockingbird
Chirihue	*Sicalis luteola*	Grassland Yellow Finch
Tordo	*Curaeus curaeus*	Austral Blackbird
Loica	*Sturnella loyca*	Lon-tailed Meadowlark
Cometocino de Gay	*Phrygilus gayi*	Grey-hooded Sierra-Finch
Yal	*Prygilus fruticeti*	Mourning Sierra-Finch
Platero	*Prygilus alaudinus*	Band-tailed Sierra-Finch
Diuca	*Diuca diuca*	Common Diuca-Finch
Chincol	*Zonotrichia capensis*	Rufous-collared Sparrow
Jilguero	*Carduelis barbatus*	Black-chinned Siskin

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[1] Orellana Miquel M. E. 2006.

Gorrión	*Passer domesticus*	House Sparrow
Observadas y no descritas[2]		
N. común	N. científico	N. ingles
Lechuza	*Tyto alba*	Common Barn Owl
Chiricoca	*Chilia melanura*	Crag Chilia
Trile	*Agelaius thilius*	Yellow-winged Blackbird
Tentativas[3]		
N. común	N. científico	N. inglés
Pimpollo	*Rollandia rollans*	White - tufted Grebe
Blanquillo	*Podiceps occidentalis*	Silvery Grebe
Huala	*Podiceps major*	Great Grebe
Picurio	*Podilymbus podiceps*	Pied - billed Grebe
Garza Cuca	*Ardea cocoi*	Cocoi (White-necked) Heron
Garza grande	*Ardea alba*	Great Egret
Garza chica	*Egretta thula*	Snowy Egret
Huairavo	*Nycticorax nycticorax*	Black-crowed Night-Heron
Cisne de cuello negro	*Cygnus melancoryphus*	Black-necked Swan
Caiquén	*Chloephaga picta*	Upland Goose
Pato Jergón grande	*Anas georgica*	Yellow-billed Pintail
Pato Jergón chico	*Anas flavirostris*	Speckled (Chilean) Teal
Pato gargantillo	*Anas bahamensis*	White-cheeked Pintail
Pato real	*Anas sibilatrix*	Chiloe (Southern) Wigeon
Pato colorado	*Anas cyanoptera*	Cinnamon Teal
Pato cuchara	*Anas platalea*	Red Shoveler
Pato rana de pico delgado	*Oxyura vittata*	Lake Duck
Cóndor	*Vultur gryphus*	Andean Condor
Jote cabeza colorada	*Cathartes aura*	Turkey Vulture
Aguilucho chico	*Buteo albigula*	White-throated Hawk
Vari	*Circus cinereus*	Cinereous Harrier
Pidén	*Pardirallus sanguinolentus*	Plumbeous Rail
Tagüita	*Porphyriops melanops*	Spot-flanked Gallinule
Tagua chica	*Fulica leucoptera*	White-winged Coot
Tagua	*Fulica armillata*	Red-gartered Coot
Tagua de frente roja	*Fulica rufifrons*	Red-fronted Coot
Perrito	*Himantopus melanurus*	White - backed (Southern) Stilt
Becacina pintada	*Nycticryphes semicollaris*	South American Painted - Snipe
Becacina	*Gallinago gallinago*	South American Snipe
Perdicita cordillerana	*Attagis gayi*	Rufous-bellied Seedsnipe
Perdicita cojón	*Thinocorus orbignyianus*	Grey-breasted Seedsnipe
Perdicita	*Thinocorus rumicivorus*	Least Seedsnipe
Gaviota dominicana	*Larus dominicanus*	Kelp Gull
Gaviota Cahuil	*Larus maculipennis*	Brown-hooded Gull
Tórtola cordillerana	*Metropelia aymara*	Black-winged ground Dove
Cotorra	*Myiopsitta monachus*	Monk Parakeet
Tucuquere	*Bubo magellanicus*	Magellanic Horned Owl
Nuco	*Asio flammeus*	Short-eared Owl
Bandurrilla	*Upucerthia dumetaria*	Scaled-throated Earthcreeper
Churrete chico	*Cinclodes oustaleti*	Grey-flanked Cinclodes
Churrete	*Cinclodes patagonicus*	Dark bellied Cinclodes
Churrete acanelado	*Cinclodes fuscus*	Bar-winged Cinclodes
Trabajador	*Phleocryptes melanops*	Wren-like Rushbird
Mero	*Agriornis livida*	Great Shrike-Tyrant

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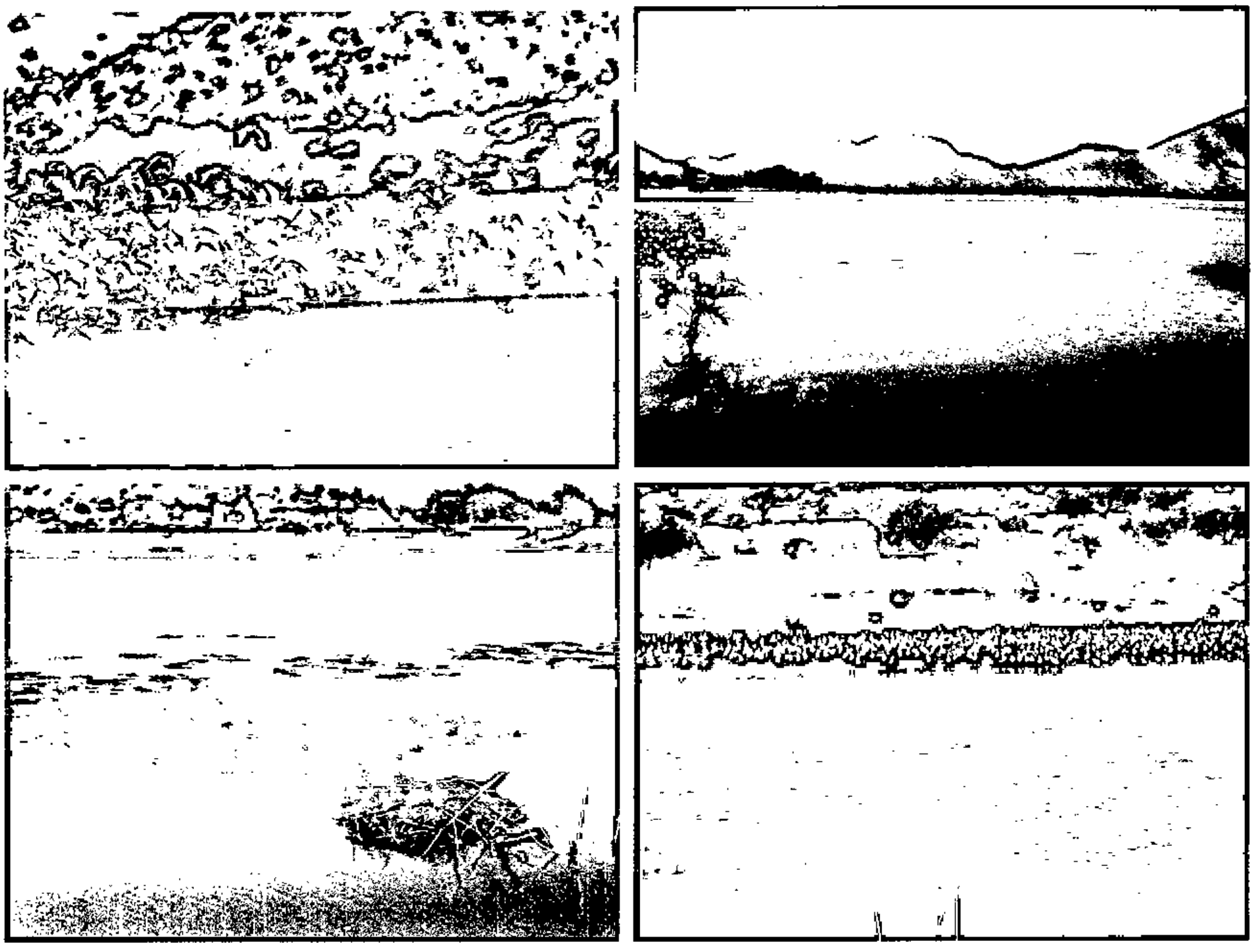
[2] Observaciones personales.

[3] Propuestos en base a la actual presencia de aves en tranques artificiales y la avifauna característica de ambientes similares.

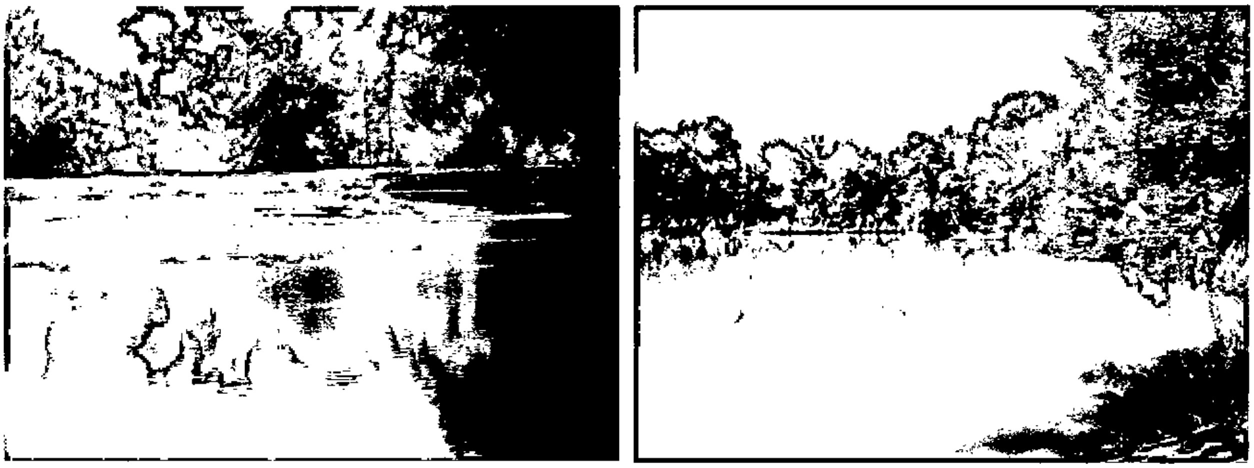
Mero gaucho	*Agriomis montana*	Black-billed Shrike-Tyrant
Dormilona de nuca rojiza	*Muscisaxicola rufivertex*	Rufous-naped Ground-Tyrant
Dormilona tontita	*Muscisaxicola macloviana*	Dark-faced Ground-Tyrant
Colegial	*Lessonia oreas*	Austral (Patagonian) Negrito
Run-run	*Hymenops perspicillata*	Spectacled Tyrant
Siete colores	*Tachuris rubrigastra*	Many-colored Rush-Tyrant
Golondrina de dorso negro	*Pygochelidon cyanoleuca*	Blue-and-white Swallow
Chercán de las vegas	*Cistothorus platensis*	Grass (Sedge) Wren
Bailarín chico	*Anthus correndera*	Correndera pipit
Mirlo	*Molothrus bonariensis*	Shiny Cowbird

Anexo 2

Imágenes: Sector tranque mayor.



Imágenes: Sector tranque menor.



Imágenes: Sector vegetación matorral espinoso


Verano


Inverno

Imágenes: Sector vegetación bosque esclerófilo.

DIVERSIDAD ECOLOGIA SOCIEDAD • IEB •

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INSTITUTE OF ECOLOGY AND BIODIVERSITY (IEB)

Santiago, Julio 2010

Marcelo Alejandro Orellana Reyes
Administrador Estación Experimental
Facultad de Cs. Agronómicas
Universidad de Chile

Estimado Sr. Orellana:

Mi nombre es Cecilia Smith, soy Dra. en Ecología, trabajo en la Universidad de Chile. A través de CONAF y del Instituto de Ecología y Biodiversidad (IEB) estamos desarrollando un proyecto de Restauración Ecológica llamado "Implementación de un estudio a largo plazo del potencial de restauración pasiva del bosque esclerófilo de Chile Central". Este proyecto se realiza con el financiamiento del fondo de investigación del bosque nativo y el IEB. Por su carácter, este es un estudio pionero en Chile y sus resultados pretenden dar sustento empírico para el desarrollo de nuevas soluciones de recuperación del bosque esclerófilo de la zona central.

El objetivo del proyecto es evaluar a largo plazo medidas que puedan acelerar el proceso de restauración pasiva a través del control de limitantes. Para esto, pretendemos instalar ocho exclusiones de 2400 m^2 cada una, ubicadas en sectores costeros y e interiores de la zona central del país.

Debido a que este es un estudio de largo plazo, nos ha sido dificultoso encontrar sitios que puedan asegurarnos la continuidad del proyecto. Hasta el momento contamos con la aprobación de CONAF para utilizar la Reserva Nacional Peñuelas ubicada en la Cordillera de la Costa de la Región de Valparaíso y estamos en conversaciones con la Universidad Católica de Chile para utilizar la estación experimental que poseen en San Carlos de Apoquindo ubicada en la precordillera de la Región Metropolitana. Otra opción que manejamos es la estación experimental que Ud. administra, para ello le solicito a través de esta carta la autorización formal para en primera instancia prospeccionar el área y, en el caso de cumplir las exigencias técnicas necesarias poder instalar cuatro de las ocho exclusiones que tenemos contempladas. Como lo comente anteriormente, este es un estudio a largo plazo por lo que el tiempo de permanencia de los ensayos sería de al menos 10 años. Junto a esta carta, le adjunto un archivo para mayor información sobre el proyecto y los investigadores responsables.

Sin más que agregar y esperando una positiva acogida a nuestra solicitud,
se despide atentamente de Usted,

Dra. Cecilia Smith
Instituto de Ecología y Biodiversidad (IEB), Universidad de Chile
Teléfono: 78790531 y 63-247975

Título del proyecto

Implementación de un estudio a largo plazo del potencial de restauración pasiva del bosque esclerófilo de Chile Central

http://www.investigacion.conaf.cl/efpa/nomina.php?id_expediente=893449&nomina=evaluacion

Organismos participantes

Corporación Nacional Forestal (CONAF)

Instituto de Ecología y Biodiversidad, Universidad de Chile (IEB)

Investigadores

Dra. Cecilia Smith, e-mail: csmith@willnet.cl; teléfonos: 63-247975, 9-78790531

Dr. Pablo Becerra, e-mail: pbecerro@uc.cl; teléfonos: 2-6864169, 9-92301201

Alejandro Miranda, e-mail: mirandac.alejandro@gmail.com; teléfonos: 9-98956062

Inao Vásquez, e-mail: inaovas@gmail.com; teléfonos: 9-91594788

Cristian Delpiano, e-mail: delpiano.cristian@gmail.com; teléfonos: 9-95559203

Tiempo de duración: Al menos 10 años

Objetivo general

Determinar el potencial de regeneración natural que tiene el bosque esclerófilo para la implementación de planes de restauración pasiva.

Objetivos específicos

1.- Determinar el efecto de la exclusión de herbívoros y granívoros en superficies degradadas en el proceso de recuperación natural del bosque esclerófilo

2.- Determinar las condiciones de sitio que pueden aumentar la probabilidad de éxito de medidas de restauración pasiva del bosque esclerófilo.

Pontificia Universidad Católica de Chile
Facultad de Agronomía e Ingeniería Forestal
Departamento de Ecosistemas y Medio Ambiente

Viernes, 23 de septiembre del 2011

Señor Marcelo Orellana Reyes
Administrador Estación Experimental Germán Greve
Facultas de Ciencias Agronómicas
Universidad de Chile

Junto con saludarlo, a través de esta carta me permito oficializar la solicitud presentada personalmente el día 29 de julio del 2011 durante una vista a la Estación Germán Greve. En esa oportunidad se solicitó el arrendamiento de una parcela para el desarrollo de ensayos experimentales sujetos a un proyecto de tesis doctoral a cargo del Sr. Juan Ovalle, Ingeniero Agrónomo y estudiante de doctorado en Ciencias de la Agricultura de la Pontificia Universidad Católica de Chile.

Los ensayos experimentales a realizar, contemplan el establecimiento de 200 plantas de Quillay, lo que requiere de una superficie aproximada de 1620 m^2. El tiempo estimado de duración del proyecto es de 18 meses a contar del mes de octubre del presente año.

El costo por el uso de agua para la mantención del ensayo, será acordado a partir de las condiciones de cobro que estipule la Administración del predio.

Cabe destacar, que el presente proyecto está patrocinado y financiado en su totalidad por la Facultad de Agronomía e Ingeniería Forestal de la Universidad antes mencionada.

El desarrollo del ensayo, no compromete en ningún caso, el deterioro del entorno natural, ni la degradación de los recursos de propiedad de la Estación experimental Germán Greve. Dando énfasis en esto último, al cumplirse el plazo de término del presente proyecto, se procurará dejar el sitio de trabajo en las mismas condiciones que se encontró antes de comenzar el ensayo.

Agradeciendo sinceramente la voluntad expresada por su institución y usted de colaborar en el desarrollo de esta tesis, se despide atentamente,

PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE
FACULTAD DE AGRONOMÍA E INGENIERÍA FORESTAL
DEPARTAMENTO ECOSISTEMAS Y MEDIO AMBIENTE

Juan Ovalle
Estudiante de doctorado

Eduardo Arellano
Profesor guía

Pontificia Universidad Católica de Chile
Facultad de Agronomía e Ingeniería Forestal
Departamento de Ecosistemas y Medio Ambiente

Santiago, 04 de junio del 2013

Señor Marcelo Orellana Reyes
Administrador Estación Experimental Germán Greve
Facultas de Ciencias Agronómicas
Universidad de Chile

Junto con saludarlo, a través de esta carta quisiera informar del término del acuerdo de cooperación prestado por la Estación Experimental Germán Greve durante el periodo 2011-2012 para el desarrollo de ensayos experimentales correspondientes al proyecto de tesis doctoral del Sr. Juan Ovalle, Ingeniero Agrónomo y estudiante de doctorado en Ciencias de la Agricultura de la Pontificia Universidad Católica de Chile.

Los ensayos experimentales llevados a cabo en el sector de Quebrada de la Plata, que comprendían el establecimiento de plantas de Quillay en una superficie de 1600 m^2, fueron dejados en las mismas condiciones que se encontraron antes de comenzar el ensayo, cumpliendo así con el acuerdo pactado en un inicio con el administrador de la estación.

Agradeciendo sinceramente la cooperación prestada durante el desarrollo del proyecto de investigación, se despide atentamente,

Juan Francisco Ovalle Ortega, Ing. Agr.

PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE
FACULTAD DE AGRONOMÍA E INGENIERÍA FORESTAL
DEPARTAMENTO DE ECOSISTEMAS Y MEDIOAMBIENTE

RESUMEN EJECUTIVO:

Evaluación de técnicas de producción de plántulas de *Quillaja saponaria* (Mol.) con énfasis en el mejoramiento de su calidad morfológica y fisiológica, sobrevivencia y crecimiento inicial en ambientes mediterráneos semiáridos de Chile central

JUAN FRANCISCO OVALLE ORTEGA

Av. Vicuña Mackenna 4860 - Campus San Joaquín – Santiago de Chile
Fono: 56-2-3544169 – Correo jrovalle@uc.cl
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1. ANTECEDENTES GENERALES DEL PROYECTO

Este documento ha sido elaborado para ser presentado a las entidades que estarían dispuestas a colaborar con el desarrollo del Capítulo IV de la presente tesis doctoral. Dentro de los ensayos experimentales que comprende este capítulo, está la realización de una plantación con Quillay **(Ver punto 4.4. Establecimiento en campo)** en un sitio de características abióticas representativas del ecosistema mediterráneo semiárido de Chile central. Tomando en cuenta esto último, el propósito del documento es detallar los requerimientos, compromisos y condiciones que comprenderá la implementación de este ensayo experimental.

Comité de tesis:
Dr. Eduardo Arellano (profesor guía)
Dra. Rosanna Ginocchio (co-guía)
Dr. Eduardo Olate (informante)
Dr. Pablo Becerra (colaborador)

Entidad patrocinante: Dpto. de Ecosistemas y Medioambiente, FAIF, PUC

Duración: 20 meses (julio 2011 a marzo 2013)

2. INTRODUCCIÓN

La utilización de especies arbóreas nativas con propósitos de compensación y restauración forestal se ha incrementado ostensiblemente los últimos años en Chile. Dentro de ellas, Quillay (*Quillaja saponaria* (Mol.)), especie endémica de la zona central, ha sido una de las más utilizadas en restauración debido a la facilidad para producirla en vivero y a su alta plasticidad a la variabilidad ambiental y topográfica de su área de distribución.

Sin embargo, la alta mortalidad post-transplante, debido a la baja calidad de la planta producida en vivero y a la baja disponibilidad hídrica en época estival (Di Castri y Mooney, 1973; Holmgren y Scheffer, 2001), impide el normal establecimiento de esta especie. Este fenómeno conduce al fracaso de las plantaciones en fase de establecimiento, junto con el incumplimiento de normativas legales referidas a compensaciones forestales (>75% de sobrevivencia) (D.L. 20.283 Art. 14 MINAGRI, 2008).

La sobrevivencia de una plántula durante el arraigo y establecimiento, está determinada por su capacidad de responder de forma temprana y oportuna al estrés post-transplante (Rietveld, 1989; Burdett, 1990; Grossnickle y Folk, 1993; Valladares, 2004). Más aún, en zonas de sequía estacional marcada (clima mediterráneo), la sobrevivencia estará fuertemente relacionada con rasgos morfo-funcionales que confieran mecanismos de mitigación al estrés hídrico (Padilla y Pugnaire, 1997).

En este sentido, la producción de plántulas destinas a ambientes áridos y semiáridos requiere del desarrollo de estándares de calidad, que considere el mejoramiento de ciertos atributos morfológicos y fisiológicos (Landis, 1985; Duryea, 1985; Vallejo *et al.,* 2003; Haase, 2008; Del Campo *et al.,* 2010), apuntando a la formación de plántulas de fenotipo xeromorfo con características rusticas (Vilagrosa *et al.,* 2005).

Oliet *et al.* (2009), en plántulas de *Pinus halepensis* sometidas a un pre-acondicionamiento nutricional en vivero, reportaron una sobrevivencia de 79% al séptimo año post-transplante en condiciones mediterráneas. El régimen nutricional habría proporcionado atributos morfológicos y fisiológicos favorables para el establecimiento en campo. En vista de estos resultados, los autores recomiendan considerar parámetros de calidad de planta, tales como, altura (H) igual a 40 cm, relación parte aérea:parte radical (PA:PR) igual a 2,5 y una moderada a alta concentración de N y P foliar.

La aplicación de regímenes de fertilización y riego son las prácticas culturales de mayor importancia en la producción de plantas, especialmente en contenedor (Landis, 1985). Específicamente, el Nitrógeno (N) es considerado un nutriente esencial en todos los procesos de arraigo descritos (Oliet *et al.*, 1997). Algunos trabajos han constatado el efecto favorable de un incremento en el aporte y la concentración de N sobre la extensión de nuevas raíces tras la plantación (Van den Driessche, 1992), originando el adelanto en el inicio de la actividad fotosintética que incrementaría la capacidad de evitación de la sequía en la plántula (Moreno *et al.*, 2005). Otro de los efectos positivos de la fertilización es que, al promover el crecimiento radical, permite la obtención de una proporción mas balanceada de la parte aérea / parte radical, demostrando tener implicancias favorables en el desempeño de la plántulas en condiciones de campo bajo condiciones de sequía (Domínguez *et al.*, 2000).

Sin embargo, son conocidos algunos efectos desfavorables de la fertilización nitrogenada sobre la capacidad de tolerar la sequía, entre ellos, los desequilibrios morfológicos por un mayor desarrollo aéreo (Van den Driessche, 1992; Landis *et al.*, 1994), formación de tejidos suculentos (Landis *et al.*, 1994) o pérdida de otras facultades fisiológicas relacionadas con la tolerancia a estrés hídrico Van den Driessche, 1992).

Hasta ahora, las experiencias de fertilización en Quillay se limitan mayoritariamente a las prácticas habituales realizadas en vivero y en campo con algunos estudios de fertilización en base a distintas dosis de N, P y K en la forma de urea, nitrato de amonio, sulfato de potasio y superfosfato triple. (Ezquerra, 2003; Malfanti, 2004; Valenzuela, 2007).

Como hipótesis de trabajo se plantea que la incorporación de tecnologías como la aplicación de fertilizantes de liberación controlada (FLC), proporcionarían ventajas respecto a los hidrosolubles convencionales, ya que optimizan la tasa de entrega de nutrientes y minimizan las pérdidas por lixiviación. Se predice entonces, que éstos regímenes nutricionales promueven un mayor desarrollo de atributos de calidad de planta (parte aérea y radical), una mayor sobrevivencia y crecimiento inicial en plántulas de *Quillaja saponaria* (Mol.) durante la etapa de establecimiento en campo.

Es así como es posible contar con técnicas de producción de plantas que mejoren los atributos de calidad (morfológicos y fisiológicos), y a la vez, avalen el éxito de establecimiento en campo (Burdett, 1983; Landis, 1985; Duryea, 1985; Rose *et al.*, 1990; Birchler *et al.*, 1998; Stape *et al.*, 2001; Haase, 2008).

3. OBJETIVOS

Como **objetivo general** se busca evaluar, en plántulas de *Quillaja saponaria* (Mol.), el efecto de fertilizantes con distinta tasa de entrega y dosis nutricional sobre el desarrollo de atributos morfológicos y fisiológicos de calidad de planta y el desempeño post-transplante bajo condiciones de sequía en la zona mediterránea semiárida de Chile central.

Para dar cumplimiento al objetivo general se definen los siguientes **objetivos específicos:**

3.1. Evaluar el efecto de los regímenes nutricionales sobre el desarrollo de atributos morfológicos, tales como, longitud, área y volumen radical, altura (H), diámetro de altura de cuello (DAC), antes y después de la plantación.

3.2. Evaluar el efecto de los regímenes nutricionales sobre atributos fisiológicos, tales como, contenido nutricional en tejidos, potencial hídrico xilemático, razón biomasa PA/PR y fluorescencia de la clorofila, antes y después de la plantación.

3.1. Evaluar el efecto de los regímenes nutricionales sobre la tasa de sobrevivencia post-transplante.

4. MATERIALES Y MÉTODOS

4.1. Material vegetal

Se utilizarán plántulas de Quillay (*Quillaja saponaria* (Mol.)) de 6 meses (6 - 8 cm de altura) producidas en bolsa de polietileno negro de 12 x 15 cm (400 cm^3) llenadas con una mezcla a igual razón de tierra de hoja, compost, arena y suelo del lugar.

Quillay es una especie arbórea siempreverde, representativa del tipo forestal bosque y matorral esclerófilo de Chile central (Gajardo, 1994). Se distribuye entre los 30°30´S y 38°S. Alcanza hasta los 15 m de altura y posee hábito de enraizamiento profundo (Hoffmann, 1998). Posee intereses en el ámbito de la industria (saponinas), en la apicultura por su flora melífera y en programas de restauración y compensación forestal, entre otros.

4.2. Área de estudio

Las etapas de producción de plantas (Etapa I) y establecimiento en campo (Etapa II), comprendidas en este capítulo, se llevarán a cabo en diferentes áreas, sin embargo, ambas se encuentran dentro de la Región Metropolitana (33°27´S, 70°42´W). La precipitación anual promedio es de 426 mm y se concentra (79%) en los meses de mayo y septiembre. El periodo de sequía se extiende normalmente desde octubre hasta abril.

En específico, la Etapa I se realizó en un área de invernaderos de la Facultad de Agronomía e Ing. Forestal PUC, Comuna de Macul, Chile. La Etapa II, se realizará en un área silvestre, con presencia de vegetación nativa representativa del bosque y matorral esclerófilo de la zona mediterránea semiárida de Chile central (sitio por definir).

4.3. Etapa I: Producción de plantas

4.3.1. Descripción del ensayo

El ensayo se estableció con plántulas de Quillay provenientes de un vivero de la zona (Vivero Pumahuida, Quilicura, Chile). La duración del ensayo fue de 6 meses a partir de febrero del 2011. Se cultivaron bajo condiciones de semi-sombra proporcionadas por mallas rashell de 50% para evitar el exceso de radicación durante el periodo estival.

4.3.2. Tratamientos

Los tratamientos están definidos por diferentes fuentes de Nitrógeno (N): un fertilizante recubierto de liberación controlada y una mezcla de fertilizantes hidrosolubles de uso tradicional en vivero. Además, se cuenta con un tratamiento control que no recibe fertilización, de manera de evaluar la fertilidad natural del sustrato de crecimiento mediante un análisis químico del suelo. Al momento de definir las dosis se establece un aporte de N igual para todos los tratamientos, independiente de la fuente del cual provenga.

El FLC utilizado es Basacote® Plus (Compo) 15:8:12 en tres dosis crecientes (F_{LC1}, F_{LC2}, F_{LC3}). Estas últimas se definen a partir de una dosis media recomendada por el fabricante (6 - 7 kg m^{-3} de sustrato). Además, se toma como criterio las dosis definidas para diversos ensayos experimentales de nutrición con FLC aplicados en especies forestales cultivadas en vivero (Jacobs *et al.*, 2003; Jacobs *et al.*, 2005; Bustos *et al.*, 2008; Thiers *et al.*, 2008). La mezcla de fertilizantes tradicionales (F_T) está compuesta por fosfato diamónico ($(NH_4)_2HPO_4$) 18:46:0 y cloruro de potasio (KCl) 0:0:60. La dosis utilizada es única y se establece a partir del aporte de N y K del FLC.

Todas las plantas se riegann a capacidad de campo cuando su contenido de humedad alcanza el 39%, proporcionando un rango de humedad de suelo óptimo para el desarrollo morfológico y fisiológico normal de plántulas forestales (Khan *et al.*, 1996).

Cuadro 1. Tratamientos

Tratamiento	**Dosis de N según la fuente de fertilización**
F_{LC1}	0,18 g N planta^{-1} (1,2 g Basacote Plus x planta^{-1})
F_{LC2}	0,36 g N planta^{-1} (2,4 g Basacote Plus x planta^{-1})
F_{LC3}	0,72 g N planta^{-1} (4,8 g Basacote Plus x planta^{-1})
F_T	0,36 g N planta^{-1} (2 g $(NH_4)_2HPO_4$ + 0,48 g KCl x planta^{-1})
F_0	Sin fertilización

4.3.3. Mediciones

Al momento de establecer los ensayos se miden parámetros de arquitectura radical (longitud total (cm), diámetro medio de raíces (mm), volumen radical (cm^3) y área de absorción (cm^2)), H (cm), DAC (mm), PS de biomasa aérea y radical (g), relación PA:PR y contenido nutricional foliar (mg/kg, %), a partir de una muestra de 15 plántulas. Además, se realizan análisis químicos de agua de riego y de sustrato, obtenidos en el laboratorio de servicios de la Facultad de Agronomía e Ingeniería Forestal PUC.

Al finalizar la Etapa I y previo al transplante, una muestra de 5 plantas por tratamiento y repetición se extraen para evaluar parámetros de arquitectura radical (citados anteriormente), sobrevivencia (%), incremento en volumen del tallo (cm^3), índice de calidad de Dickson (ICD). Adicionalmente, una muestra de 10 plantas por tratamiento se extrae para realizar la prueba de potencial de crecimiento radical (PCR) (Ritchie, 1985).

4.3.4. Diseño experimental

El ensayo se plantea con un diseño de bloques completamente aleatorizados con 4 repeticiones. Dentro de cada bloque (repetición) se distribuyen al azar los 4 tratamientos de fertilización más un tratamiento control. La unidad experimental corresponde al grupo de plantas dentro de un tratamiento por bloque. Cada tratamiento posee 20 plantas ordenadas en una hilera (unidades de muestreo). El número total de plantas del ensayo es 400.

4.4. Etapa II: Establecimiento en campo

4.4.1. Descripción del ensayo

El transplante a campo se realizará durante la estación de invierno del 2011 (agosto). Con el propósito de mantener una distribución espacial controlada de las raíces, y al mismo tiempo, facilitar las labores de cosecha y disminuir el riesgo de daño radical por extracción, se adecuarán sacos troquelados de cinta de polipropileno permeables al agua de 40 x 65 cm, como contenedores. Para disminuir el riesgo de acumulación excesiva de agua en el saco se harán perforaciones en la tela y se dejarán 5 cm de arena en la base. El sustrato de relleno se obtendrá del volumen de suelo extraído en la excavación de la casilla de plantación. Los contendores se ubicarán en casillas de 0,4 x 0,4 x 0,6 m de profundidad. El marco de plantación será de 3 m sobre hilera por 3 m entre hilera, formando una superficie total de 730 m^2 aproximadamente. Una vez plantadas, todos los tratamientos se regarán durante los meses de verano con dosis uniformes de 3 L cada 15 días, de acuerdo a las prácticas convencionales realizadas en compensaciones forestales.

4.4.2. Mediciones

Se realizará una evaluación inicial (antes de plantación) de parámetros morfológicos de la parte aérea y radical (descritos anteriormente en ensayo de etapa I). Posteriormente, con una frecuencia de 3 meses (fin de cada estación) se evaluará el incremento en H (cm), DAC (mm), sobrevivencia (%). Además, durante los meses secos (primavera y verano), se evaluarán parámetros fisiológicos útiles para determinar estrés hídrico, tales como, fluorescencia de la clorofila y potencial hídrico (variables hídricas puntuales).

Al finalizar la segunda temporada de verano desde su plantación (marzo 2013), se tomará una muestra de 5 plantas por tratamiento y repetición para evaluar los siguientes parámetros: arquitectura radical (longitud total (cm), diámetro medio de raíces (mm), volumen radical (cm^3) y área de absorción (cm^2)), H (cm), DAC (mm), sobrevivencia (%), incremento en volumen del tallo (cm^3), PS de biomasa aérea y radical (g), relación PA:PR, ICD, IEP, contenido nutricional en tejidos (foliar) (mg/kg, %).

Se contará con análisis químicos de agua de riego y de suelo del lugar, obtenidos en el laboratorio de servicios de la Facultad de Agronomía e Ingeniería Forestal PUC.

4.3.3. Diseño experimental

El ensayo se plantea con un diseño de bloques completamente aleatorizados con 4 repeticiones. Dentro de cada bloque (repetición) se distribuyen al azar los 4 tratamientos de fertilización más un tratamiento control. La unidad experimental corresponde al grupo de plantas dentro de un tratamiento por bloque. Cada tratamiento posee 5 plantas ordenadas en una hilera (unidades de muestreo). El número total de plantas del ensayo es 100.

4.5. Análisis estadístico

El efecto de los tratamientos, los bloques y sus interacciones se verifica en todas las variables, mediante un análisis de varianza paramétrico de un factor (ANDEVA), con un nivel de confianza de 95% ($p < 0{,}05$). Para las variables de crecimiento, se analiza el incremento periodo a periodo mediante un análisis de covarianza, utilizando como covariable el diámetro o altura inicial, según corresponda. Cuando existen diferencias estadísticas, se utiliza la prueba de comparaciones múltiples de Tukey, para evaluar la significancia de estas diferencias entre los tratamientos. Además, la relación entre las variables se determina mediante modelos de regresión y pruebas de bondad de ajuste. Todos los análisis estadísticos son realizados mediante los procedimientos estándar del programa SAS.

La relación entre el desempeño en campo (crecimiento y sobrevivencia) y los atributos de calidad de planta obtenidos en vivero son analizados mediante una correlación linear simple. El coeficiente de correlación de Pearson es aplicado a las variables cuantitativas y el coeficiente de correlación de Spearman a las variables no paramétricas de sobrevivencia.

Para minimizar la posibilidad de cometer un error Tipo II, asociado a un reducido numero de unidades muestrales en algunos tratamientos, los efectos de los tratamientos en ANOVA son considerados significativos con un $P < 0{,}10$.

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Santiago, 10 de Abril de 2014

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El Departamento de Ecosistemas y Medio Ambiente de la Facultad de Agronomía e Ingeniería Forestal de la Pontificia Universidad Católica de Chile, a través de mi coordinación, se encuentra desarrollando el proyecto "Evaluación de técnicas pasivas y activas para la recuperación del bosque esclerófilo de Chile central", financiado por CONAF. Este proyecto tiene por objetivo estudiar diferentes metodologías de restauración del bosque nativo, tales como siembra y plantación de especies nativas de la zona central, en áreas que hayan sufrido un incendio reciente, comparándolas con áreas no incendiadas. Por esta razón, nos gustaría solicitar autorización para desarrollar parte del proyecto en el área baja de la Quebrada de la Plata del predio de Rinconada de Maipu de la Universidad de Chile. Recientemente el predio contiguo a la Quebrada de la Plata sufrió un incendio (Fundo San Francisco). Lamentablemente el incendio no dejó vegetación remanente no quemada en este predio. Nuestro proyecto empleará esta área incendiada del fundo San Francisco para evaluar el proceso de recuperación de la vegetación en ella, pero requerimos un área no quemada similar con la cual contrastar lo observado en el área quemada. Para ello, el área baja de la Quebrada de la Plata nos sería de gran utilidad para el proyecto, con la cual comparar las observaciones que realizaremos en el área incendiada del fundo San Francisco. Por esto, solicitamos autorización para emplear un sector en la ladera norte (de exposición sur) del área baja de la Quebrada (Imagen más abajo).

Las actividades del proyecto que solicitamos realizar en el Predio Rinconada de Maipú son las siguientes: primero, instalación de 20 cercos de 3 x 4 m, construidos en base a polines y malla hexagonal, distribuyéndolas en áreas con bosque esclerófilo, espinales y matorral. Cabe indicar que lo mismo será instalado en el área incendiada del predio vecino. Estas protecciones serían instaladas durante abril. Posteriormente, en cada una de estas protecciones se realizaría una plantación de 4 plantas y una siembra de semillas de 4 especies nativas del área (Quillaja saponaria (Quillay), Lithrea caustica (Litre), Schinus polygamus (Huingán), Kageneckia oblonga (Bollén)). Estas protecciones serían monitoreadas aproximadamente 1 vez por mes, durante 4 años (hasta diciembre de 2017).

Sin otro particular, le saluda atentamente

Pablo Becerra Osses,
Investigador principal Proyecto "Evaluación de técnicas pasivas y activas para la recuperación del bosque esclerófilo de Chile central",
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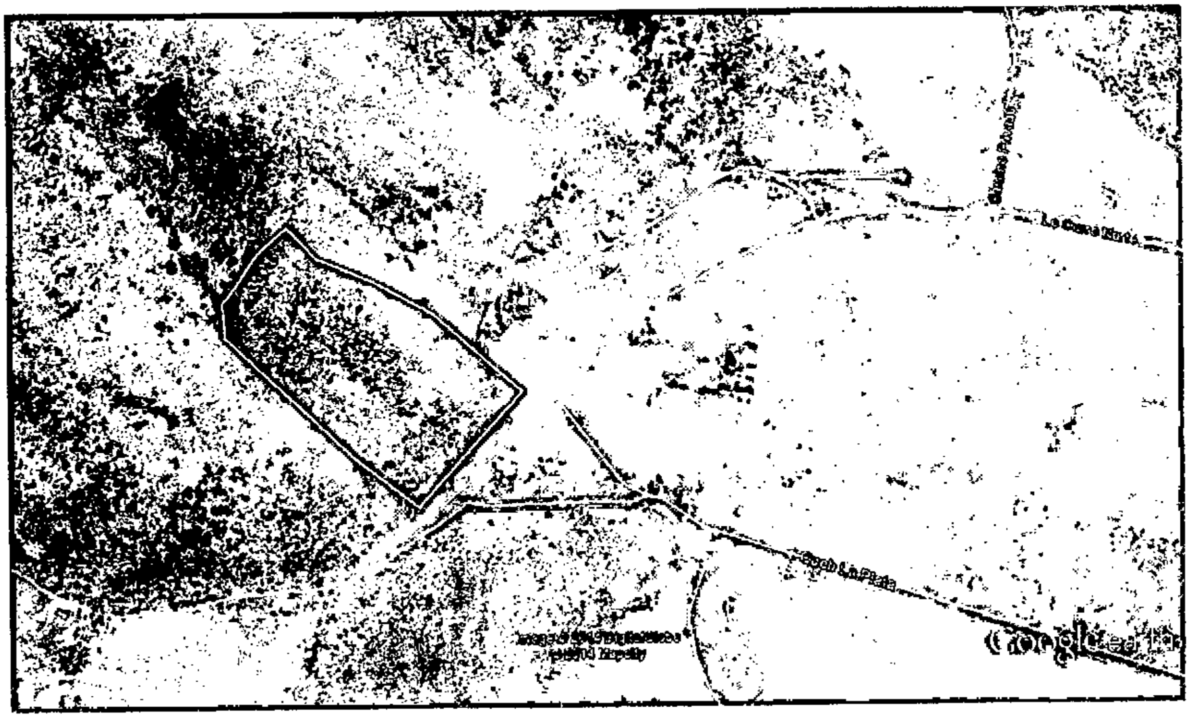

Área potencial para desarrollar el estudio (polígono color blanco), específicamente para la instalación de 20 protecciones de 3 x 4 m.

Chloris chilensis

Revista chilena de flora y vegetación

Año 8. N° 2

COMUNIDADES VEGETALES DE LA QUEBRADA DE LA PLATA, REGIÓN METROPOLITANA (CHILE)

Plant communities from quebrada de la Plata, Metropolitan Region (Chile)

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RESUMEN

Se efectuó un diagnóstico del estado actual de la vegetación en la quebrada de la Plata, provincia de Santiago, Región Metropolitana. Para levantar la información en terreno se empleó la metodología de la Carta de Ocupación de Tierras. Los resultados fueron analizados en comparación con los estudios fitosociológicos realizados en el lugar y en el resto de la región. Se identificaron once agrupaciones vegetales, las que pueden ser relacionadas con siete asociaciones vegetales, de acuerdo a la sintaxonomía fitosociológica vigente en Chile. Las agrupaciones son las siguientes: *Puya berteroniana-Echinopsis chiloensis, Baccharis paniculata-Baccharis linearis, Cryptocarya alba, Quillaja saponaria-Lithraea caustica, Peumus boldus-Lithraea caustica, Acacia caven, Flourensia thurifera, Proustia cinerea, Proustia cuneifolia, Trevoa trinervis-Colliguaja odorifera, Senna candolleana.*

Palabras clave: vegetación de Chile central, bosque esclerofilo, matorrral espinoso.

ABSTRACT

The current state of the vegetation was assessed in quebrada de la Plata, province of Santiago, Metropolitan Region. To obtain the information in the field, the methodology of the Land Use Map was used. The results were analyzed in comparison with the phytosociologic studies carried out in the place and in the rest of the region. Eleven plant groups were identified, which can be related to seven associations according to the valid phytosociologic sintaxonomy of Chile. The groups are the following: *Puya berteroniana-Echinopsis chiloensis, Baccharis linearis, Cryptocarya alba, Quillaja saponaria-Lithraea caustica, Peumus boldus-Lithraea caustica, Acacia caven, Flourensia thurifera, Proustia cinerea, Proustia cuneifolia, Trevoa trinervis-Colliguaja odorifera, Senna candolleana.*

Key words: vegetation of central Chile, quebrada de la Plata, sclerophyllous forest, thorny scrub

INTRODUCCIÓN

La vegetación de la zona central de Chile se caracteriza por poseer un nivel de degradación producido por el hombre desde hace cientos de años que ha provocado un considerable desequilibrio ecológico, llegando a establecerse como un proceso continuo que conduce a situaciones de deterioro cada vez más agudas (Balduzzi, 1982; Gajardo, 1994). La vegetación de la quebrada de la Plata no escapa a esta situación, ya que corresponde a un ecosistema compuesto por comunidades de matorrales y bosques esclerofilos alteradas fuertemente en el pasado y actualmente amenazadas por la expansión urbana (Tapia, 2005).

En este contexto, el objetivo de este trabajo es establecer un diagnóstico del estado de la vegetación que permita contar con la información actualizada necesaria para la elaboración de planes de manejo apropiados para el desarrollo de actividades de protección, principalmente, acciones de rehabilitación o restauración.

MATERIAL Y MÉTODO

Antecedentes del área de estudio

La quebrada de la Plata se encuentra ubicada en la Comuna de Maipú, Región Metropolitana, a una distancia aproximada de 30 km al SW de la ciudad de Santiago (**Figura 1**). Posee un clima de tipo mediterráneo semiárido con una precipitación anual de 317 mm (Olivares et al., 1998). La vegetación presente en el lugar, desde el punto de vista fitogeográfico, corresponde a la zona mesomórfica y a la de zona de los matorrales arborescentes escleròfilos y xerófitos (Pisano,1966). Las comunidades vegetales existentes se encuentran fuertemente diferenciadas, principalmente, debido a efectos combinados de altura, exposición, suelo e intervención humana (Schlegel, 1963, 1966) (**Foto 1**).

METODOLOGÍA

El diagnóstico de la vegetación actual se realizó mediante la Cartografía de Ocupación de Tierras (COT), procedimiento metodológico que consiste en la representación cartográfica de la vegetación actual, expresada mediante su estructura, composición florística e impacto del hombre sobre el medio (Etienne y Prado, 1982). Comprendió las etapas de fotointerpretación a escala 1:5000, descripción en terreno y síntesis de la información. Los datos recopilados fueron ingresados y analizados a través de un sistema de información geográfico (SIG).

Posteriormente, las unidades de vegetación identificadas fueron reinterpretadas y reclasificadas en función de las propuestas fitosociológicas vigentes, sobre la base de los trabajos de Schlegel (1963, 1966) para el área de estudio y de Schmithüsen (1954), Oberdorfer (1960), Villaseñor y Serey (1980) y Balduzzi et al. (1981, 1982) para el resto de la región. Para ello se identificaron agrupaciones vegetales, que corresponden a conjuntos de unidades COT con la misma combinación de especies dominantes, las que fueron comparadas con la composición característica de especies de las asociaciones identificadas por los autores antes mencionados.

RESULTADOS

Carta de Ocupación de Tierras

Mediante el análisis COT, se determinaron 275 unidades de vegetación homogéneas, en cuanto a fisonomía, especies dominantes y grado de artificialización. En estudios previos del lugar Etienne y Contreras (1981) y Gallardo (1993) distinguieron 197 y 133 unidades de vegetación, respectivamente, utilizando la misma metodología, pero empleando un nivel de percepción a escala 1:10.000.

La proporción que ocupa cada formación vegetal se exhibe en **Tabla 1**. En él se puede apreciar que la formación con mayor superficie corresponde al tipo "leñosa baja", con 591 ha, representando al 66% del área de interés.

Agrupaciones Vegetales

Se identificaron 11 agrupaciones vegetales, que a continuación se describen tomando en consideración su estructura, las especies características y el ambiente en el que se desarrollan. Su distribución en el área de estudio se muestra en la **Figura 2**.

Puya berteroniana-Echinopsis chiloensis (chagual y quisco)

Se caracteriza estructuralmente por presentar un estrato de plantas suculentas que puede sobrepasar los 2 m de altura, y coberturas entre 10 y 75%. Es posible encontrarlo asociado con un estrato arbustivo bajo, que generalmente no supera el metro de altura, y con coberturas entre 25 y 90%. También se desarrolla un estrato herbáceo estacional de baja cobertura. La especie suculenta más representativa de esta agrupación corresponde a *Puya berteroniana*, la que se encuentra acompañada frecuentemente por la cactácea *Echinopsis chiloensis*. En el nivel arbustivo, se desarrollan *Proustia cinerea* y *Colliguaja odorifera*.

La unidad se ubica, principalmente, en laderas de exposición norte y en ocasiones, sobre laderas expuestas al oeste; en altitudes que oscilan entre los 800 y los 1100 m. Los lugares donde se desarrolla presentan un porcentaje promedio de suelo desnudo que alcanza el 35%, y una superficie muy pedregosa.

Gallardo y Gastó (1987), señalan a esta comunidad como representativa de un estado de sucesión avanzado o de clímax en laderas de exposición norte, en condiciones de aridez extrema (xéricas), con abundante afloramiento rocoso; y cuyas especies más representativas aparecen estrechamente relacionadas a este tipo de ambiente.

Gajardo (1994) ubica a esta comunidad en su formación del Matorral Espinoso de la Cordillera de la Costa y la caracteriza como típica de los sectores con afloramientos rocosos y muy frecuente en laderas expuestas al norte.

En la clasificación fitosociológica se puede establecer una correspondencia con la asociación *Puyo-Trichocereetum chilensis* (Villaseñor y Serey 1980), puesto que presenta los elementos florísticos dominantes típicos de esta comunidad.

Baccharis linearis (romerillo)
Se caracteriza estructuralmente por poseer un estrato arbustivo dominante de hasta 2 m de altura, cuya cobertura oscila entre 25 y 50%, a menudo acompañado por un estrato herbáceo estacional con coberturas máximas de 100%, que forma habitualmente una pradera que generalmente no sobrepasa los 25 cm de altura. Ocasionalmente es posible encontrarlos asociados a suculentas. La especie característica y dominante entre los arbustos es *Baccharis linearis*. En laderas expuestas al norte, puede estar acompañada por *Proustia cinerea* y *Flourensia thurifera*, mientras que de forma esporádica, aparecen *Baccharis paniculata* y *Quillaja saponaria*. También puede aparecer asociada a suculentas como *Puya berteroniana*. Por otra parte, el nivel herbáceo, que en ocasiones resulta ser el estrato dominante, se encuentra constituido, principalmente, por *Vulpia* spp. o *Erodium cicutarium*, y más esporádicamente por *Avena barbata* o *Senecio adenotrichius*.

La agrupación se desarrolla sobre laderas expuestas al este, al sur y principalmente hacia el norte, en altitudes que fluctúan entre los 700 y los 950 m.s.n.m. La proporción de suelo desnudo no sobrepasa el 28% en promedio.

Baccharis linearis, la especie dominante de esta agrupación, relaciona a la comunidad con la asociación *Gutierrezio-Rosmarinifolietum*, descrita por Oberdorfer (1960), debido a que la dominante, al igual que sus acompañantes, coinciden con las especies características de dicha asociación. Por otra parte, en la clasificación de Gajardo (1994), esta agrupación podría corresponder a la asociación de *Baccharis linearis-Plantago hispidula*, perteneciente a la formación del Matorral Espinoso del Secano Costero.

Balduzzi et al. (1982), señalan que este matorral se desarrolla junto al denominado espinal de *Acacia caven*, pero cubriendo pequeñas áreas con mayor o menor xericidad. Al mismo tiempo, señalan que esta comunidad deriva de la degradación de la asociación *Peumo-Cryptocaryetum albae* en laderas húmedas de exposición sur; mientras que, en aquellas laderas cálidas y secas expuestas al norte, la degradación es más rápida y la asociación *Gutierrezio-Baccharidetum linearis* deriva a menudo de la asociación Quillajo-*Lithraeetum causticae*.

Cryptocarya alba (peumo)
Está formada por un estrato arbóreo dominante que alcanza alturas máximas de 15 m con una cobertura aproximada de 70%, y cuyas especies más representativas son *Cryptocarya alba* y *Quillaja saponaria*. En esta agrupación se incluyen situaciones de ladera y de quebrada que no fue posible discriminar mediante el análisis de COT. La primera se caracteriza por la presencia de *Retanilla trinervia*, *Kageneckia oblonga* y

Lithraea caustica, mientras que en la segunda, por la de *Cryptocarya alba*, *Aristotelia chilensis*, *Escallonia illinita* y *Maytenus boaria*.
En general, se desarrolla sobre laderas bajas, medias y altas de exposición sur, con pendientes medias de 40%, pero alcanza mayor crecimiento en fondos de quebradas o en lugares adyacentes a éstas.
Gajardo (1994), en su formación del Matorral Espinoso de la Cordillera de la Costa, también reconoce estas dos situaciones, distinguiendo la comunidad de *Cryptocarya alba-Luma chequen*, típica de las quebradas, y la de *Cryptocarya alba-Quillaja saponaria* típica de laderas de exposición sur. En el marco de la sintaxonomía fitosociológica, la situación de laderas se puede relacionar con la asociación *Boldo-Cryptocaryetum* (Oberdorfer, 1960).

Quillaja saponaria-Lithraea caustica (quillay y litre)
Esta comunidad está formada por un estrato arbóreo dominado por *Quillaja saponaria* que, en general, no supera los 9 m de altura, pero puede llegar hasta 16 m; mientras que, *Lithraea caustica*, se encuentra formando un estrato con fisonomía de matorral, junto con otras especies, tales como *Retanilla trinervia*, *Acacia caven*, *Podanthus mitiqui*, *Eupatorium salvia* y *Colliguaja odorifera*, con alturas máximas de 4 m. En conjunto, ambos estratos alcanzan una cobertura de 50%.
Estos bosques se desarrollan sobre laderas medias a altas, con exposición sur principalmente, y con pendientes medias de 25%. Es posible observarlos, ocasionalmente, en terrenos expuestos hacia el norte, donde la especie dominante *Quillaja saponaria* alcanza menor desarrollo que el señalado anteriormente, mientras que *Lithraea caustica* tiende a desaparecer.

Esta agrupación se relaciona con la asociación *Quillajo-Lithraeetum causticae* (Schmithüsen 1954), mientras que según la clasificación de Gajardo (1994), correspondería a la asociación de *Acacia caven-Lithraea caustica*, perteneciente a la formación del Matorral Espinoso de la Cordillera de la Costa.

Peumus boldus-Lithraea caustica (boldo y litre)
Se presenta bajo la forma de un estrato arbustivo, con alturas que oscilan entre 1 y 2 m, y coberturas comprendidas entre 25 y 50%. Las especies más representativas son *Peumus boldus* y *Lithraea caustica*, son acompañadas por *Quillaja saponaria*, *Colliguaja odorifera* y *Retanilla trinervia*. Ocasionalmente es posible encontrar *Proustia cuneifolia* y *Podanthus mitiqui*.
Se desarrolla en laderas altas, entre 800 y 1000 m.s.n.m. expuestas principalmente hacia el sur y hacia el SW. Presenta una proporción de suelo desnudo que no supera el 15% y un suelo pedregoso hasta muy cerca de la superficie.
De acuerdo con la clasificación de Gajardo (1994), esta comunidad se encuentra inserta en las formaciones del Matorral Espinoso de la Cordillera de la Costa y del Secano Costero, por lo tanto, está fuertemente restringida a aquellos sectores expuestos a la escasa influencia marina del área de estudio. Su composición florística señala relaciones con la asociación *Boldo-Lithraeetum causticae* (Schmithüsen 1954).

Acacia caven (espino)

Esta agrupación está conformada por un estrato arbóreo dominante, compuesto principalmente por *Acacia caven*, con una altura que difícilmente supera los 5 m y cuya cobertura aproximada alcanza al 25%. También es posible observar algunos individuos aislados de *Quillaja saponaria*; mientras que en el piso se desarrolla una pradera compuesta por especies herbáceas anuales de origen europeo, tales como: *Vulpia* sp., *Erodium cicutarium* y *Avena barbata* (**Foto 2**).

El ambiente en el que se desarrolla corresponde a los sectores más bajos, sobre laderas de exposición norte y una pendiente media de 20%.

Esta agrupación representa al denominado espinal o sabana de *Acacia caven*, formación caracterizada por la dominancia de individuos de tamaño arbóreo desarrollados generalmente por rebrotes de tocón y por un estrato herbáceo en el piso.

Oberdorfer (1960) la señala como una etapa regresiva de la sucesión ecológica, mientras que para Rundel (1981) corresponde a una formación clímax. Por su ubicación en la quebrada de la Plata, es posible que se haya formado posterior al desmonte y a un excesivo pastoreo. Según la clasificación de Gajardo (1994) esta agrupación puede corresponder a la asociación *Acacia caven-Lithraea caustica* de la formación del Matorral Espinoso de la Cordillera de la Costa, caracterizada por ser de origen secundario y fuertemente intervenida por el hombre. En la clasificación fitosociológica, se relaciona claramente con la asociación *Cestro-Trevoetum* (Oberdorfer, 1960).

Flourensia thurifera (incienso)

Se caracteriza estructuralmente por un estrato arbustivo dominante, de hasta 2 m de altura, cuya cobertura oscila entre 25 y 90%, a menudo acompañado por un estrato herbáceo con coberturas máximas de 50%. Ocasionalmente es posible encontrarla asociada con plantas suculentas.

Flourensia thurifera es la dominante en el estrato arbustivo y suele estar acompañada por *Colliguaja odorifera* y *Baccharis paniculata*. Cuando se presentan suculentas, a la comunidad se agrega *Puya berteroniana*. El estrato herbáceo, que en ocasiones resulta ser el dominante, se encuentra constituido, principalmente, por *Vulpia* spp.

La agrupación se desarrolla sobre laderas expuestas al este y al norte, en altitudes que fluctúan entre los 700 y los 850 m.s.n.m. La proporción de suelo desnudo no sobrepasa el 15% en promedio.

Gajardo (1994) señala que esta comunidad, perteneciente a la formación del Matorral Espinoso de las Serranías, es escasa en la región y que responde con seguridad a una situación de transición. Aunque la información disponible es escasa se podría relacionar con la asociación *Cestro-Trevoetum* (Oberdorfer, 1960), dado que la especie dominante en esta agrupación forma parte del elenco de especies características de la asociación señalada.

Proustia cinerea (huañil)

Se caracteriza estructuralmente por poseer un estrato arbustivo dominante de hasta 2 m de altura, cuya cobertura oscila entre 25 y 90%, que en ocasiones se presenta junto a un estrato herbáceo con coberturas máximas de 90%, o junto a un estrato con suculentas.

La especie característica corresponde a *Proustia cinerea,* que suele estar acompañada por *Colliguaja odorifera*, *Baccharis paniculata* o *Retanilla trinervia*; mientras que ocasionalmente está acompañada por *Acacia caven* o *Flourensia thurifera*. Es posible encontrar asociadas a suculentas como *Puya berteroniana*, o un estrato herbáceo con *Vulpia* sp.

Se desarrolla, principalmente, sobre laderas expuestas al norte y, en menor medida, hacia el oriente o hacia el poniente; en altitudes que fluctúan entre los 650 y los 900 m.s.n.m. La proporción de suelo desnudo no sobrepasa el 24% en promedio.

En la clasificación de Gajardo (1994), corresponde a la asociación *Colliguaja odorifera-Proustia cinerea*, perteneciente a la formación del Matorral Espinoso de las Serranías. Por sus especies dominantes, podría relacionarse con la asociación *Cestro-Trevoetum* (Oberdorfer, 1960).

Proustia cuneifolia (huañil)

Se caracteriza estructuralmente por poseer, exclusivamente, un estrato arbustivo dominante de hasta 2 m de altura, cuya cobertura oscila entre 25 y 90%.

La especie característica corresponde a *Proustia cuneifolia,* que suele estar acompañada por *Retanilla trinervia*, y ocasionalmente por *Colliguaja odorifera*.

Se desarrolla, principalmente, sobre laderas expuestas al este y, en menor medida, hacia el sur; en altitudes que fluctúan entre los 700 y los 900 m.s.n.m. La proporción de suelo desnudo no sobrepasa el 15% en promedio.

Dada su composición florística puede corresponder a la comunidad definida por Gajardo (1994) como asociación de *Acacia caven-Proustia cuneifolia,* perteneciente a la formación del Matorral Espinoso de la Cordillera de la Costa. De acuerdo con la clasificación fitosociológica de la región, podría corresponder a una facie de la asociación *Cestro-Trevoetum* (Oberdorfer, 1960).

Retanilla trinervia-Colliguaja odorifera (tebo y colliguay)

Está constituida por un estrato arbustivo, que en algunos sectores alcanza alturas máximas de 4 m, formando un matorral arborescente. Se desarrolla frecuentemente junto a un estrato herbáceo, que en algunos sectores puede ser dominante. También es posible encontrar plantas suculentas, principalmente en aquellos sectores más xéricos del lugar, como las cumbres altas expuestas al norte y con bastantes afloramientos rocosos. En algunos casos se desarrolla una formación arbórea expresada de manera muy aislada y de poco desarrollo que generalmente no supera el 25% de cobertura.

Las especies características de esta agrupación corresponden a *Colliguaja odorifera* y *Retanilla trinervia*. En el estrato arbustivo es posible encontrarlas acompañadas por un gran número de especies, siendo las más habituales *Proustia cinerea*, *Baccharis linearis*, *Baccharis paniculata*, y ocasionalmente *Proustia cuneifolia*, *Flourensia thurifera* y *Acacia caven*; en los sectores de mayor altitud aparece la especie *Podanthus mitiqui*. En aquellos sectores con formaciones arbóreas, es posible encontrar *Quillaja saponaria*, *Acacia caven*, y en ocasiones, *Lithraea caustica*; mientras que donde se desarrolla el estrato herbáceo, es posible encontrar con frecuencia *Vulpia* spp., y en menor medida *Erodium cicutarium*, *Avena barbata* y *Senecio adenotrichius*. En los lugares con presencia de rocas es posible encontrar *Puya berteroniana*.

Se distribuye ampliamente sobre laderas de exposición norte y este, y en menor medida sobre laderas de exposición sur y oeste; pese a que en estas últimas constituye la principal agrupación vegetal. Los sitios donde se desarrolla se ubican a una altitud comprendida entre los 550 y los 1100 m.s.n.m y presentan una proporción promedio de suelo desnudo de 21%.

Gajardo (1994) señala que esta comunidad es la dominante del paisaje de la formación del Matorral Espinoso de la Cordillera de la Costa. En la sintaxonomía fitosociológica corresponde claramente a la asociación *Cestro-Trevoetum* (Oberdorfer, 1960).

La presencia de individuos aislados de *Quillaja saponaria* y *Lithraea caustica*, puede indicar que corresponde a una etapa regresiva desde el bosque dominado por dichas especies siempreverdes. Balduzzi et al. (1982), señalan que, indudablemente, esta agrupación deriva de una antigua degradación de la asociación *Quillajo-Lithraeetum causticae.*

Por otra parte, dada la dominancia de *Retanilla trinervia* en gran parte del área, se puede suponer que se trata de una zona que ha sufrido el impacto de incendios, factor al que dicha especie responde produciendo grandes cantidades de semillas, aumentando así su cobertura y distribución en un lugar quemado (Holmgren et al., 1994).

Senna candolleana (quebracho)

Esta agrupación está compuesta por un solo estrato que no supera los 8 m de altura dominado por *Senna candolleana*, con algunos individuos de la misma especie, pero de menor desarrollo, ocupando un nivel inferior. Aisladamente se puede observar individuos de *Retanilla trinervia* y *Colliguaja odorifera* formando un estrato arbustivo abierto de no más de 2 m de altura.

Se ubica en la parte baja de la quebrada, bordeando los 600 m.s.n.m., en exposición NE, con una pendiente media de 10%, pero con una superficie del suelo muy pedregosa.

Gallardo y Gastó (1987), señalan que la especie *Senna candolleana* es importante en las etapas iniciales de la sucesión secundaria en sectores costeros, sobre terrenos descubiertos de vegetación o de cultivo agrícola cuando se dejan de intervenir.

No son claras sus relaciones sintaxonómicas, aunque *Senna candolleana* aparece, aunque con muy baja presencia, dentro de la asociación *Cestro-Trevoetum* (Oberdorfer, 1960).

El esquema sintaxonómico que se propone para ubicar las agrupaciones vegetales descritas es el siguiente:

Clase *Gutierrezio-Trichocereetea* Oberdorfer 1960
  Orden *Saturejo-Puyetalia chilensis* Balduzzi et al. 1981
    Alianza *Puyion violaceae* Balduzzi et al. 1981
      Asociación *Puyo-Trichocereetum chilensis* Villaseñor y Serey 1980
        (=*Puya berteroniana-Echinopsis chiloensis* Schlegel 1963)
          Agrupación ***Puya berteroniana-Echinopsis chiloensis***
    Alianza *Saturejion gilliesii* Oberdorfer 1960, prov

Asociación *Gutierrezio-Rosmarinifolietum* Oberdorfer 1960

Agrupación ***Gutierrezia paniculata-Baccharis linearis***

Clase *Lithraeo-Cryptocaryetea* Oberdorfer 1960

Orden *Cryptocaryetalia* Schmithüsen 1954

Alianza *Cryptocaryion* Schmithüsen 1954

Asociación *Boldo-Cryptocaryetum* Oberdorfer 1960

(=*Cryptocarya alba-Myrceugenella chequen* Schlegel 1963)

Agrupación ***Cryptocarya alba***

Alianza *Lithraeion* Schmithüsen 1954

Asociación *Quillajo-Lithraeetum causticae* Schmithüsen 1954

Agrupación ***Quillaja saponaria-Lithraea caustica***

Asociación *Boldo-Lithraeetum causticae* Schmithüsen 1954

Agrupación ***Peumus boldus-Lithraea caustica***

Orden *Colliguajetalia odoriferae* Balduzzi, Tomaselli, Serey & Villaseñor 1982

Alianza Colliguajion odoriferae Balduzzi, Tomaselli, Serey & Villaseñor 1982

Asociación *Cestro-Trevoetum* Oberdorfer 1960

Agrupación ***Acacia caven***

Agrupación ***Flourensia thurifera***

Agrupación ***Proustia cinerea***

Agrupación ***Proustia cuneifolia***

Agrupación ***Retanilla trinervia-Colliguaja odorifera***

Agrupación ***Senna candolleana***

DISCUSIÓN

La vegetación de la quebrada de la Plata corresponde a bosques y matorrales esclerofilos fuertemente perturbados en el pasado, aunque en la actualidad ha disminuido la presión antrópica sobre ellos. Producto de lo anterior, más las particularidades microclimáticas, hacen que la vegetación se presente en mosaico muy heterogéneo (Di Castri y Mooney, 1973).

Debido a la intervención antrópica pasada, es posible encontrar diversas condiciones de vegetación típicas de un estado original degradado. Tal es el caso de los espinales o bosques de *Acacia caven* que se desarrollan en la parte baja y en los sectores más accesibles del área. Esta condición, que podría ser transitoria en el caso de una exclusión total, corresponde a un típico estado de deterioro del bosque de *Quillaja saponaria* y *Lithraea caustica* (Oberdorfer, 1960), el que luego de acciones destructivas puede llegar a dar paso al dominio de un estrato herbáceo (Olivares y Gastó, 1971). Este espinal se origina, probablemente, por sobrepastoreo en un bosque latifoliado existente previamente, lo que es evidenciado por la presencia en forma aislada de individuos de *Quillaja saponaria* y *Lithraea caustica*. Esta formación de *Acacia caven* puede corresponder a una etapa inferior al clímax climático, constituyendo un sub-clímax (Olivares y Gastó, 1971), lo que se fundamenta en que el ganado no permite el establecimiento de otras especies arbóreas esclerofilas, y ayuda a dispersar las semillas de *Acacia caven* (Gutiérrez y Armesto, 1981; Fuentes et al., 1986). Balduzzi et al. (1982) señalan al espinal como una etapa degradada de la comunidad *Colliguaja odorifera-Trevoa trinervis*. Sin embargo, la presencia de individuos aislados de *Quillaja saponaria* y *Lithraea caustica* desarrollados de rebrote, hace suponer la existencia en el pasado de un bosque con tales especies. Otro factor de deterioro que se manifiesta en la quebrada de la Plata, es la condición de los bosques esclerofilos, cuya fisonomía está formada, en general, por individuos regenerados vegetativamente, es decir, de retoños de tocón, lo que hace suponer una fuerte explotación maderera en el pasado, o eventualmente, presencia de incendios causados por el hombre. Al respecto, Schlegel (1963, 1966) señala que en los años 1957, 1959 y 1962 ocurrieron daños de estas características. Una condición muy particular la conforma la escasa regeneración existente de especies arbóreas. Tal situación se puede explicar, en forma preliminar, por la escasa disponibilidad hídrica del lugar, acentuada por el efecto negativo adicional constituido por la presencia de animales herbívoros silvestres, como por ejemplo, el conejo europeo (*Oryctolagus cuniculus*), el cual puede afectar la regeneración de especies arbóreas (Fuentes, 1988).

Por otra parte, la presencia de una formación de matorrales adaptados a las condiciones de mayor aridez en el lugar, confirma otro estado de deterioro, especialmente en laderas de exposición sur, donde se ha pasado de condiciones más húmedas a estados más xerofíticos. También es probable que esto haya ocurrido por incendios, lo que se evidencia por la presencia dominante del arbusto espinoso *Retanilla trinervia*, el que luego de un incendio responde produciendo mayor cantidad de ejemplares originados de semilla, además de los originados de tocón (Holmgren et al., 1994).

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URL: http://www.chlorischile.cl

Volver a la portada

Fot 1. Vista panorámica desde la Quebrada de la Plata hacia el valle de Santiago.

Foto 2. Agrupación de *Acacia caven* (primer plano).

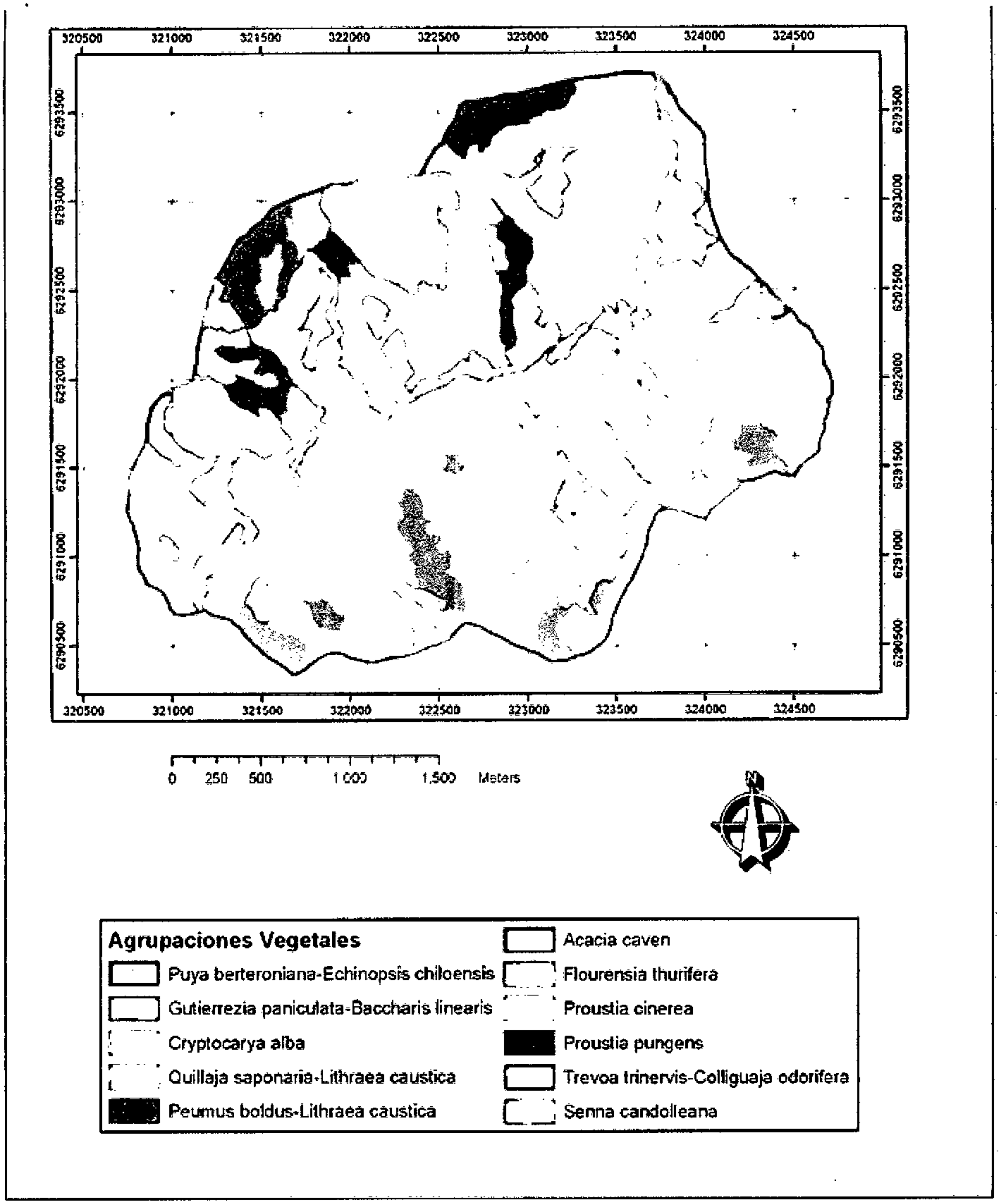

Figura 2. Distribución Geográfica de las Comunidades Vegetales existentes en la Quebrada de la Plata.

AGU PUBLICATIONS

Earth's Future

COMMENTARY

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Conservation easements and mining: The case of Chile

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Key Points:

- Mining activity in protected areas threatens conservation strategies
- Private protected areas (PPAs) may add unreliable protection
- Chilean law would poorly balance mining and conservation

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Abstract Private protected areas (PPAs) are important designations with the potential to complement and improve public protected area (PA) networks in many countries. PPAs come in many forms and offer a wide variety of incentives, rights, responsibilities, and protections. One popular model, now being considered for adoption in Chile, is the conservation easement. In this article, we examine how well conservation easements would perform as PPA designations in countries such as Chile that have strong mining industries. Mining, and other concessions, in PAs is emerging as an important point of contention between conservation and development. PPA designations should be carefully designed to offer protections that conform to standards that will complement PA networks, that are perpetual, and that require a publically accountable and transparent process to overturn or modify.

1. Introduction

Conflicts between the exploitation of natural resources and reliable conservation of nature are at the heart of the struggle for sustainability in the Anthropocene. Protected areas, whether public or private, are an established approach to resolving this conflict. Private protected areas (PPAs) have a long history; one of their contemporary uses is to help complement efforts by states that lack capacity for systematic protection. As such, PPAs are a growing trend in South American conservation policy [*Crouzeilles et al.*, 2013; *Ladle et al.*, 2013] (J. Cope, The conventional wisdom on conservation easements in Latin America. Phase 1-Improving and expanding use of conservation easements in Latin America: A learning portfolio, 2005. Downloaded from http://www.ibcperu.org/doc/isis/8380.pdf on 10 June 2013, hereinafter referred to as Cope, online report, 2005).

Public protected areas (PAs) are state-designated, often state-owned and state-managed sites, which may have a range of management goals and levels of conservation protection, as systematized by the IUCN (International Union for Conservation of Nature and Natural Resources, Morges, Switzerland) Protected Areas Categories System (www.iucn.org, accessed July 2013). PPAs are less well-defined. They can take a variety of legal forms, offering different rights, responsibilities, and protections, as well as a range of practical or monetary incentives and benefits [*Brockington et al.*, 2008; *Korngold*, 2011] (Cope, online report, 2005). In the best case scenario, PPAs would complement or extend coverage by public PAs, while the State facilitates and supports private conservation initiatives. Nevertheless, setting private land aside for ecosystem services, recreation, and research is fraught with ethical, technical, and legal challenges.

Conservation easement is a legal tool for creating PPAs, which has generally been successful in the United States [*Brewer*, 2011; *Korngold*, 2011; but see *Rissmann et al.*, 2007] (Cope, online report, 2005). An easement restricts the usage rights of a property, and sets up a legally binding agreement on land uses and management between the owner and a title holder, which in the US context is usually a conservation trust or government organism [*Brewer*, 2011]. The easement follows the property, rather than its owner, i.e., it can persist after the death of the landowner, although in practice this may be contested (Cope, online report, 2005). In the United States, a conservation easement reduces the value of the land for tax and inheritance purposes, and the price of an easement represents the opportunity cost to the landowner of not developing the land [*Korngold*, 2011].

Although conservation organizations in several Latin American countries have implemented contracts and other legal instruments modeled on conservation easements since 1992 (Cope, online report, 2005), a contractual obligation (easement) that follows a property is a concept unavailable in South American law

[*Calderón Rojas*, 2010]. Chile prides itself as being the first South American country to consider introducing conservation easements into its legal code, a step that it believes other South American countries are watching with interest. To assess the potential benefits or weaknesses of the proposed easement law as a means for developing a legal framework for PPAs, we examine the case of mining activity on a private research station in Chile. This case study draws attention to conflicts between the delivery of conservation policy on PPAs and Chilean mining law. We use this case study to illustrate the challenges of PPA policy development in countries with a strong mining industry. *Duran et al.* [2013] have recently shown that globally 27% of metal-mining activities are within 10 km of a PA; overlap with PPAs is unknown. More broadly, we consider how policy tools can preserve or fail to preserve the balance between conservation and natural resource exploitation when outsourcing these decisions from state actors to private individuals.

2. Existing Legal Frameworks for PPAs in Chile

Chile has 36 National Parks (IUCN category II), 49 National Reserves (IUCN category IV), and 15 Natural Monuments (IUCN category III), 9 Biosphere Reserves (effectively IUCN category V), 1 site of cultural patrimony (Easter Island, IUCN category VI), and 9 Ramsar Sites (IUCN category IV), covering 19% of its territory, and mainly concentrated in the scenic south of Chile (CONAF, www.conaf.cl, accessed 2013) [*Calderón Rojas*, 2010]. Chile is far from reaching the target of 10% of its "ecological regions effectively conserved" and "areas of particular importance to biodiversity protected," as stated in the 2010 targets adopted at the seventh meeting of the conference of the parties to the Convention on Biological Diversity, to which Chile is signatory (Annex II COP7 Decision VII/30, UNEP/CBD/COP/7/21, Decisions adopted by the conference of the parties to the Convention on Biological Diversity at its seventh meeting, 2004. Downloaded from www.cbd.int/decisions/cop/, 19 Dec. 2012) [*Calderón Rojas*, 2010]. Since 1994 the state has recognized the need to "develop and incentivize the creation of protected forest areas on private land" [*Law 19300*, 1994; *Armesto et al.*, 1998; *Pauchard and Villarroel*, 2002]. Notably, central Chile, although the only Mediterranean climate region in South America and the area of Chile with highest endemicity of flora and richness of fauna, also has the lowest PA coverage [*Pauchard and Villarroel*, 2002].

The organism currently in charge of the PA network (CONAF), with funding from the Global Environment Facility (GEF), has collaborated with private groups to support the creation of PPAs [*Sepúlveda Luque*, no date]. There are an estimated 500 PPAs in Chile today [*Sepúlveda Luque*, no date]. There is no PPA law in Chile. Private owners with an interest in conservation on their lands can choose from a confusing range of policy tools and designations, such as becoming a Nature Sanctuary (Comité Nacional Pro Defensa de la Fauna y Flora (CODEFF), Las areas silvestres protegidas privadas en Chile, Una herramienta para la conservación, 1999. Downloaded from www.asiseconservachile.org, 14 Dec. 2012, hereinafter referred to as CODEFF, online report, 1999). Various private organizations exist to advise and provide support for PPAs, such as Parques Para Chile and Así Conserva Chile. In response to the lack of a legal framework, a new conservation easement law was proposed in 2008 and is being considered by the government. Parques Para Chile, Así Conserva Chile, and The Nature Conservancy, the only international conservation NGO active in central Chile, have expressed support for this legal project (www.parquesparachile.cl, www.asiconservachile.org, http://espanol.tnc.org/dondetrabajamos/chile, all accessed 2012).

3. Chile's Proposed Conservation Easement Law

The conservation easement law under consideration, which passed the Chamber of Deputies (the lower house) in August 2012 and was sent by the Senate for further consideration by various committees ("Proyectos de Ley en tramitación," www.camera.cl, accessed 19 September 2013), would permit the creation of conservation easements (derecho real de conservación) that would allow lands to be set aside as PPAs for conservation for defined periods (15–40 years). The conservation easement concept is considered an innovative legal development within the South American property rights legal tradition [*Calderón Rojas*, 2010]. As there is no current law governing PPA creation or management in Chile, conservation easements, if passed, would provide a legal tool with which to create PPAs. On the face of it, this is an important and useful development that can address Chile's shortfalls in compliance with the CBD [*Calderón Rojas*, 2010].

The Chilean conservation easement would differ in some ways from the US model. No tax incentives, compensation for opportunity cost, or monetary support for management are considered in the law. Unlike in the United States, easements cannot be granted in perpetuity. The Commission on Natural Resources, National Properties and the Environment in their report on the law [*Calderón Rojas*, 2012] are vague about the definition of dedicating a property to conservation, noting that landowners have many different visions, corresponding to many different management goals. The latest available version of the law [*Calderón Rojas*, 2012] states that the easement contract must include at least one of the following: a restriction on property uses, an obligation to maintain the property, and/or an obligation to execute a sustainable use management plan. A use that cannot be restricted is mining (see below) [*Calderón Rojas*, 2012]. The law does not restrict other concessionary rights either. It weights the state's need to promote investment in infrastructure over private conservation initiatives, as indicated in the comment by member of the Chamber of Deputies Sr. Vallespín that "a landowner should not be able to attempt to block an electrical project through the constitution of a conservation easement" [*Calderón Rojas*, 2010]. Unfortunately, this situation is likely to lead to a long-term failure to comply with CBD targets.

4. Case Study: Mining at the Quebrada de la Plata Research Station

Here we examine the case of current mining activity at a research station also used as a community recreation site in central Chile, considering what protections it has under current law and how the proposed conservation easement law would change the situation. The Quebrada de la Plata, a section of the Germán Greve Silva Agronomical Research Station, a ~3000 ha silvopastoral habitat also known as La Rinconada (henceforth: Quebrada de la Plata Research Station), privately owned by the Faculty of Agronomy of the University of Chile since 1933, is being explored by various mining companies without the permission of the Faculty [*Farías*, 2012] (C. Araneda and C. Ehijos, personal communication, 2012; Figure 1). There are currently 11 concessions being explored, with 16 more under consideration [*Farías*, 2012]. This mining activity is perfectly legal. The right to mine is enshrined in the Chilean constitution. Since the 1983 mining law, mining concessions are defined as property "distinct and independent from the ownership of the superficial property" [*Law 18248*, 1983, article 2], and thus may be purchased and exploited by owners other than the owners of the topsoil without their permission. The mining law states that "Anyone may explore or excavate, freely, in open or uncultivated terrain, whomsoever the owner may be" [*Law 18248*, article 15]. The superficial property owner's permission is required only for mining in orchards, vineyards, or in areas with buildings.

Eight million hectares north of Chile are already under mining concessions held by fewer than 20 large companies [*Ramos*, 2011]. To increase competition and development of the mining sector, CORFO (the governmental agency Corporation for Development and Production) has a program subsidizing small- and medium-sized mining companies wishing to undertake exploration and prospection ("Fondo de Exploración Minera Fénix," www.corfo.cl, accessed 15 January 2013). Owing to the benefits of better infrastructure, easier access to water, and cheaper labor, and the presence of smaller mineral deposits not attractive to large mining companies, it is likely that small- and medium-sized mining companies will increasingly seek concessions in central Chile in the near future. Given the large number of mining concessions already covering the Metropolitan Region alone, this could represent an upcoming threat to conservation (see Figure 1).

The Research Station is classed within a Priority Site under the state's Strategy for the Conservation of Biodiversity in the Metropolitan Region (www.mma.gob.cl/biodiversidad/1313/w3-article-49498.html, accessed 19 September 2013), and as a Zone of Ecological Preservation and a Zone of Ecological Protection with Controlled Development in the Regulatory Plan for the Santiago Metropolitan Area (http://www.seremi13minvu.cl/opensite_20080710120043.aspx, accessed 19 September 2013), but mining is not restricted by zoning laws [*Law 18248*, 1983]. There appear to be two avenues to end mining activity at the research station (CODEFF, online report, 1999). One is to apply for an exception from the Mining Ministry from mining activity on the basis that the site is of scientific interest. The other is to apply for status as a Nature Sanctuary, which is officially a type of National Monument (IUCN category III), to which large changes (such as mining activity) would have to be approved by a national council. In both cases, the station must prove that it is of special scientific value. In the case of a Nature Sanctuary, the Faculty would take on the cost of management appropriate to this designation. A third option, which

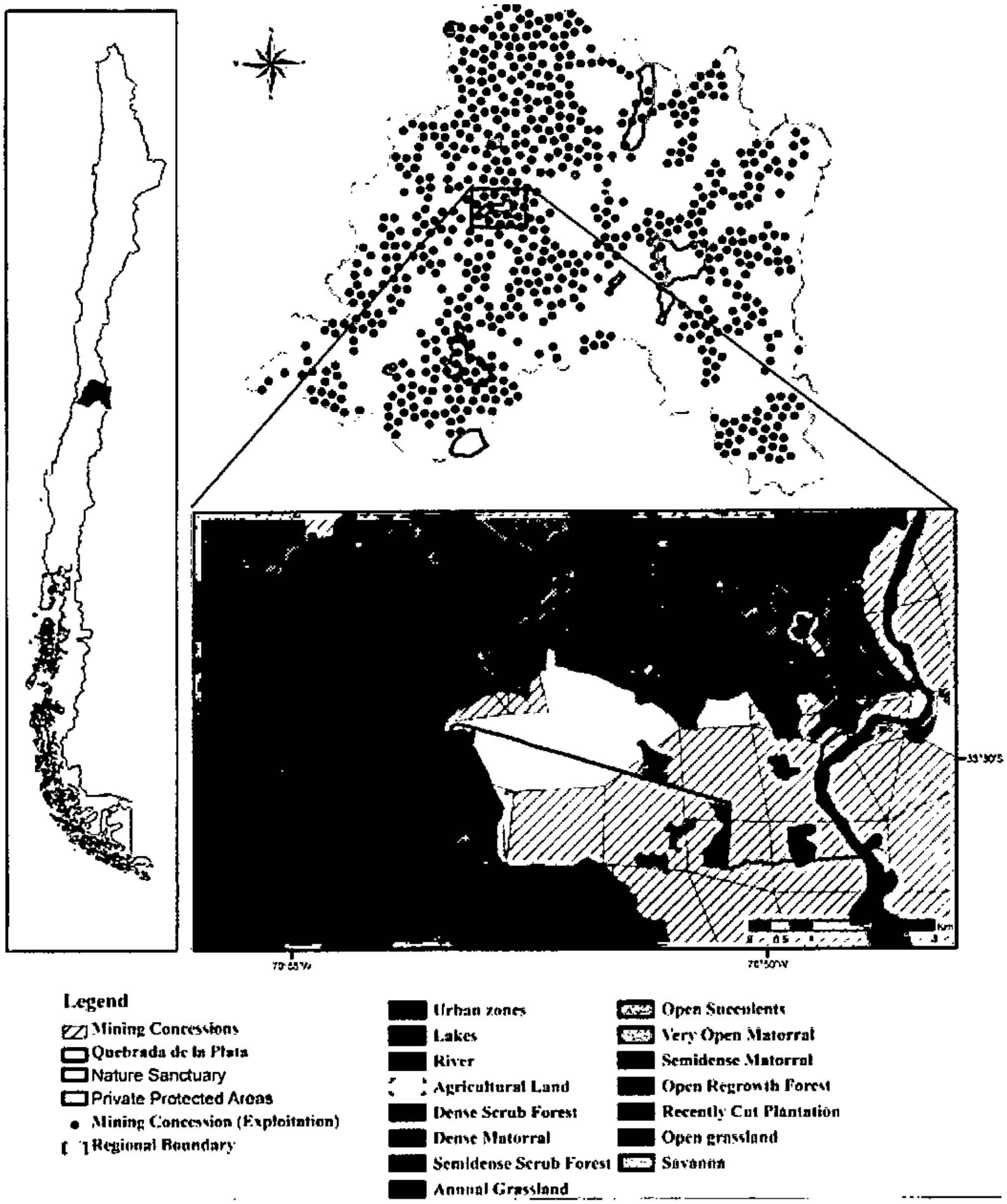

Figure 1. Mining concessions, private and public protected areas, and habitat types in the Metropolitan Region administrative district of central Chile. At left, the shaded area shows the Metropolitan Region, in the center of central Chile. Top right, the Metropolitan Region in more detail. We obtained the locations of mining concessions under exploitation from the publically accessible online platform http://catastro.semageomin.cl. We requested a shape file of the concession areas but got no response, so we show only the approximate center of each concession. Inset, details of the Quebrada de la Plata Research Station, showing its extent, habitat types, and the estimated extents of the mining concessions in the area. The area of the research station was derived from an image obtained courtesy of Cristián Araneda.

would protect the remainder of the site, would be for the Faculty of Agronomy to buy the remaining mining concessions, without exploiting them. This is recommended by CODEFF (online report, 1999) and indeed is standard practice for any property developer [*Ramos*, 2011]. A fee of about $8 per hectare must be paid every year to maintain the concessions [*Law 18248*, 1983]. This would imply a yearly and perpetual cost on the order of $7000. In fact, efforts to protect the Research Station are being led by a local citizens' group, who are using legal challenges to permits and compliance in order to temporarily halt mining activities and increase costs to the company (P. Lazo, personal communication, 2013).

If the Research Station were a conservation easement under Chilean law, would this provide it with improved protection against land conversion? The answer appears to be no. If the easement agreement specifically prohibited cutting down native trees, or building infrastructure, this restriction is on the easement title holder, not on the owner of the mining concession. This is different from a conservation easement in many states in the United States, in which mining and related activities could take place only if the easement owner was a government entity and the terms of the easement were changed or revoked by a legislative body [*Brewer*, 2011; *Korngold*, 2011]. Consequently, the proposed law would do nothing new to prevent the continuous conversion of currently existing habitats of ecological value to developed or restored states. However, we see at least one possible benefit to landowners in similar situations. If applying for an exemption as a site of scientific interest from the Mining Ministry, any monitoring or research activities specified in the conservation easement contract might help to substantiate that there is scientific interest in the site.

5. Strengths and Weaknesses of the Proposed Conservation Easement Law in the Context of Mining and Other Concessions

The proposed Chilean conservation easement law is widely regarded as a good example of adapting an American legal concept (the conservation easement) to the local legal context [*Korngold*, 2011], and an advance for PPA recognition in South America. Conservation easements are not the only method for creating PPAs, and other models exist [e.g., *Crouzeilles et al.*, 2013]. We feel that the proposed conservation easement law does not offer a good balance between mining and conservation, and cannot guarantee that PPAs will contribute to Chile's obligations under the CBD to "effectively conserve" 10% of each habitat type and "protect" important biodiversity areas.

The possibility to control land use and management in perpetuity is one of the main attractions of the original US easement concept. The Chilean conservation easement law does not accord this possibility to landowners wishing to create a PPA for conservation. Strong and reliable protections against development of a landholding are still only available through the three currently possible strategies discussed above for the case of the Quebrada de la Plata Research Station. That holders of concessions can develop on conservation easements without a publically accountable and transparent decision-making process represents a failure to fully consider the value of nature preservation to the public.

The proposed conservation easements law is also expected to complement the existing PA network and contribute to conservation in Chile, but here again it falls short. What profile of private owner or private foundation will create easements and where, is not completely clear. The Nature Conservancy reports that private landowners in Chile have many different ideas and motivations for how to accomplish conservation on their properties [*Calderón Rojas*, 2012]. According to the organization Parques Para Chile, current owners of PPAs are philanthropically motivated; the lack of monetary incentives for PPAs is justified as maintaining the altruistic moral character of Chilean conservation [*Sepúlveda Luque*, no date]. In general, potential incentives for uptake of PPAs include facilitating ecotourism, a reputational or publicity advantage for companies, or the ability to protect land from control by individuals seen to lack a land ethic, e.g., heirs or buyers [*Kabii and Horwitz*, 2006; *Crouzeilles et al.*, 2013]. The proposed conservation easement law neither adds new incentives nor significantly strengthens incentives for ecotourism or reputational advantage. Furthermore, the currently proposed 40 year limit on easements is less attractive than existing perpetual designations such as Nature Sanctuaries.

Relative to creating a Nature Sanctuary, setting up a conservation easement may be easier and can be tailored to the interests and means of the landowner. The flip side of this is the lack of real protection and conservation standards: privately affordable conservation management may be inadequate to meet Chile's broader conservation goals. The lack of institutional oversight of mining activity on PPAs means that the real contributions of conservation easements to conservation in the long term will be variable, unpredictable, and unreliable.

6. Alternative Approaches to PPAs

An alternative approach to PPAs could work within the existing legislation by providing financial incentives allowing private landowners to fund the management, protection, and possibly scientific research necessary to convert their lands into Nature Sanctuaries. Another type of improvement would be to put PPAs under the management of the new Service for Biodiversity and Protected Wildlife Areas, in order to guarantee an adequate level of protection and management, and to facilitate the integration of PPAs into the PA network. To appropriately counterbalance the right to mine, the formation of Nature Sanctuaries could be restricted to landholdings of a certain size, or with certain ecological characteristics, or the government could put a cap on the total area that can eventually be converted to PPAs. Existing areas under conservation management, and ecological and silvopastoral research sites, such as the Quebrada de la Plata Research Station, should be given protection priority.

Other countries in South America may be taking a better approach to PPA creation. The Brazilian law creating Private Natural Patrimony Reserves (RPPNs), for example, prohibits activities other than tourism and scientific research on RPPNs, decrees that the RPPNs be managed in perpetuity by the Brazilian Institute of the Environment and Renewable Natural Resources, and provides small monetary incentives for their creation [*Crouzeilles et al.*, 2013; *Ladle et al.*, 2013] (Decreto 5746, http://www.planalto.gov.br/ccivil_03/_Ato2004-2006/2006/Decreto/D5746.htm. Downloaded 2013). The law exempts RPPNs from the costs associated with setting up the park under the law, and exempts the land from the rural territory property (ITR) tax. The Brazilian law further prohibits any economic activity that results in the razing of the natural vegetation. By harmonizing RPPNs with existing public PA institutions and laws, the Brazilian version of PPAs may ultimately provide more continuity of protection over time, and reduces the scope for private economic incentives to undermine the value of the PPA to the national conservation strategy.

Mining and other concessions in PAs are likely to be an increasingly common area of contention as countries attempt to meet their obligations under the CBD while also maintaining economic growth. If Chile does not take strong action to facilitate the protection of PPAs from mining exploitation, it will become an international example of poor conservation policy, in which legal innovations provide a smoke screen for an unacceptable conservation status quo. More broadly, this case study raises the question of how legal frameworks should be designed to provide an equitable balance of power between extractive industries with associated infrastructure development, and nature protection. Particularly in the case where states have outsourced to private individuals the fulfillment of some obligations under the CBD, ensuring the ability of private individuals to effectively carry out conservation and nature protection is an important challenge.

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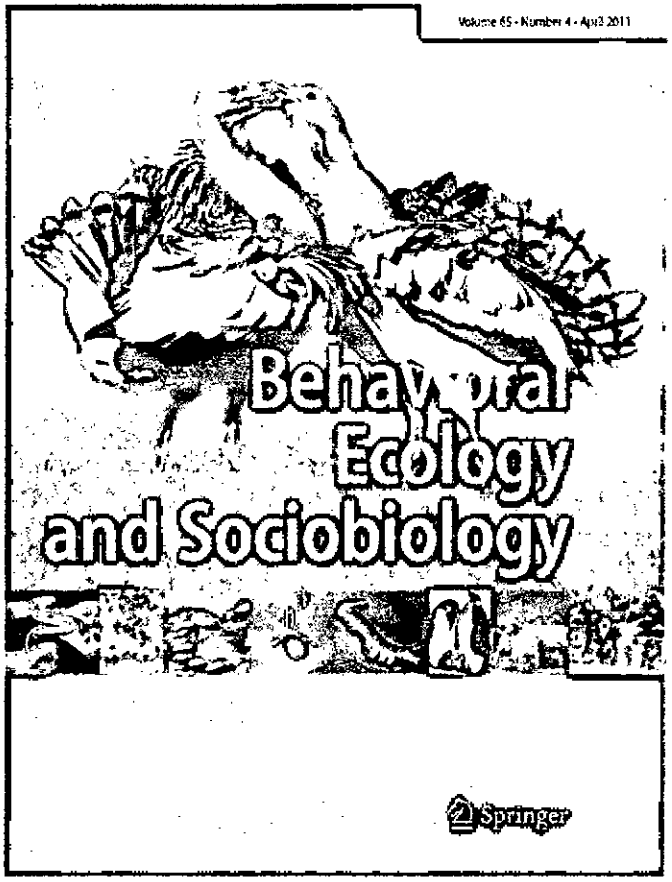

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ORIGINAL PAPER

The influence of group size on natal dispersal in the communally rearing and semifossorial rodent, *Octodon degus*

Verónica Quirici · Sylvain Faugeron · Loren D. Hayes · Luis A. Ebensperger

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Abstract In social or group living species, members of groups are expected to be affected differentially by competition through the effect of group size (i.e., the "social competition hypothesis"). This hypothesis predicts an increase in the probability of dispersal with increasing size of social groups. At a more mechanistic level and based on the known effects of competition on stress hormone levels, a positive relationship between group size and glucocorticoids of juveniles should be observed. We used a demographic approach to test these predictions on a natural population of the communally rearing and semifossorial rodent—*Octodon degus*. Burrow systems provide degus with places to rear offspring and to evade stressful thermal conditions and predators. Thus, we predicted dispersal to increase with increasing number of degus per main burrow system used, a measure of habitat saturation in degus. The probability of dispersal increased with increasing number of degus per main burrow system used. Mean fecal metabolites of cortisol in offspring increased, yet not statistically significantly, with the number of juveniles in groups. These results were consistent with a scenario in which competition drives natal dispersal in juveniles in social degus. In particular, competition would be the consequence of high degu abundance in relation to the abundance of burrow systems available at the time of offspring emergence.

Keywords Group size · Dispersal · Fecal cortisol metabolites · *Octodon degus*

Introduction

Dispersal is a sequential three-step process, in which individuals leave the natal site or social group (i.e., departure), move across unfamiliar territory (i.e., transfer), and arrive or settle (i.e., settlement) into a new home range or social group (Bélichon et al. 1996). Given its major ecological and evolutionary implications (Marzluff and Balda 1989; Johnson and Gains 1990; Hanski 2001; Barton 2001; Lenormand 2002; Postma and van Noordwijk 2005; Gros et al. 2006), dispersal has been the focus of much empirical and theoretical research (Clobert et al. 2008). These studies have revealed one major pattern: young and immature individuals are overrepresented among dispersing mammals and birds, a pattern termed natal dispersal (Greenwood 1980). However, difficulties inherent to the study of dispersal have hampered our ability to understand factors underlying its causes (Koenig et al. 1996; Dieckmann et al. 1999; Nathan 2001; Clobert et al. 2008).

Some researchers have argued that competition is the major force behind natal dispersal. Support for this argument includes evidence that juvenile deer mice (*Peromyscus maniculatus*) and song sparrows (*Melospiza leucophrys*) disperse because they are less efficient than

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adults in acquiring resources (Waser 1985; Arcese 1989). In social species, individual members of groups are expected to be affected differentially by competition through the effect of group size (i.e., the "social competition hypothesis"). As group size increases, the costs of remaining in the group are expected to increase because of increasing competition until they outweigh potential benefits (Vander Waal et al. 2009). Three lines of evidence suggest that the social competition hypothesis has considerable explanatory power in social birds and mammals. At a population level, both dispersal and group fission—the split of groups into smaller units—are more frequent whenever group size exceeds a species-specific optimum (Armitage and Schwart 2000; Koyama et al. 2002; Packer et al. 2005; Manno et al. 2007; Vander Waal et al. 2009). At a more proximate level, glucocorticoids (GC), a physiological measure reflecting the effects of social and environmental stressors (including competition), increase whenever group size exceeds some presumably optimal size in lemurs (Pride 2005) or increase with increasing group size in elephants (Foley et al. 2001) and swallows (Raouf et al. 2006). Similarly, aggression from dominants toward subordinate individuals, i.e., a major mechanism of competition by interference, increases with increasing group size (Johnstone and Cant 1999; Cant et al. 2001; Gilchrist 2006). Taken together, this evidence supports that group size is a major determinant of competition within groups in some social species. Therefore, studies of how dispersal varies with group size in social species would provide unique opportunities to determine the extent and nature (e.g., over space, food) to which competition causes natal dispersal.

Natal dispersal of social species varies with varying breeding systems. Among singularly breeding birds and mammals, in which a few members of each group reproduce (sensu Silk 2007), juveniles in some species refrain from dispersing (i.e., remain philopatric) due to a limited availability of nesting sites (Hatchwell and Komdeur 2000; Russell 2001; Russell and Hatchwell 2001), an ecological constraint, or as the consequence of relatively extended time needed to reach adulthood (Field et al. 1998), a life history constraint. Thus, natal dispersal is independent of group size in the singular breeders, a feature that decreases the utility of these species in examining the relationship between group size and natal dispersal. On the other hand, adults of solitary breeding rodents are social during the nonbreeding period but switch to solitary nesting to rear their offspring (Jannett 1982; Lambin and Krebs 1991; Winterrowd et al. 2005); juveniles and sexually immature individuals disperse (Ebensperger and Hayes 2008). As a consequence, dispersal tends to be similarly independent on group size. The plural breeders with communal care (sensu Silk 2007) are good model organisms to examine the link between group size and natal dispersal. In these species, most adult members breed and rear their offspring communally in a den or nest (i.e., "plural breeders", sensu Silk 2007). Some individuals in plural breeding rodents disperse while others remain at the natal place (Ebensperger and Hayes 2008), a condition that may result from high density conditions (Wolff 1994). More relevant to this study, dispersal in plural breeding species may depend on the group size.

The degu, *Octodon degus*, is a plural breeding rodent in which the size of social groups varies within and between populations (Ebensperger et al. 2004; Hayes et al. 2009). Degus are diurnally active (Kenagy et al. 2002; Ebensperger et al. 2004) and semifossorial rodents that dig underground burrow systems, consisting of a variable number of oblique tunnels connecting the surface to a main nest chamber (Yáñez 1976; Lessa et al. 2008). Social groups typically use more than one burrow system, i.e., a group of interconnected burrow openings (Ebensperger et al. 2004; Hayes et al. 2007, 2009). Burrow construction and expansion takes place rather infrequently (i.e., 0.2% of activity time) in degus (Ebensperger and Hurtado 2005b), implying that local abundance of these structures is rather constant across consecutive years. Degus typically breed once per year during late autumn (May–June; Rojas et al. 1977). After a 3-month pregnancy, females give birth to an average of 6±1 pups in September (Ebensperger et al. 2007), the time when aboveground parts of annual grasses and forbs (preferred food of degus, Meserve et al. 1983, 1984) are abundant. At this time, degu abundance increases threefold compared with abundance during the previous autumn (Quirici et al. 2010). This increase in degu abundance, coupled to a rather constant number of burrow systems (Ebensperger and Hurtado 2005a), provides a scenario of competition for space. Therefore, if the "social competition hypothesis" explains the relative importance of dispersal versus philopatry in social degus, a dispersal threshold in relation to the size of social groups might be expected.

Predation risk increases with distance to the nearest burrow entrances in degus (Lagos et al. 2009), implying that predation risk decreases with density of burrow entrances per burrow system. Therefore, we further predicted dispersal to increase with increasing number of degus per main burrow system used and decreasing number of burrow entrances available to each degu, two pertinent measures of habitat saturation in these rodents. Given that GC levels are thought to reflect the social effects of competition (Pride 2005), we further predicted GC levels of juveniles to increase with increasing size of social groups. At a population level, dispersal should increase with increasing competition (Waser's 1985 competition hypothesis). First, we evaluated the way competition over space would impact on natal dispersal at the population level. If degu disperse to avoid competition, we predicted a positive relationship between competition and dispersal.

Taken together, a major contribution of this study is to examine the influence of competition on dispersal at the population, social group, and individual levels. In addition, this is one of the few studies that uses probability approaches to quantify dispersal in relation to group size.

Methods

Study site and trapping

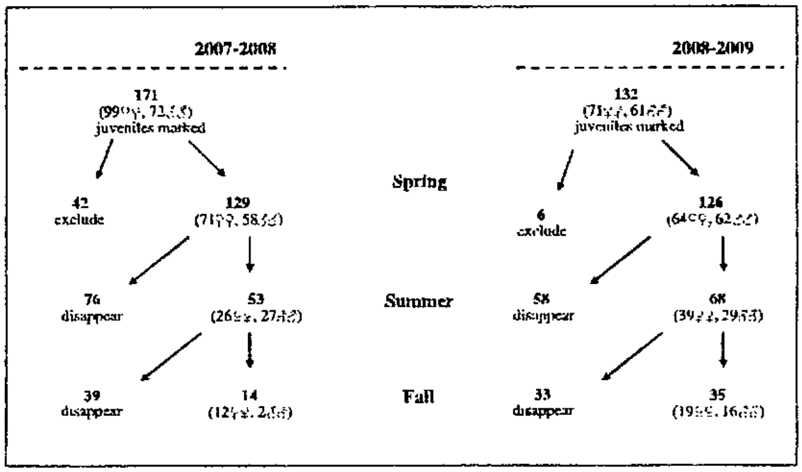
The study was conducted during the austral spring (October–November), mid summer (January–February), and mid autumn (May–June) months during 2007–2008 and 2008–2009 at the Estación Experimental Rinconada de Maipú (33°23′ S, 70°31′ W, altitude 495 m), a field station of Universidad de Chile. The study site is characterized by a Mediterranean climate with warm, dry summers (December–March) and cold wet winters (June–September) (Yáñez 1976; Meserve et al. 1984). The site consisted of open matorral with scattered shrubs (*Proustia pungens*, *Acacia caven*, and *Baccharis* spp.) and annual grasses and forbs (Ebensperger and Hurtado 2005b). Therein, we considered a 4–5-ha study area in an area known as the El Litral and in which degus were visually abundant. We first randomly selected a rectangular-shaped trapping grid of 100 by 60 m (hereafter referred as the "central grid"). We then established six linear transects with four trap stations at 40, 80, 120, and 160 m and with the distance of 40 m from each other station. All burrow systems inside the central grid (N=31 burrow systems) and along all transects (N=24 burrow systems) were permanently marked with numbered wooden stakes and coordinates recorded with a global position system. Coordinates were then converted to X–Y (north–east) coordinates with the Locate II software (Pacer Software, Truro, NS, Canada).

We trapped degu using a combination of Tomahawk (model 201, 14×14×40 cm, Tomahawk, WI, USA) and locally produced metal live traps (30×10×9.5 cm, similar to Sherman traps) all baited with rolled oats. We set traps in burrow system entrances for 2 months in spring (32 trapping days in 2007 and 45 trapping days in 2008), 2 weeks in summer (13 trapping days in 2008 and 2009), and 2 weeks in autumns (13 trapping days in 2008 and 2009), prior to the emergence of adults. Thus, traps were set at 0800 hours during spring, 0600 hours during summer, and by 0700 hours during autumn. After 1.5 h, all traps were closed, and individual identity, sex, body weight, and apparent age (adult versus juvenile, determined from body weight) of all individuals were determined. We also determined the reproductive condition of all adult females: nonpregnant, pregnant, and lactating. During trapping, we marked degu at the time of first capture by clipping no more than one toe per foot (see Quirici et al. 2010, for further details) in the period 2007–2008. During 2008–2009, we switched to marking degu with the use of metal tags on both ears (National Band & Tag Company, Newport, KY, USA).

Determination of dispersal

We first aimed to describe the timing and intensity of degu dispersal in relation to philopatry. Fates of juveniles (depicted in Fig. 1) were assessed by individual mark-recapture (Turchin 1998). With the aim of collecting a sample of natal individuals (i.e., 35–75 g), we trapped degus during spring of 2007 and 2008 on the central grid,

Fig. 1 Fates of juveniles of *O. degus* marked during emergence from natal burrows during 2 years of study



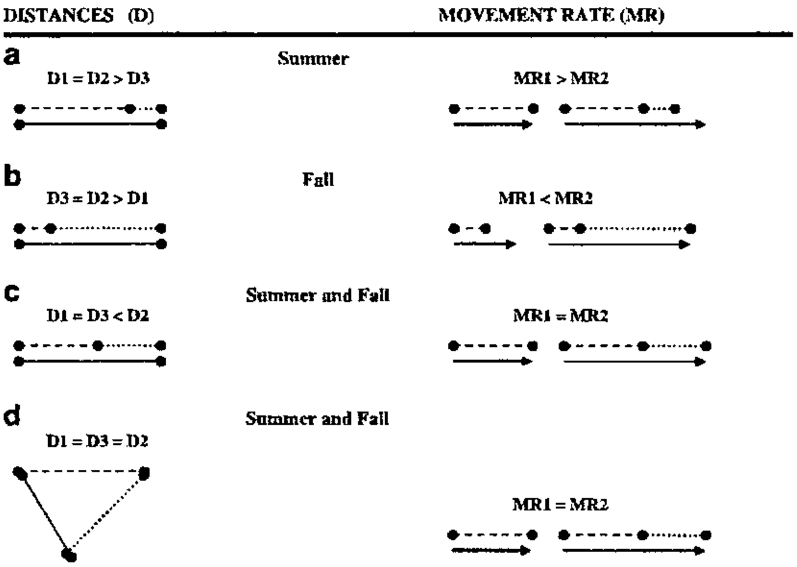
near the time of offspring emergence. Thus, we excluded from this analysis individuals that weighed more than 75 g at first capture. Individuals of this size or larger exhibit much greater mobility (Fulk 1976; Ebensperger and Hurtado 2005b; Hayes et al. 2009). It is well known that measures of dispersal distances are underestimated whenever juveniles leave their natal burrow before they can be captured and individually recognized (Waser et al. 2006). Overall, we trapped 98% of burrow systems that were located inside the central grid ($N=31$ burrow systems). Subsequently, during the summers of 2008 and 2009 and autumns of 2008 and 2009, we expanded our trapping area to include the central grid along with six 120-m linear transects (Turchin 1998).

We followed Hanski and Selonen (2008) and classified an individual as disperser whenever it has moved to a distance equal to or larger than two times the radius of the circle enclosing the size of an adult's home range; for degu, this distance was 75 m (Quirici et al. 2010). Dispersal distance was calculated as the straight-line distance from the natal burrow where an animal was first captured as a pup to the burrow where the same individual was first recaptured in summer (i.e., spring–summer distance, D1) and in autumn (spring–autumn distance, D2). We complemented the previous estimates based on absolute distance with the approach of Turchin (1998), based on movement rates. We defined movement rate 1 (MR1) as the distance moved by an individual between spring and summer (D1) divided by the number of days between first capture in spring and first capture in summer. We defined movement rate 2 (MR2) as the cumulative distance from spring to summer (D1), plus the distance moved from summer to autumn (D3), and divided this difference by the number of days between first capture in spring and first capture in autumn. Given that MR2 uses a cumulative distance (D1+D3), this may not be an appropriate measure whenever an individual moves in summer but then returns to its natal site during autumn. To solve this problem, we considered the distance an animal moved between spring and autumn (D2). Therefore, (a) if dispersal takes place mostly from spring through summer, we predicted $D1=D2>D3$. Alternatively, (b) whenever dispersal takes place between spring through autumn, we predicted $D3=D2>D1$; (c) if dispersal takes place from spring through summer and autumn, we predicted either $D1=D3<D2$ or $D1=D2=D3$. Finally, (d) whenever an individual disperses from spring through summer, but then returns to its natal site in autumn, we expected $D1=D3>D2$ (Fig. 2).

Social group determinations and burrow systems used

We needed to identify members of the same social groups and, therefore, quantify group size. Given that degus remain in their underground burrows overnight, we assigned adults to social groups based on the sharing of burrow systems during night time (Ebensperger et al. 2004). The sharing of burrow systems was established by means of burrow trapping in August–October, i.e., from late pregnancy through lactation. We then determined group composition using the SOCPROG software (Whitehead 2009) based on a matrix of associations. This symmetric matrix is an estimate of the proportion of time that two any individuals spend together or interact. In our case, we determined the association between any two individuals by dividing the number of occasions that these two animals were captured to the same burrow system by the number of trapping days that both individuals were caught simultaneously (Ebensperger et al. 2004). We performed hierar-

Fig. 2 Four possible scenarios for juvenile dispersal: *A* dispersal occurred from spring to summer; *B* dispersal occurred from spring to autumn; *C*, *D* dispersal occurred from spring to summer and into autumn. D1 (*segmented line*), D2 (*continuous line*), and D3 (*spotted line*)



chical cluster analysis of the association matrix. We confirmed the correlation between the association indices and the levels of clustering in the diagram with the cophenetic correlation coefficient (Whitehead 2009) with values above 0.8 implying an effective representation. We used the maximum modularity criteria (Newman 2004) to cutoff the dendrogram and define social groups.

Upon defining social groups, we determined burrow systems used by each group. The number of burrow entrances at each burrow system was quantified in a circular area encompassing a 3-m radius from the center of each burrow system.

Fecal cortisol metabolites

We examined whether patterns of variation in physiological stress levels were consistent with a competitive effect mediated by group size as one major determinant of dispersal in degus. We used noninvasive fecal glucocorticoid analysis to extract fecal cortisol metabolites (thereafter FCM) as a means of assessing secretion of stress hormones levels in degus. Fecal cortisol assays reliably reflect endogenous changes in adrenal activity in degus (Soto-Gamboa et al. 2009). At first capture and previous to any other handling procedure of the trapped animals (e.g., marking), we collected 3–4 fresh fecal pellets for subsequent hormonal essay of 39 juveniles in spring 2008. Fecal samples were collected within 1–2 h of capture, an adequate time to avoid a handling effect on fecal cortisol in degus (Soto-Gamboa et al. 2009). Eleven out of 39 juveniles were recaptured in summer 2009, and of these, 6 were recaptured during autumn 2009. Collected feces (spring, summer, and autumn) were immediately stored into Eppendorf tubes with 0.8 mL of 95% ethanol and refrigerated at 5°C until assayed.

We extracted FCM with 80% ethanol, as recommended in a previous study (Mateo and Cavigelli 2005). We first dried the samples in an oven (95°C; 4–5 h). Dried feces were crushed and carefully homogenized. A portion (0.1 g; in case of two samples only 0.05 g) of each sample was mixed with 1 mL of 80% ethanol, vortexed for 5 s, and centrifuged at 3,000×*g* for 20 min. The supernatants were removed and stored at −20°C until determination of FCM. Cortisol metabolites in feces were quantified in the Radio Immune Essay Laboratory at P. Universidad Católica de Chile. Fecal samples were assessed with the use of steroid-free human serum (standard zero) to provide similar protein environments (Mateo and Cavigelli 2005). The intra- and inter-assay coefficients of variation of the immunoassay were 6.9% and 14.5%, respectively (Soto-Gamboa et al. 2009). Data were reported and analyzed as nanogram of fecal metabolites of cortisol per gram of dry fecal sample assessed.

Degu abundance and competition measures

Given its potential influence on dispersal, we monitored changes in degu abundance between years. To avoid the potential bias generated by heterogeneity in individual capture probabilities that arise from trap happy versus trap shy animal effects (Efford 1992), we calculated degu abundance using a closed capture with heterogeneity model (Pledger 2000). The analysis was performed using the MARK software, release 5.1 (White and Burnham 1999; Cooch and White 2008). Given that this model rests on the assumption of a closed population (no emigration, immigration, death, or birth), we restricted this analysis to the first 11 days of each trapping season. As a measure of competition at the population level, we further divided degu abundance (total, adults and offspring) by the total number of burrow openings in the central grid.

Analytical procedure

To meet assumptions of data homocedasticity and normality, dispersal distance was squared-root-transformed. We used repeated measures analyses of variance (ANOVA) with season (spring–summer–autumns) as a repeated measure and year (period 2007–2008 versus period 2008–2009) as factors to examine dispersal distance (D1–D2–D3) and movement rate (MR1–MR2) of females. We also used repeated measures ANOVA to examine the effect of season on males' dispersal distance and movement rate during the 2008–2009 periods. We used the permutation test to examine variation in movement rate (MR1 and MR2) and dispersal distance (D1, D2, and D3) across sexes.

We calculated the percentage of individuals recaptured at 10-m intervals and generated a dispersal distance distribution (i.e., DDD), upon which we fitted the data to a probability distribution using a nonlinear model (Koenig et al. 1996). Given the low number of recaptures observed for the spring–autumn period, we were able to calculate DDDs for the spring–summer period exclusively (i.e., for D1).

To examine the effect of group size on the probability to disperse, we used logistic regression. The probability of dispersal was estimated using general linear model with a binomial distribution of residuals and a logistic link function (Nelder and Wedderburn 1972). The response variable took two values: 1, whenever an individual moved twice the radius of an adult's home range (i.e., 75 m), and 0, whenever an individual moved less than this distance. We began the analysis including all predictor variables and subsequently removed the variable with highest *P* value (backward stepwise). The best model was selected from all tested using the corrected Akaike's Information Criterion (AICc) (Akaike 1974). Models were assumed to be equivalent if AICc values<2 and the model with the fewest parameters resulted in the best model. We used the following measures as predictors: (a) total number of adults per group, (b) total number of offspring per group, (c) total group size (adults and offspring), (d) total number of adults per group per burrow system, (e) total number of offspring per group per burrow system, and (f) total group size per group per burrow system used. In addition, we examined other variables known to affect dispersal in mammals (Holekamp 1984, 1986; Lambin 1994; Jacquot and Vessey 1995), including (g) the sex ratio (female/male) of offsprings in the group, (h) offspring sex, and (i) body growth rate of offspring (calculated as grams per day—between first capture in spring and first capture in summer).

We used Spearman's rank correlation to examine how mean FCM was influenced by the number of offspring, number of adults, and total group size. All statistical tests were two-tailed and conducted using the R 2.4.1 software (R Development Core Team 2006).

Results

Pattern of natal dispersal

The proportion of juveniles that dispersed did not differ between males and females within season (Table 1). When comparing between observation periods, the proportion of males and females that dispersed from spring to summer was higher in 2007–2008 compared with 2008–2009 (χ^2= 4.16, *df*=1, P=0.04, χ^2=17.28, *df*=1; P<0.001). The proportion of females that dispersed from spring to autumn did not differ between 2007–2008 and 2008–2009 (χ^2= 2.87, *df*=1, P=0.09). No males were recaptured during autumn 2008.

Dispersal distance distributions (DDDs) of females and males both fit to a negative exponential function during spring 2007–summer 2008 and spring 2008–summer 2009 (Fig. 3). Dispersal distance of females was not influenced by observation period ($F_{1,\ 27}$=3.26, P= 0.08), season ($F_{2,\ 54}$=0.94, P=0.39) or by a year × season interaction ($F_{2,\ 54}$=2.11, P=0.13) (Table 1). For males, dispersal distances were statistically similar in 2008–2009 ($F_{2,\ 24}$=2.14, P=0.14). There were no sex differences linked to D1 (P=0.89), D2 (P=0.99), or D3 (P=0.99) during 2008–2009 (Table 1).

For females, there were no statistically significant main effects of season ($F_{1,\ 26}$=0.57, P=0.46) or year by season interactions ($F_{1,\ 26}$=0.003, P=0.98) on movement rates (Table 1). For males, movement rates were statistically similar in 2008–2009 ($F_{1,\ 13}$=4.24, P=0.06). There were no sex differences in MR1 (P=0.92) or MR2 (P=0.472) (Table 1). To summarize, there was no sex bias linked to the onset of dispersal, distance moved, or movement rate. These findings are consistent with (C) and (D) dispersal scenarios (Fig. 2).

Degu abundance, FCM, and competition over space

Degu abundance was higher in spring and summer than in autumn (Table 2). Mean FCM of offspring was higher in spring (149.95±41.22 ng/g) and summer (150.73± 41.71 ng/g) compared with autumn (114.78±14.37 ng/g) (Friedman ANOVA by ranks, χ^2=6.33, *df*=2, N=6, P< 0.04; Z=0.31, P=0.75 for spring versus summer; Z=2.2,

Table 1 Frequency of philopatric and dispersing individuals during summer and autumn

Observation period	Offspring sex	Philopatric	Dispersing	% Dispersing	Distances: D1, D2, D3 (m ± SD)	Movement rate (m/day)
Spring 2007–summer 2008	Female	13	12	48.0	43.32±48.79	0.56±0.62
	Male	19	8	29.6	34.56±54	–
		χ^2=1.85, *df*=1, P=0.17				
Spring 2007–autumn 2008	Female	10	2	16.6	38.94±48.03	0.35±0.35
	Male	–	–	–		–
Summer 2008–autumn 2008	Female	10	2		45.82±50.37	
	Male	–	–	–	–	
Spring 2008–summer 2009	Female	39	2	4.9	18.91±18.84	0.20±0.19
	Male	24	2	7.7	33.49±34.45	0.33±0.35
		χ^2=0.22, *df*=1, P=0.64				
Spring 2008–autumn 2009	Female	16	0	0.0	28.64±21.74	0.18±0.12
	Male	13	1	7.1	23.08±30.28	0.25±0.22
		χ^2=1.18, *df*=1, P=0.28				
Summer 2009–autumn 2009	Female	16		0	14.49±16.5	
	Male	13		1	16.76±15.81	

Dispersing individuals were those that moved more than 75 m from natal burrows

Dispersal distances (D1, D2, and D3) and movement rates (MR1 and MR2)

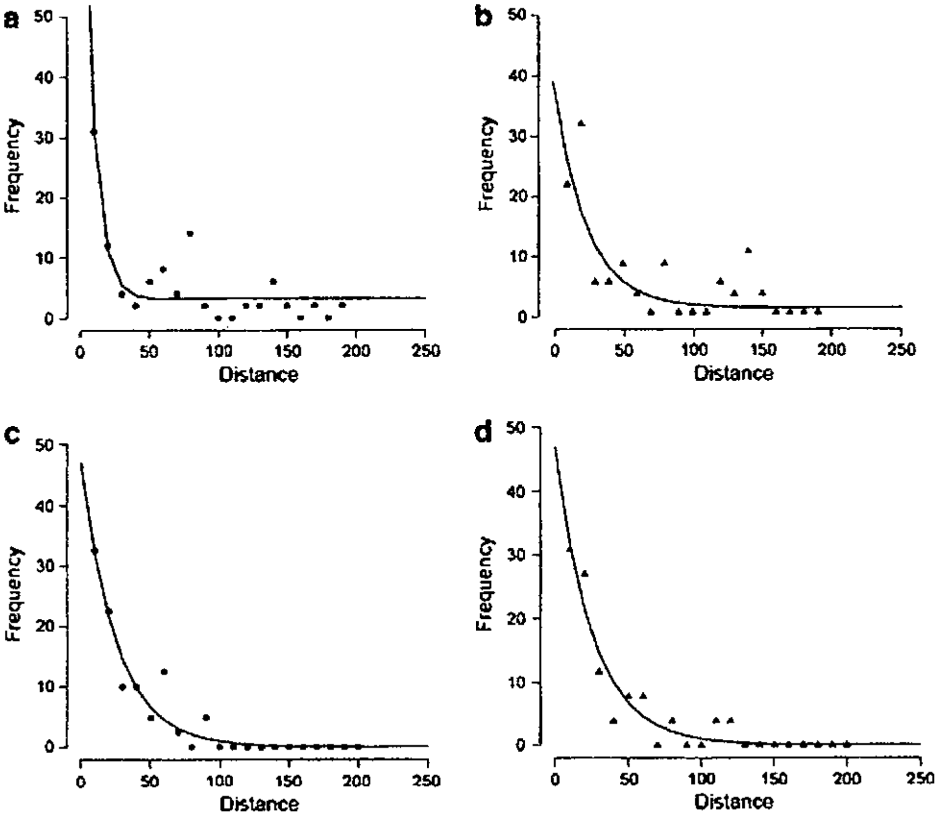


Fig. 3 Distribution of dispersal distance in males and females during the spring–summer period. Data fitted to a negative exponential distribution in all cases: $y = a + b*\exp(c*x)$. **a** Females 2008: $a=3.14$, $b=-97.26$, $c=-0.12$ ($\chi^2=1.29$, $df=1$, $P=0.25$); **b** males 2008: $a=1.7$, $b=-37$, $c=-0.04$ ($\chi^2=0.97$, $df=1$, $P=0.32$); **c** females 2009: $a=0.12$, $b=-46.8137$, $c=-0.039$ ($\chi^2=2.97$, $df=1$, $P=0.08$); and **d** males 2009: $a=0.45$, $b=-49.72$, $c=-0.04$ ($\chi^2=3.37$, $df=1$, $P=0.07$)

$P=0.03$ for spring versus autumn; and $Z=1.99$, $P=0.05$ for summer versus autumn). Competition for space (degu abundance/total number of openings ($N=413$)) was higher in spring 2007 than in spring 2008 (Fig. 4).

The effect of group size and habitat saturation on dispersal

Observations of philopatric and dispersing juveniles between spring 2007 and summer 2008 were fitted to a logistic regression; not enough dispersing individuals were recorded from spring 2008 through summer 2009 (Table 1). Using the backward stepwise algorithm, the probability that a juvenile dispersed increased as the ratio of the number of offspring to the number of burrow systems per group increased (four offspring per burrow system) (Fig. 5). This ratio was greater for dispersing (6.94±1.55) than for philopatric juveniles (4.23±1.86) (Mann–Whitney *U* test—$U=107$, $P<0.001$, $N=20$, $N=32$).

The effect of group size on FCM

FCM was not significantly different between female (176.75±70.65 ng/g) and male offspring (213.03±138.66 ng/g) (Mann–Whitney *U* test—$U=164.5$, $P=0.65$, $N=15$ males, $N=24$ females), so data on both sexes were pooled. There was no statistically significant relationship between mean FCM of offspring and total group size (Spearman's rank correlation, $r_s=0.05$, $P=0.95$) (Fig. 6a). Intriguingly, mean FCM of offspring tended to decrease with increasing number of adults ($r_s=-0.90$, $P=0.083$)

Table 2 Degu abundance and group size composition

	Degu abundance (±SE)			Group size (spring 2007: $N=9$; spring 2008: $N=7$)		
	Adults	Offspring	Total	Adults	Offspring	Total
Spring 2007	69 (19)	179 (4)	248	6.9 (1.0)	17.8 (7.8)	24.6 (8.5)
Summer 2008	75 (43)	102 (4)	177			
Autumn 2008	18 (1)	36 (1)	54			
Spring 2008	47 (2)	105 (7)	152	6.4 (2.1)	21.2 (2.4)	27.6 (1.8)
Summer 2009	74 (4)	88 (40)	162			
Autumn 2009	29 (1)	35 (2)	64			

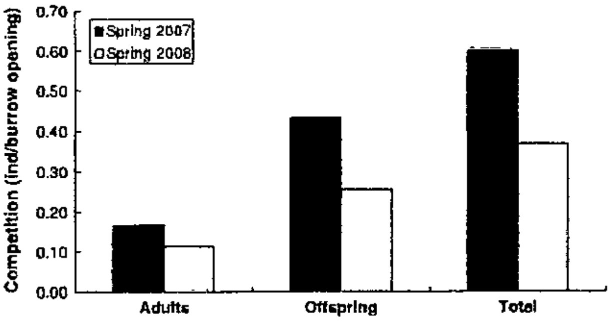


Fig. 4 Estimates of competition in the population during spring 2007 and spring 2008

(Fig. 6b) and increase with increasing number of offspring in groups (r_s=0.7, P=0.23) (Fig. 6c).

Discussion

Pattern of natal dispersal

The proportion of offspring that dispersed was similar during both years of the study. Dispersal distance distribution was similar in male and female offspring. Although we did not correct for sampling bias (Koenig et al. 1996; Sharp et al. 2008), dispersal movement rates of males and females were similar. Together, these data suggest a pattern of unbiased natal dispersal in degus.

Our results of unbiased dispersal do not fit to the general trend according to which dispersal is male biased in mammals like (e.g., *Microtus arvalis*—Gauffre et al. 2009). However, similarly unbiased dispersal patterns have been observed in some lagomorphs, e.g., American pika (*Ochotona princeps*—Smith and Ivins 1983) and rodents, e.g., pine voles (*Microtus pinetorum*—Solomon et al. 1998) and mole rats (*Cryptomys hottentotus*—Spinks et al. 2000).

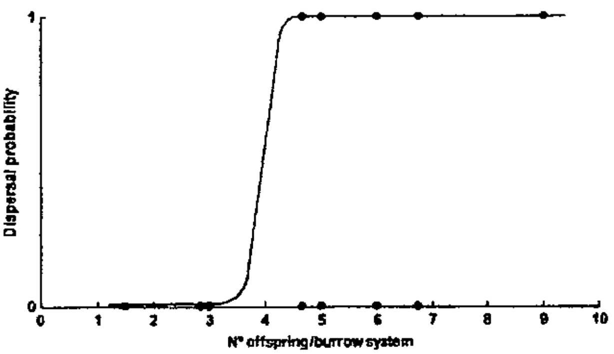


Fig. 5 Logistic regression between the ratio number of offspring per burrow system and the probability of natal dispersal: exp(−6.96+1.21x)/(1+exp(−6.96+1.21x)) (P<0.001)

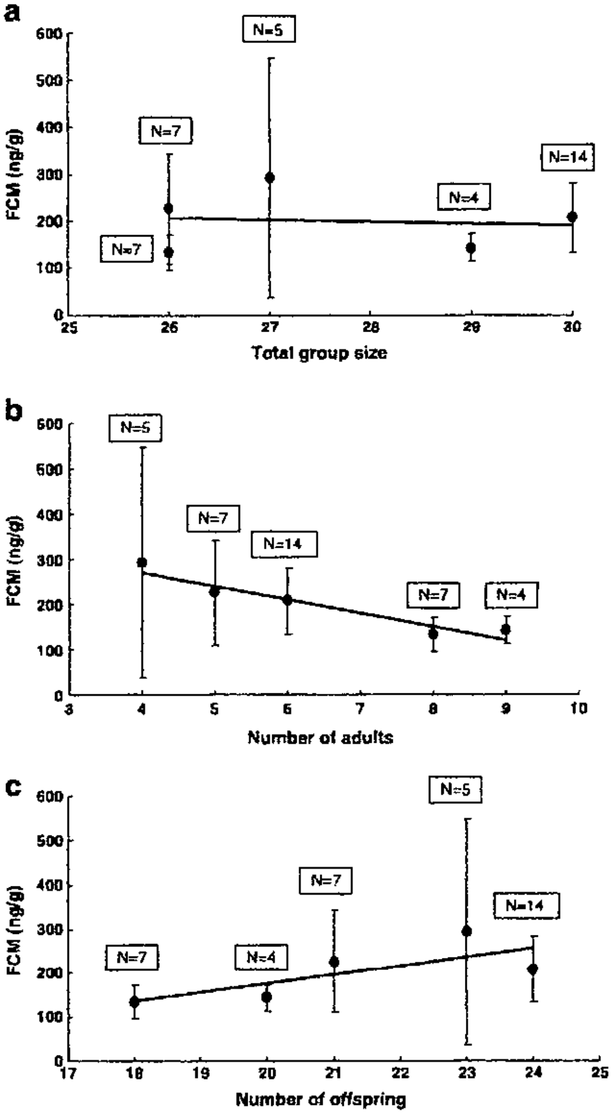


Fig. 6 Spearman's rank correlation between mean FCM (nanogram/gram) of offspring per group and **a** total group size, **b** number of adults per social group, and **c** total number of offspring per social group. *Error bars* are used to describe within-group variation, but do not represent statistical replicates during statistical analysis

As it has been observed in other small mammals, including American pikas (Smith and Ivins 1983), banner-tailed kangaroo rats (*Dipodomys spectabilis*—Winters and Waser 2003) and Columbian ground squirrels (*Urocitellus columbianus*—Viblanc et al. 2010), dispersing degu offspring settled within the radius of an adult's home range, implying that spatially, degus settle near their natal burrows. This pattern of settlement could result in the formation of temporally stable kin groups, a prerequisite for kin selection to operate (Hamilton 1964; Maynard Smith 1964; Chesser 1991). Indeed, kin-selected behavior has been implied by some lab studies (Jesseau et al. 2009; Villavicencio et al. 2009), but not others (Ebensperger et al. 2007; Quirici et al. 2008). However, recent demographic analyses have revealed high turnover rates of offspring and adults (Ebensperger et al. 2009) and mean sanguinity coefficients within social groups not different from background levels (Quirici et al. unpublished results, this study). Therefore, opportunities for the evolution of kin-selected social behavior appear to be limited in this population.

Resource competition hypothesis

At the level of population, dispersal was higher in 2007 than in 2008, a pattern that tracked estimates of competition, implying competition may have caused dispersal. This suggestion is further supported by the observed relationship between population size and FCM. Offspring were more stressed in spring and summer (i.e., when competition was higher) than in autumn (i.e., when competition was lower).

Our results indicated that the probability of dispersal increases with increasing number of offspring per burrow system, a measure of habitat saturation in degus. Offspring raised in groups with relatively large numbers of offspring tended to exhibit higher levels of fecal cortisol metabolites though not statistically, suggesting that large groups might be stressful to degu offspring. Together, these observations tend to be consistent with the social competition hypothesis for natal dispersal.

That dispersal increases with increasing number of degus per burrow system opposes previous studies documenting an inverse relationship between measures of habitat saturation and dispersal (Wolff et al. 1988; Sandell et al. 1991; Getz et al. 1993; McGuire et al. 1993; Cochran and Solomon 2000; Lin and Batzli 2001; Lucia et al. 2008, but see Gaines et al. 1979). Instead, our results parallel those of Negro et al. (1997) and VanderWaal et al. (2009). The probability of dispersal in the lesser kestrel (*Falco naumanni*) increases with the degree of saturation in natal colonies (Negro et al. 1997). Similar to degus, the probability of dispersal in lions (*Panthera leo*) increases with increasing group size (VanderWaal et al. 2009). In contrast to degus, however, group size interacted with food abundance to influence dispersal in lions. Thus, dispersal decreases in social groups that inhabit areas with abundant prey, but increases in groups using areas with less abundant prey (VanderWaal et al. 2009). In degus, food abundance is not a predictor of degu group size or dispersal (Hayes et al. 2009; Quirici 2010). In contrast, burrow systems appear to be more relevant for degus to hide from predators and rear their offspring (Ebensperger et al. 2004, 2007; Lagos et al. 2009). The increase in degu abundance in late spring and in summer coupled to a rather constant number of burrow system (Ebensperger and Hurtado 2005a) provides a scenario of high competition over burrow systems. FCM levels were higher in spring and summer and then decreased in autumn, a pattern that mirrored degu abundance, and was consistent with that juveniles were more stressed during spring and summer. Studies aimed to understand how the ability of groups to hold burrow systems is influenced by ecological or social conditions are strongly needed.

Alternative explanations

Our results contradict some alternative causal hypotheses for mammalian natal dispersal. For example, offspring may disperse from large groups if such conditions are attractive to predators (Mateo 2007). In this scenario, a positive relationship between the total number of adults and FCM is expected. Our observations of a negative correlation between the number of adults and offspring fecal cortisol metabolites suggest that this hypothesis does not explain natal dispersal in degus. One hypothesis that we have yet to explore is that social parasitism drives natal dispersal in degus (Sorci et al. 1994; Boulinier et al. 2001; Tschirren et al. 2007). If bigger social groups contained more parasites (Brown and Brown 1992; Raouf et al. 2006), we might expect dispersal to increase with increasing group size. However, our result of no effect of social group alone in the probability of natal dispersal makes this hypothesis unlikely.

A scenario for natal dispersal in degus

Our results suggest a scenario in which dispersal in degus is driven by social competition. In particular, the threefold increase in degu abundance after parturition would limit the ability of burrow systems to hold this higher pool of individuals present. As a result, juvenile male and female disperse to avoid competition for space with other juveniles within their social group. Eventually, juveniles would compete with individuals from neighboring groups as they disperse. As a result, DDDs would fit a negative exponential distribution. Currently, we are conducting genetic analyses to complement our dispersal estimates based on demographic approaches.

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Original Article

Absence of kin structure in a population of the group-living rodent *Octodon degus*

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Variation in sociality may have an important impact on population genetic structure. In highly social species, the formation of kin clusters leads to decreasing variation within but increasing genetic variation among social groups. Studies on less social species in which social groups may be more short lived have revealed a greater diversity of consequences on the genetic structure of populations. Thus, studies on populations of less social species can more precisely highlight how social structure and genetic structure covary in wild populations. We explored the relationship between natal dispersal and social structuring (i.e., whether social group are composed of kin) at the local population in a social rodent, *Octodon degus*, using a combination of direct (capture–mark–recapture) and indirect (codominat genetic markers) methods. Previous studies of degus indicated that social groups were characterized by high turnover rate of group members and no sex bias dispersal. As we expected, there was an absence of correlation between social and genetic structure; moreover, social groups were not characterized by high levels of genetic relatedness (*R* no different form background population). Direct and indirect (corrected assignment index) methods revealed an absence of sex-biased dispersal. Moreover, this method reveled that our study population was composed of resident and immigrant individuals. Moreover, dispersal distances have no effect on kin structure as reveled by the spatial genetic autocorrelation analysis. Beside some degree of offspring association (*R* among juveniles of a same group higher than background population), high turnover rate, dispersal, and perhaps a promiscuous or polyandry mating system seem to avoid a kin genetic structure, thereby limiting the opportunity for the evolution of kin-selected social behavior. *Key words:* offspring associations, relatedness, social groups, spatial genetic autocorrelation analysis. *[Behav Ecol 22:248–254 (2011)]*

Sociality, or the tendency of animal species to live in groups, may have consequences on the genetic structure of their populations (Sugg et al. 1996; Dobson 1998). In particular, the stability or temporal persistence of groups may impact population structure. For example, significant genetic subdivision among small families or social groups within colonies and subpopulations occurs in highly social species in which groups are stable and persist for long periods of time. For these species, the temporal persistence of kin associations at the population level is expected to correlate with decreasing variation within but increasing genetic variation among social groups (Sugg et al. 1996). In contrast, studies on less social species in which social groups may be more short lived have revealed a greater diversity of consequences on the genetic structure of populations. In particular, social groups may (Blundell et al. 2004; Matocq and Lacey 2004; Hare and Murie 2007; Lebigre et al. 2008) or may not (Túnez et al. 2009; Gauffre et al. 2009; Viblanc et al. 2010) represent kin clusters characterized by high levels of genetic relatedness. Thus, studies on populations of less social species can more precisely highlight how social structure and genetic structure covary in wild populations (Dobson 1998).

Quantifying the genetic structure of populations without accounting for social subdivision may lead to higher than expected levels of homozygosity, or Wahlund effect (Dobson 1998). In theory, genetic subdivision in social populations decreases with natal dispersal but increases with natal philopatry. Relatedness within groups is expected to decrease relative to population levels whenever natal dispersal is frequent but expected to increase whenever dispersal is low. Given that dispersal may be sex biased, stronger correlations are expected between genetic and social subdivision in the more philopatric compared with the more dispersing sex (Dobson 1998). In mammals, females most often represent the philopatric sex, whereas males represent the dispersing sex (Greenwood 1980; Dobson 1982; Pusey 1987; Wolff 1994; Clarke et al. 1997; Dale 2001; Petit et al. 2001). Thus, evidence of kin structure may predict the extent of philopatry and dispersal in highly social species (Sugg et al. 1996).

We explored the relationship between natal dispersal and social structuring (i.e., whether social group are composed of kin) in a social rodent, *Octodon degus*. Degus are small to medium sized (170–300 g) diurnally active rodents (Woods and Boraker 1975) that typically breed once per year during late autumn (May–June, Rojas et al. 1977). After a 3-month pregnancy, females give birth to an average of 6 ± 1 pups in September. Both natal philopatry and dispersal influence the composition of social groups (Ebensperger et al. 2009). Although degus are known to live in social groups (composed of 0–5 males and 1–8 females Ebensperger et al. 2004; Hayes et al. 2009), sociality in these animals seems intermediate between highly social (Pope 1992, 1998; Reeve et al. 1990; Faulkes et al. 1997; Spong and Creel 2004) and solitarily living mammals (Cutrera et al. 2005). First, although solitary living does not occur in degus (Hayes et al. 2009), social groups are

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highly unstable in that they are short lived and ruled by an extensive turnover of group members (Ebensperger et al. 2009). Although allonursing seems to occur in captivity (Jesseau et al. 2009), social behavior of these rodents (Ebensperger and Bozinovic 2000; Quirici et al. 2008) does not include forms of cooperative behavior found in other mammals such as coordinated antipredator vigilance (Clutton-Brock et al. 1999) or division of labor (Jarvis 1981; Jarvis and Bennett 1993). Based on these characteristics of degu sociality, we predicted a weak (if any) correlation between social and genetic structuring. Given that neither immigration by adults (Ebensperger et al. 2009) nor offspring dispersal (Quirici et al., forthcoming) are sex biased in degus, we further predicted the correlation between social and genetic structure not to be influenced by sex.

The formation of temporally stable kin groups is thought to be a prerequisite for kin selection (Hamilton 1964; Maynard Smith 1964) to operate (Chesser 1991). In degus, some laboratory studies (Jesseau et al. 2009; Villavicencio et al. 2009, but not others: Ebensperger et al. 2007; Quirici et al. 2008) support that kinship influences social behavior. Although those studies supporting a role for kinship are inconsistent with the instability that characterizes social groups of these animals, kinship may still play some role under natural conditions through the formation of sibling associations during dispersal (i.e., sibling dispersal).

We tested these hypotheses with a combination of direct (capture–mark–recapture) and indirect (codominat genetic markers) methods, a powerful approach to examine the relationship between dispersal, social behavior, and population structure (Clobert et al. 2001; Cano et al. 2008; Sharp et al. 2008).

MATERIALS AND METHODS

Study site and trapping design

The study was conducted between the austral spring (October–November) of 2007 and late autumn (May–June) of 2008 at the Estación Experimental Rinconada de Maipú (lat 33°23′S, long 70°31′W, altitude 495 m), a field station of Universidad de Chile. The study site is characterized by a Mediterranean climate with warm dry summers (December–March) and cold wet winters (June–September) (Yáñez 1976; Meserve et al. 1984). The site consisted of open areas with scattered shrubs (*Proustia pungens*, *Acacia caven*, and *Baccharis* spp.) and annual grasses and forbs (Ebensperger and Hurtado 2005). Therein, we considered a 4–5 ha study area in an area known as the El Litral and in which degus were visually abundant and have been studied (Hayes et al. 2007). In spring 2007, we established a rectangular shaped trapping grid of 100 × 60 m.

We trapped *O. degus* using a combination of Tomahawk (model 201, 14 × 14 × 40 cm, Tomahawk, WI, 300 traps) and locally produced metal live traps (30 × 10 × 9.5 cm, similar to Sherman traps, 100 traps) all baited with rolled oats. We set traps in burrow system entrances for 2 months in spring (32 trapping days) and 2 weeks in autumn (13 trapping days), prior to the emergence of adults. Thus, traps were set before animals emerge to daily activity (spring: 08:00 AM; autumn: 07:00 AM). After 1.5 h, all traps were closed and individual identity, sex, body weight, apparent age (adult vs. juvenile, determined from body weight), and reproductive condition (females only) were recorded for every caught animal. During trapping, we marked degus at the time of first capture by clipping no more than one toe per foot (for further details, see Quirici et al. 2010). Tissue samples were stored in 95% ethanol for genetic analyses of relatedness. All burrow systems were permanently marked with numbered wooden stakes and coordinates recorded with a GPS. Coordinates were then converted to *X*–*Y* (north-east) coordinates with the Locate II software (Pacer Software, Truro, NS, Canada).

Social group determination

Degus remain in underground burrows with conspecifics during the night time (Ebensperger et al. 2004). Therefore, we assigned animals to social groups based on the sharing of burrow systems during night time (Ebensperger et al. 2004). The sharing of burrow systems was established by means of burrow trapping in autumn. We then determined group composition using the SOCPROG 2.3 software (Whitehead 2009) based on a matrix of associations. This symmetric matrix is an estimate of the proportion of times that any 2 individuals were captured in the same burrow system simultaneously. In our case, we determined the association between any 2 individuals by dividing the number of occasions that these 2 animals were captured in the same burrow system simultaneously by the number of trapping days that both individuals were caught (Ebensperger et al. 2004). We performed hierarchical cluster analysis of the association matrix. We confirmed the correlation between the association indices and the level of clustering in the diagram with the cophenetic correlation coefficient (Whitehead 2009): values > 0.8 indicated an effective data representation. We used the maximum modularity criteria (Newman 2004), as implemented in SOCPROG 2.3, to cut off the dendrogram and define social groups. On defining social groups, we determined burrow systems used by each group. For each social group, degus were assigned to 2 alternative categories: residents (i.e., philopatric)—those that were present in the 2007 spring, and immigrants (i.e., dispersers)—those not present during the 2007 spring. Because trapping effort during spring 2007 was more extensive than in previous years (Hayes et al. 2009), we are confident that degus assigned to immigrants were unlikely the result of animals previously present but not trapped.

Genetic analyses

DNA was extracted from tissue samples using the DNeasy Tissue Extraction Kit (QIAGEN Inc., Valencia, CA). Individuals were genotyped for 4 *Spalacopus cyanus* microsatellite loci (Scy1, Scy3, Scy5, and Scy6; Schroeder et al. 2000) and 2 degu microsatellite loci (OCDE1 and OCDE3, Quan et al. 2009), using the conditions recommended by the respective authors. These loci were chosen because they were polymorphic and showed no linkage disequilibrium in our study population. We verified polymerase chain reaction amplification by examining samples on agarose gels. Samples were analyzed on an ABI 310 capillary sequencer (Applied Biosystems, Foster City, CA) in the Laboratory of Molecular Diversity at the Pontificia Universidad Católica de Chile. Fragment sizes were determined and genotypes were assigned using PeakScanner 1.0 (Applied Biosystems).

Quantification of allele frequencies and analyses of linkage disequilibrium were conducted using GENEPOP 3.4 (Raymond and Rousset 1995). Deviations from Hardy–Weinberg equilibrium were evaluated using the Monte–Carlo randomization test of Guo and Thompson (1992) and the *U* statistic of Rousset and Raymond (1995), as implemented in ML-Relate software (Kalinowski et al. 2006). Pairwise coefficient of relatedness (*R*) among individuals was calculated using the ML-Relate software (Kalinowski et al. 2006). The ML-Relate program was chosen because it provides maximum likelihood estimates of relatedness, an accurate approach compared with other estimators available (Milligan 2003). We used *R* to refer to any estimate of genetic relatedness rather than *r*, which denotes the true relatedness based on knowledge of a pedigree (Winters and Waser 2003).

Analyses of kin structure

We first tested the null hypothesis of no association between capture association and genetic relatedness. We evaluated correlations between capture association and R matrices using Dietz (1983) R-test. This test is implemented in SOCPROG 2.3 and differs from the Mantel test in that matrices of ranked values are used instead of raw values. The Dietz R-test is less strongly affected by large (or small) outlying values than the Mantel test. We assessed associations for males and females separately based on 1000 permutations.

We evaluated whether mean R values within groups (calculated for females, males, and all group members) were significantly larger than background levels across social groups in the study population. To calculate background R values, we used bootstrapping using the R 2.4.1 software (R Development Core Team 2006). In particular, we calculated 10 000 values (with replacement) of mean R from N randomly selected R values obtained from nongroup members. The value of N varied according the total number of adults, males, or females per social group examined. Observed means that fell outside 95% interval confidence intervals for randomly selected individuals were considered different from background.

In addition, we calculated the percentage of pups born to the same burrow systems during spring that stayed in the same natal burrow (i.e., were philopatic: distance moved from spring to autumn was equal to zero) or moved and settle into same or different burrow systems (i.e., dispersed: distance moved from spring to autumn was different from zero). In case of dispersers, we further determined whether offspring from same natal burrows also moved to same burrow systems. Dispersal distance was calculated as the straight-line distance from the burrow system where pup was first captured (i.e., natal burrow) to the burrow system where the same individual was first recaptured in autumn (Quirici et al., forthcoming). We then evaluated whether mean R values between offspring that stayed or moved to same burrow systems were significantly higher than background levels of genetic similarity in the study population.

Analysis of dispersal

An absence of sex-biased dispersal in degus was previously reported based exclusively on capture–mark–recapture (Quirici et al., forthcoming). Given that this approach may lead to problems (Koenig et al. 1996; Dieckmann et al. 1999), we used genetic markers to confirm this pattern. To quantify the extent to which dispersal is sex biased in our local population, we used "assignment index (AI) values" for males and females based on 1000 permutations using FSTAT 2.9.3 (Goudet 1995). The AI measures the probability that an individual genotype would appear in the population from which it was sampled, correcting for differences in population genetic diversity (Farve et al. 1997). AI values are randomly distributed around zero, with negative values indicating that an individual is more likely than average to be a recent immigrant. The variance in AI is expected to be higher in the dispersing sex because of the increased probability that population samples will contain both philopatric and immigrant individuals (Goudet et al. 2002). During these analyses, each of our 7 social groups was treated as a "distinct" population.

To complete our understanding of the impact of dispersal on degu sociality, we performed an autocorrelation spatial analysis. This method employs a multivariate approach to simultaneously assess the spatial signal generated by multiple genetic loci (Peakall et al. 2003), as implemented in GenAlEx 6.3. The autocorrelation coefficient generated (r) is a correlation coefficient, bounded by $[-1, +1]$ and provides a measure of the genetic similarity between pairs of individuals whose geographic separation falls within the specific distance class. Positive autocorrelation implies that dispersal is limited. Separate analyses were run for males and females. Distance class intervals were set to 10 m, and the total number of distance class used were chosen based on the maximum distance to same sex individuals. Confidence intervals for r values were derived from 1000 bootstrap estimates. Whenever the confidence interval generated does not include the zero, significant spatial genetic structure needs to be inferred.

RESULTS

Microsatellite variation

No evidence of linkage disequilibrium was detected among the loci screened (all $P > 0.05$). Number of alleles per locus range from 2 to 10 (6.67 ± 2.66); observed heterozygosity range from 0.26 to 0.77 (0.54 ± 0.17) (Table 1). Significant departures from Hardy–Weinberg expectations, however, were detected for 4 loci ($P < 0.001$, Table 1). Calculations of R were performed adjusting relatedness to accommodate the possible presence of null alleles with the ML-Relate software. In addition, AI analyses are robust enough to departures from Hardy–Weinberg equilibrium (Paetkau et al. 1995). Thus, data from all 6 loci screened were included in our analyses of kinship.

Social groups and kin structure

Based on the maximum modularity criteria (Newman 2004), 7 social groups were identified and monitored in autumn 2008. There were 3.8 ± 2.3 (range: 1–6) residents females and 1 ± 0 residents males per group. There were 3 ± 2.9 (range: 1–8) immigrant females and 1.6 ± 0.9 (range: 1–3) immigrant males per group (Table 2). In total, 55.9% of 34 females present in autumn were residents and the remaining 44.1% were immigrants. In contrast, 14.3% of 14 males present in autumn were residents and the remaining 85.7% were immigrants. Thus, males were less likely than females to become residents (Yates corrected $\chi^2 = 5.38$, $P = 0.02$). There was a nonstatistically significant trend for males (mAI = 0.529) to exhibit higher mean AI compared with females (mAI = −0.249) (mAI: $P = 0.93$). The variance linked to AI did not statistically differ between females (vAI = 3.827) and males (vAI = 2.187) (vAI: $P = 0.711$). Altogether, this method reveled that our study population was composed of resident and immigrant individuals.

The spatial genetic autocorrelation analysis did not detect fine-scale genetic structure for females (Figure 1a) or males (Figure 1b). Thus, genetic structure is not influenced by

Table 1

Diversity of the microsatellite loci used to estimate relatedness in *Octodon degus*

Locus	No. of alleles	H_o	H_e	P value
Scy1	6	0.26	0.65	<0.001
Scy3	7	0.60	0.82	<0.001
Scy5	2	0.50	0.48	0.54
Scy6	8	0.54	0.85	<0.001
OCDE1	7	0.77	0.84	0.38
OCDE3	10	0.56	0.83	<0.001

P value indicates significance of differences between observed (H_o) and expected (H_e) heterozygosity.

Table 2

Number of resident and immigrant female and male degus per social group

Social group ID	Female (res)	Female (imm)	Mean R (±SD)	95% CI	Male (res)	Male (imm)	Mean R (±SD)	95% CI	Total	Mean R (±SD)	95% CI	Offs (dist)	Mean R (±SD)	95% CI
G1	—	2	0.08	0–0.5	—	1			3	0.03 (0.04)	0–0.35		—	—
G2	2	8	0.11 (0.23)	0.02–0.26	—	3	0.25 (0.28)	0–0.35	13	0.15 (0.26)	0.03–0.23		—	—
G3	1	1	0	0–0.5	—	1			3	0.16 (0.24)	0–0.35		—	—
G4	4	3	0.16 (0.23)	0–0.29	1	1	0	0–0.43	9	0.16 (0.22)	0.02–0.25	3 (25 m)	0.16 (0.29)	0–0.35
G5	6	—	0.15 (0.16)	0–0.31	1	1	0.2	0–0.43	8	0.17 (0.16)	0.01–0.26	3 (20 m)	0.32 (0.25)	0–0.35
												3 (0 m)	0.27 (0.26)	0–0.35
G6	—	1			—	3	0.27 (0.29)	0–0.35	4	0.17 (0.23)	0–0.32		—	—
G7	6	—	0.22 (0.29)	0–0.31	—	2	0.3	0–0.43	8	0.19 (0.29)	0.01–0.26	3 (30 m)	0.56 (0.11)	*0–0.35

Mean (±standard deviation, SD) pairwise R values and its confidence interval (CI) for total group, female group, male group, and siblings. Abbreviations: res, residents, imm, immigrant, offs, offspring, dist, distance. See text for details.

*R values that fell outside the 95% confidence interval.

distance among individuals. Only in 3 of 35 distance classes, the calculated confidence interval around r did not include the zero. Relatedness tended to be directly correlated with spatial distance in females that were within 10 m or less. In contrast, relatedness and spatial distance were inversely related in females and males that were within 110 and 120 m, respectively.

Mean R of entire social groups ranged from 0.03 to 0.19 (0.15 ± 0.05). These values range from 0.08 to 0.19 (0.14 ± 0.05) for females and 0 to 0.27 (0.21 ± 0.12) for males. When each social group was examined separately, R values within groups were not different from the total (0.13 ± 0.2), females (0.13 ± 0.19), and males (0.12 ± 0.18) background levels of genetic similarity in the study population (Table 2).

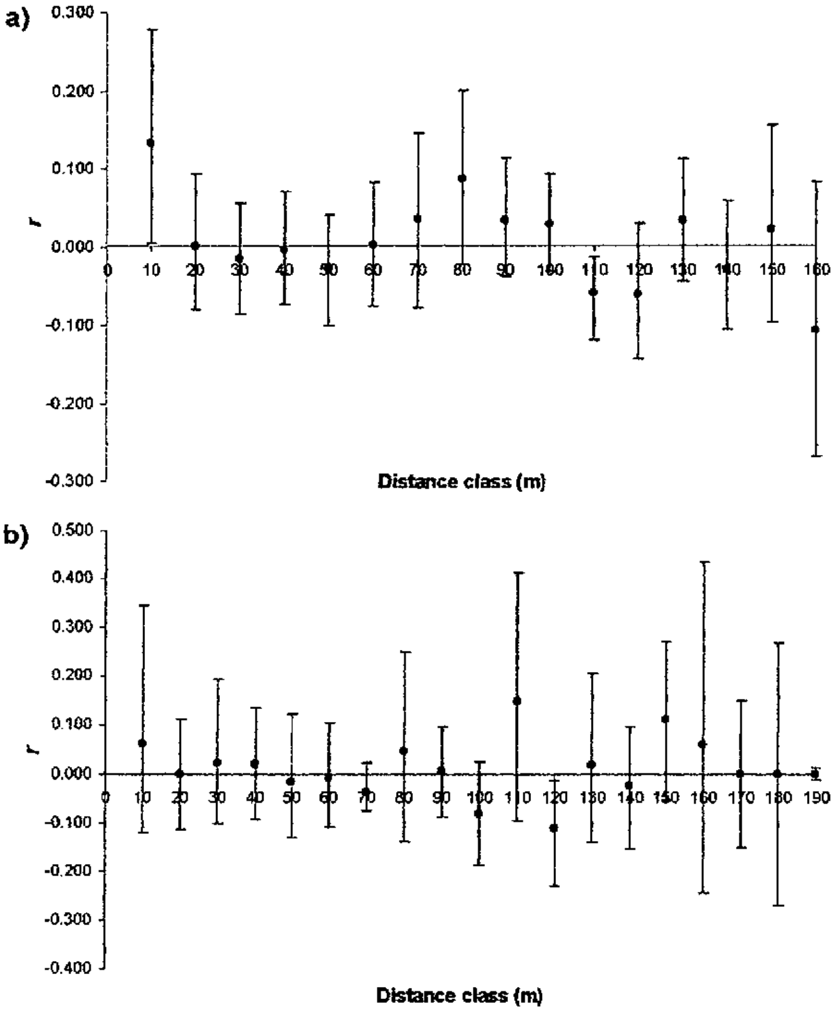

Figure 1
Spatial genetic autocorrelation estimated over cumulative distance class for females a) and males b).

Based on 1000 permutations, we detected no correlation between genetic and social associations based on burrow trapping neither for males ($N = 14$, Dietz R-test: $R_D = 0.014$, $P = 0.41$) nor females ($N = 34$, Dietz R-test: $R_D = 0.031$, $P = 0.21$). Thus, social groups determined from trapping were independent of genetic similarity of individuals.

Relatedness of offspring

Of the 175 pups marked in spring 2007 (103 females and 72 males), 16 (9.14%) were recaptured subsequently in autumn 2008 (15 females and 1 male). The mean body mass of these pups at first capture in spring 2007 (59.03 ± 13.21 g) was lower than expected for juveniles exhibiting exploratory behavior (Fulk 1976), implying that natal burrows for these animals were estimated accurately. Twelve of these 16 pups (75%) were recaptured in 4 associations of 3 animals each and 4 (25%) were recaptured alone. Of these 4 associations, 3 represented cases of individuals that moved at least 20 m from natal burrow system (Table 2). The R value in one of these associations departed from background expectations was marginally significant in another and not significantly different in the remaining association (Table 2). Only one association represented a case of animals staying at their natal burrow system and calculated R did not depart from background expectations (Table 2).

DISCUSSION

Kin structure: turnover rates and mating system

We found no correlation between pairwise relatedness (R) and the composition of social groups inferred from trapping (or spatial association) (Dietz correlation by ranks not different from random expectations), suggesting that composition of social groups in degus is not influenced by genetic relatedness. Although mean genetic relatedness within groups was not very different from that reported during one previous analysis (Ebensperger et al. 2004), social groups were not characterized by genetic relatedness higher than background levels in our study population. On the contrary, it seems that groups of individuals sharing burrows rather constitute a single global population at the spatial scale of this study (100 × 60 m). Two factors, namely short life span coupled to high rates of turnover within groups and a potentially promiscuous or polyandry mating system may explain these patterns.

Life span is known to affect turnover rate of group members in social species (McShea 1990; Kokko and Lundberg 2001), which in turn impact dispersal, philopatry, and kin structure (Branch 1993; Solomon 2003; Randall et al. 2005; Nunes 2007). For example, strong evidence of kin structure characterizes relatively long-lived social species such as Columbian ground squirrels (*Urocitellus columbianus*) (Viblanc et al. 2010) and coypus (*Myocastor coypus*) (Túnez et al. 2009). As expected, no evidence of kin structure characterizes some short-lived species with relatively high turnover rates of group members, including black grouses (Lebigre et al. 2008), woodrats (*Neotoma macrotis*) (Matocq and Lacey 2004) and degus (this study). Besides life span, dispersal distance seems to have a major impact on the observed patterns of kin structure in solitary living species, including the banner-tailed kangaroo rats (*Dipodomys spectabilis*) (Winters and Waser 2003; Busch et al. 2009) and tuco-tucos (*Ctenomys talarum*) (Cutrera et al. 2005). Based on the minimum genetic autocorrelation observed, our study did not support an influence of dispersal distance in social degus. However, studies on other social species are needed to confirm these findings.

Mating system strongly influences genetic relatedness within groups of social species (Ross 2001). High relatedness is expected in groups in which 2 or a few group members breed, that is, in species with high breeding skew. In contrast, relatively low genetic relatedness is expected in groups of species in which plural breeding is the norm, that is, breeding is shared more equally among group members (Ross 2001). In addition, genetic relatedness may increase in polygynous species characterized by female choice over few males (Chesser 1991). Social rodents seem to fit to these expectations. Whereas high relatedness characterizes colonies of highly skewed naked mole-rats (*Heterocephalus glaber*) (Reeve et al. 1990), more intermediate relatedness characterizes the social group of polygynous coypus (*M. coypus*) (Túnez et al. 2009). Thus, if mating system is a major determinant of relatedness within groups in rodents, we predict degus to exhibit a rather polygynous to promiscuous mating system. Although Soto-Gamboa (2004) reported degus to exhibit a socially polygynous mating system, subsequent paternity analyses may reveal a more promiscuous system. However, based on absence of sex bias dispersal (Quirici et al., forthcoming)—implying that the cost of dispersal and benefits of philopatry did no vary in relation to sex (Greenwood 1980; Gardner 2010)—we predict promiscuous mating system.

Offspring associations

Dispersal may dilute kinship within groups and reduces the potential influence of kin selection on social behavior (Emlen 1997; Perrin and Goudet 2001; Ross 2001; Gardner and West 2006). Sibling dispersal could be a mechanism to reduce such dilution (Johnson and Gaines 1990; Ross 2001; Gardner and West 2006). Sibling dispersal has been documented in several social birds (Heinsohn et al. 2000; Koenig et al. 2000; Williams and Rabenold 2005; Sharp et al. 2008) but in only a few social mammals (Lambin et al. 2001; Bradley et al. 2007). In degus, most offspring (75%) exhibited joint dispersal, that is, animals were recaptured after dispersal jointly with previous natal burrow mates. However, data on 4 such associations revealed that relatedness may or may not be high. Preliminarily therefore, "sibling" associations may not be strong mechanism to reduce the effect of kinship dilution by dispersal in the local population under study. The low recovery of juveniles from spring to autumn are consistent with the hypothesis that most disappearances were due to high predation in the population under study (Ebensperger and Wallem 2002, Lagos et al. 2009) rather than long-distance dispersal from the grid (Quirici et al., forthcoming). If so, high juvenile mortality might prevent sibling association from reducing the any possible effect of kinship dilution by dispersal. A comparative study among degu populations facing different regimes of predation risk will bring light into this topic. If predation risk dilutes sibling association, we expect to find higher level of sibling associations, which could result in stronger kin structure, in those populations facing lower risk of predation.

High to moderate levels of kinship are thought to be required for kin-selected behavior (Chesser 1991). Whereas some laboratory studies suggest a relationship between kinship and social behavior in degus, others do not (Ebensperger et al. 2006, 2007; Quirici et al. 2008). Instead, social familiarity, that is, animals born and raised together, may be more important. Villavicencio et al. (2009) demonstrated that social familiarity instead of phenotypic similarity determines kin discrimination in degus. Our field data revealing that offspring disperse together are consistent with a greater role of social familiarity reported by Villavicencio et al. (2009). As it has been suggested in social birds (Sharp et al. 2008; Sonsthagen et al. 2010) and rodents (Mateo 2007), offspring associations may be the result of rearing together. This mechanism conducting to sibling associations is likely to operate in degus in which offspring are reared communally in underground burrow systems for at least 3 weeks (Ebensperger et al. 2004; Hayes et al. 2009). However, this result should be taken with caution, due to low recapture of juveniles.

To summarize, our study revealed no evidence of kin structure in the population of social degus studied. High turnover rates of group members and dispersal are likely contributors to the lack of kin structure in degu groups. Therefore, opportunities for the evolution of kin-selected social behavior (e.g., cooperative care of young) appear to be limited in this local population. Subsequent studies are needed to better quantify the extent to which sibling associations may promote kin selected or other forms of cooperation, in which individuals with kin or familiar mates should have enhanced fitness compared with individuals without kin or familiar companions (e.g., Viblanc et al. 2010).

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Burrow limitations and group living in the communally rearing rodent, *Octodon degus*

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Group living is thought to evolve whenever individuals attain a net fitness advantage due to reduced predation risk or enhanced foraging efficiency, but also when individuals are forced to remain in groups, which often occurs during high-density conditions due to limitations of critical resources for independent breeding. The influence of ecological limitations on sociality has been studied little in species in which reproduction is more evenly shared among group members. Previous studies in the caviomorph rodent *Octodon degus* (a New World hystricognath) revealed no evidence that group living confers an advantage and suggest that burrow limitations influence formation of social groups. Our objective was to examine the relevance of ecological limitations on sociality in these rodents. Our 4-year study revealed no association between degu density and use of burrow systems. The frequency with which burrow systems were used by degus was not related to the quality of these structures; only in 1 of the 4 years did the frequency of burrow use decrease with decreasing abundance of food. Neither the number of females per group nor total group size (related measures of degu sociality) changed with yearly density of degus. Although the number of males within social groups was lower in 2008, this variation was not related clearly to varying density. The percentage of females in social groups that bred was close to 99% and did not change across years of varying density. Our results suggest that sociality in degus is not the consequence of burrow limitations during breeding. Whether habitat limitations contribute to variation in vertebrate social systems is discussed.

Key words: caviomorph rodents, density, ecological constraints, habitat, hystricognath, sociality

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Animal sociality ranges from short-term associations and aggregations (e.g., foraging or roosting groups) to relatively long-term socially cohesive units (e.g., communal rearing groups—Krause and Ruxton 2002; Parrish et al. 1997). Social interactions that occur over long periods are thought to evolve because group-living individuals attain net fitness advantages in relation to solitary animals (Alexander 1974; Bertram 1978; Ebensperger 2001; Ebensperger and Blumstein 2006; Krebs and Davies 1993). Alternatively, sociality can be the result of limited availability of breeding sites due to high population density, a patchy distribution of critical resources, or a combination of these (Arnold and Owens 1998; Brown 1987; Emlen 1982; Johnson et al. 2002; Koenig et al. 1992; Waser 1988). Generally referred to as the ecological limitations (or constraint) hypothesis, this model states that limited availability of resources essential for independent breeding determines that the direct fitness cost of remaining philopatric (i.e., social) is small compared to the costs and risks of dispersal (i.e., leaving the group to live and reproduce independently—Emlen 1982, 1995). Thus, the ecological limitations hypothesis predicts that sociality increases with increasing density of conspecifics and with decreasing availability of resources essential for breeding. From a proximate perspective the ecological limitations hypothesis states that changes in sociality (e.g., group size) are driven mainly by natal philopatry as opposed to other demographic

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processes such as immigration (Ebensperger and Hayes 2008; Emlen 1995). Establishing the relative importance of adaptation and constraints on the evolution of group living and subsequent variation in group size and composition is a major goal of sociality theory.

Most support for the ecological limitations hypothesis comes from studies of singularly breeding vertebrates (sensu Solomon and Getz 1997). In groups of singular breeders reproduction is dominated by a male–female pair, whereas offspring are reared communally. Thus, a variable number of nonbreeding adults, typically (but not always) previous offspring of the breeding pair (Ekman et al. 2004; Solomon and Getz 1997), contribute by giving care to the offspring of breeders. Observational studies on singularly breeding fishes and birds have reported links between habitat availability and philopatry or group size (Bergmüller et al. 2005; Buston 2003; Carrete et al. 2006; Moreira 2006; Russell 2001; Woolfenden and Fitzpatrick 1984). In addition, several studies on birds suggest that formation of social groups increases at high population densities but decreases when critical space needed for breeding (e.g., cavities) is enhanced experimentally (Komdeur et al. 1995; Pruett-Jones and Lewis 1990; Walters et al. 1992). Taken together, evidence from singularly breeding vertebrates indicates that ecological limitations to independent breeding can enforce sociality.

The ability of the ecological limitations hypothesis to explain group living in mammals has been questioned. The available evidence for mammals is meager (Russell 2004), and life-history traits related to reproduction would make mammals less likely to be constrained than other vertebrates (Mumme 1997). Also, the applicability of this hypothesis appears to vary even within bird species or lineages (Doerr and Doerr 2006; Hatchwell and Komdeur 2000), implying that such variation might also apply to other vertebrates such as mammals. However, theoretical and empirical considerations suggest that ecological constraints can apply to social mammals. Mammals include species that use specialized burrows for living and rearing young (Hayes 2000). The relatively high energetic costs and risks of burrow construction and maintenance (Ebensperger and Bozinovic 2000) can constrain dispersal and force individuals to share these specialized structures (Jarvis et al. 1994; White and Cameron 2009). Correlative and experimental studies support a positive association between the formation of social groups and population density in at least 3 singularly breeding rodents (Cochran and Solomon 2000; Lucia et al. 2008; Powell and Fried 1992; Randall et al. 2005). For 2 of these species (*Microtus pinetorum* and *Rhombomys opimus*) underground burrows are essential for breeding, and the authors imply that abundance and quality of these structures can be a limiting resource (Powell and Fried 1992; Randall et al. 2005).

In contrast to singular breeding, in plurally breeding species groups multiple females breed and provide care to offspring communally (Hayes 2000; Lewis and Pusey 1997). The role of habitat limitations among social vertebrates known to breed plurally has been studied less than it has been in singularly breeding species. However, evidence supports an influence for habitat limitations in some species. Both group living and communal rearing of offspring increases with density conditions in at least 2 species of rodents (*Peromyscus leucopus* and *P. maniculatus*—Wolff 1994). The implication of these findings is that density can influence the formation of groups without compromising breeding activity of group members. More recently, it has been reported that availability of burrows does not influence communal nesting in warthogs (*Phacochoerus africanus*—White and Cameron 2009). Although intriguing, these findings imply that more attention to plurally breeding vertebrates (and mammals in particular) is needed to determine the extent to which limitations to independent breeding (if any) influence sociality and whether this factor imposes a fitness cost to group members. The objective of this study was to examine the role of ecological limitations in explaining group living in a burrowing, plurally breeding mammal. In particular, we examined whether burrow limitations due to high population density influence the tendency of semifossorial degus (*Octodon degus*) to form social groups.

Degus are New World hystricognaths, medium-sized rodents (about 180 g body mass) that feed mostly on grasses and forbs, breed once per year, and in which multiple lactating females share underground nests and rear their litters communally (Ebensperger et al. 2002, 2004, 2007). A recent study did not support roles for decreased predation risk or foraging benefits as benefits of group living in degus (Hayes et al. 2009). This study showed that group living does not enhance number of offspring produced per capita or survival of the young (Hayes et al. 2009). These direct-fitness patterns are more consistent with the ecological limitations hypothesis.

Some features of degus suggest that burrows could be a limiting factor. Members of social groups share a variable number of burrow systems, which include nest sites for rearing their offspring communally (Ebensperger et al. 2004; Soto-Gamboa 2004), and larger social groups use more burrows than do smaller groups (Hayes et al. 2009). Degus, which are diurnally active, use these underground burrows to hide from predators (Lagos et al. 2009). As in other semifossorial rodents (Taraborelli 2009), burrow systems of degus persist over a span of ≥5 years (L. A. Ebensperger, and L. D. Hayes, pers. obs.). Therefore there may be times, as during periods of high density, when the number of burrows is limited.

Other evidence, however, casts some doubts on the previous interpretation. Although degus live in year-round social groups, these groups are short-lived; only 31% of social groups persist from one year to the next (Ebensperger et al. 2009). Most critical, and contrary to predictions from the ecological limitations hypothesis, immigration seems to play an important role in determining the composition of social groups compared to adult fidelity and offspring philopatry (Ebensperger et al. 2009).

In summary, if burrows limit dispersal of young, enforce group living, and ultimately decrease independent breeding in degus, we expect use of individual burrows to increase with increasing degu density. Because burrow systems differ in quality and quantity (Komdeur et al. 1995; Stacey and Ligon 1991; White and Cameron 2009), high-quality burrows could be more important to degus than total number of burrows. Therefore, we also expect use of individual burrows to increase with increasing burrow quality. As a result, with increasing degu density we also expect size of social groups to increase and proportion of breeding females within social groups to decline.

MATERIALS AND METHODS

Study site.—The study was conducted between 2005 and 2008, in months when females are gravid and lactating (June–October), on a natural population of degus at the Estación Experimental Rinconada de Maipú, a field station of Universidad de Chile. This study area is characterized by a Mediterranean climate with cold, wet winters and warm, dry summers. Data from the Pudahuel weather station (Dirección Meteorológica de Chile, Santiago, Chile), 15 km from the Rinconada field station, indicate that mean annual rainfall was 239 mm during 2005–2008, most of which (73% on average) was during the austral winter, from June to August. Mean monthly temperature (8.9°C) is relatively low from June to August and highest from December to March (19.6°C).

We designated as our study site a 4- to 5-ha area in a locality known as Pajaritos (33°23′S, 70°31′W, altitude 495 m) and in which degus were sighted frequently. We established 2 grids approximately 150 m apart. The grids were characterized by a similar distribution of grasses, forbs, and shrubs and covered 0.18 ha (30 × 60 m; grid 1) and 0.25 ha (50 × 50 m; grid 2), respectively.

Our study involved 2 stages. First we conducted grid trapping to determine density of the population in June, and then in August–October we determined social group composition using telemetry to locate degus at night and trapping at burrow entrances in the morning. No trapping relevant to this study was conducted in July. Grid trapping was restricted to the 2 grids, but night telemetry and morning burrow trapping were extended to a larger area because of the natural movement of social groups (Burger et al. 2009; see below).

Grid trapping and radiocollaring.—We conducted grid trapping to estimate density on the 2 study grids during mid-June (late austral fall). Degus were captured using locally produced metal live traps (9.5 × 10 × 30 cm, similar to Sherman live traps [H. B. Sherman Traps, Inc., Tallahassee, Florida] in design) baited with rolled oats. Traps were set at fixed stations at 5-m intervals, resulting in 91 traps (7 × 13 array) on grid 1 and 121 traps (11 × 11 array) on grid 2. Traps were opened for 5 days during the morning (0800 h) prior to emergence of degus from burrows and closed after 3 h. We determined sex, body mass (to 0.1 g), and reproductive condition of females (whether they had perforate vaginas—an indicator of sexual receptivity, were gravid, or were lactating) for each degu. Gravid females typically had enlarged abdomens, and fetuses could be detected easily by gentle palpation. Lactation was recorded if a female exhibited milk after we gently squeezed 2 randomly selected nipples. We estimated degu density on each grid by dividing the total number of individual degus caught through the 5 days of trapping by the area covered by the grid (grid 1 = 0.18 ha; grid 2 = 0.25 ha). Density estimates for the 2 grids were averaged for each year.

Adults weighing >170 g were fitted with 8-g radiocollars (BR radiocollars; AVM Instrument Co., Colfax, California) or 7- to 9-g radiotransmitters (RI-2D; Holohil Systems Limited, Carp, Ontario, Canada, and SOM-2190A; Wildlife Materials Incorporated, Murphysboro, Illinois) with unique pulse frequencies. Later, as additional degus were trapped during burrow trapping, they also were given radiocollars. All radiocollars were removed from radiocollared degus during late October.

We assigned each adult degu a unique identification number and marked it at 1st capture by removing the 1st or 2nd phalanges of 1–4 toes, no more than 1 toe per foot (Hayes et al. 2009; Quirici et al. 2010). We used toe clipping because of the need to permanently mark a large number of individuals required to quantify spatial patterns (Ebensperger et al. 2009; Hayes et al. 2007) and reproduction (Hayes et al. 2009; Quan et al. 2009). We minimized pain by making rapid cuts with sharp sterilized clippers. In the event that an individual was bleeding (estimated $<20\%$), we applied light pressure to stop bleeding before an individual was released. We applied a topical antibiotic to reduce the risk of subsequent infections. Infections were extremely rare (1 infection for every 100 degus clipped). Tissue samples (toe clippings) were kept for genetic analyses (Quan et al. 2009). This study followed the guidelines of the American Society of Mammalogists (Gannon et al. 2007) and was approved by the Institutional Animal Care and Use Committee of University of Louisiana at Monroe and adhered to laws of the United States and Chile (permit 1-58.2005 [2711] by the Servicio Agrícola y Ganadero).

Burrow trapping, night telemetry, and determination of social groups.—Degus are diurnally active and remain in underground burrows during the night (Ebensperger et al. 2004). Thus, the main criterion used to assign degus to social groups was the sharing of burrow systems during the night (Ebensperger et al. 2004; Hayes et al. 2009). To determine which degus shared burrows we used night telemetry (to identify which degus were in the burrow) and morning trapping, both conducted in August–October (to identify degus as they emerged from burrows).

During night telemetry radiocollared adults were located from above the ground as they rested in burrows at night. Telemetry was conducted once per night and began approximately 1 h after sunset. We used an LA 12-Q receiver (for radiocollars tuned to 150,000–151,999 MHz frequency; AVM Instrument Co.) and a handheld, 3-element yagi antenna (AVM Instrument Co.).

For burrow trapping we defined a burrow system as a group of burrow openings around a central location, with the systems

TABLE 1.—Trapping and radiocollaring effort of degus (*Octodon degus*) in central Chile for each year of the study.

	Year			
	2005	2006	2007	2008
Total no. adults trapped and assigned to a social group	82	65	60	44
No. radiocollared individuals	30	16	34	21
Locations per radiocollared individual (± *SE*)	24.8 ± 1.8	34.0 ± 3.2	18.3 ± 4.2	16.0 ± 0.9
No. burrow systems trapped	32	58	32	43
No. trapping days per burrow system (± *SE*)	16.8 ± 0.5	17.3 ± 0.5	31.4 ± 1.2	45.3 ± 1.6
No. traps used per burrow system (± *SE*)	11.9 ± 0.2	11.9 ± 0.2	9.7 ± 0.2	8.0 ± 0.1

having a diameter of 1–3 m (Fulk 1976; Hayes et al. 2007). Because of the natural distribution and movement of the degus during the study, burrow systems were trapped over an area that varied in size from year to year and included the 2 density grids and area around each of them. The total area sampled ranged from 0.61 to 2.16 ha across years of study.

In burrow trapping live traps (model 201 Tomahawk; Tomahawk Live Trap Company, Tomahawk, Wisconsin) were set near burrow entrances before adults emerged from burrows in the morning (0600 h). After 1.5 h the identity and location of all captured degus were determined, and traps were closed until the next early morning trapping. As for grid trapping, we determined sex, body mass (to 0.1 g), reproductive condition of females (perforate, gravid, or lactating), and individual identification of degus.

To determine group composition we compiled a symmetrical similarity matrix of pairwise association of burrow locations for all adult degus detected by burrow trapping and night telemetry (Whitehead 2008). We determined the association (overlap) between every pair of individuals by dividing the number of times that the 2 degus were captured at or tracked with telemetry to the same burrow system by the total number of times that both individuals were detected by trapping or telemetry in the same trapping day or telemetry night (Ebensperger et al. 2004). Adult degus were considered to associate with a given social group if they overlapped in ≥10% of the same trapping or telemetry sessions with other individuals in the group (Hayes et al. 2009). Animals with <10% overlap were not considered part of the same group; typically, degus overlap 50% or more with other group members (Ebensperger et al. 2004; Hayes et al. 2009).

Burrow quantity.—We considered 2 complementary measures of the extent to which burrows were used (i.e., limited, or not available to other individuals) in terms of quantity. We monitored burrow systems that were used repeatedly by individuals radiocollared during density trapping. To this sample we added a variable number of randomly selected burrow systems that exhibited fresh droppings at their burrow entrances and where animals were seen active nearby. Upon determining social groups, we categorized burrow systems as in use or vacant. Burrow systems considered to be in use were those in which group members were repeatedly trapped and located during night telemetry; those considered to be vacant were those with no records of captures and those in which a minority of group members were trapped infrequently or found only occasionally during night telemetry. Burrow systems were categorized as in use (i.e., occupied) or vacant for each year of the study. This population-level, quantitative measure of burrow system availability provided only 4 temporal replicates (1 per year).

Because a variable number of degu captures were recorded in both used and vacant burrow systems, we complemented this population-level approach with another that examined use of individual burrows. In particular, we used yearly data from burrow trapping to quantify use of burrows as the total number of captures per burrow system, standardized by the number of traps used and days of trapping at each burrow. Thus, this burrow-level measure included the total number of burrow systems sampled (used and vacant). The total number of burrow systems examined in our population every year (Table 1) represented a compromise between the natural movement of animals and our logistic ability to monitor a relatively large number of burrow systems.

Burrow quality.—To examine whether quality of burrows influences use by degus, we recorded 3 ecological attributes of burrows that we thought reflected their quality: abundance of preferred food, hardness of soil, and density of openings at each burrow system. We considered burrow quality to increase with increasing abundance (biomass) of preferred food—grasses and forbs (Meserve et al. 1983). We considered harder soils to be of lower quality, because burrowing costs for degus increase with hardness of soil (Ebensperger and Bozinovic 2000). Predation risk for degus increases with distance to the nearest burrow entrance (i.e., safe havens—Lagos et al. 2009), so we considered burrow systems with more openings per unit area to be safer and of higher quality. We did not find any other species that potentially could affect the quality of burrows to be permanent residents of burrows.

Ecological sampling was conducted during early spring (September and October) when most offspring began to emerge from burrows to forage aboveground. To track changes in the abundance of primary food (Meserve et al. 1983) we collected samples of green forbs and grasses at 3 and 9 m from the center (a point located centrally between entrances) of each burrow system in the north, east, south, or west directions. We placed a 250 × 250-mm quadrat at each sampling point and removed the aboveground parts of all green forbs and grasses within the quadrat. Samples were stored immediately inside 2-kg-capacity paper bags. In the laboratory we oven-dried each plant sample at 60°C for 72 h to

Table 2.—Population density and quantity and quality of burrows for a population of degus (*Octodon degus*) in central Chile. Burrow quantity was measured by percentage of available burrows used and by number of degus using each burrow. Burrow quality was measured by abundance of food (grasses and forbs) and by soil hardness—each at 3 m and 9 m from center of main burrow system—and by density of openings into burrow system. Sample sizes are given in Table 1.

	Year			
	2005	2006	2007	2008
Population density (degus/ha)	133	199	215	63
Burrow quantity				
Percentage of burrow systems used	84	40	88	65
Burrow use (captures per trap-day; ± *SE*)	0.16 ± 0.02	0.16 ± 0.02	0.17 ± 0.03	0.11 ± 0.03
Burrow quality				
Abundance of food at 3 m from main burrow system (g/m^2; ± *SE*)	128.4 ± 10.9	91.8 ± 8.4	107.2 ± 10.8	119.2 ± 10.0
Abundance of food at 9 m from main burrow system (g/m^2; ± *SE*)	154.4 ± 11.1	85.0 ± 8.6	106.3 ± 10.9	114.9 ± 10.2
Soil hardness at 3 m from main burrow system (kPa; ± *SE*)	10,474 ± 93	11,102 ± 72	11,068 ± 92	11,440 ± 85
Soil hardness at 9 m from main burrow system (kPa; ± *SE*)	10,403 ± 96	11,149 ± 74	11,132 ± 95	11,386 ± 88
Density of burrow openings (no./m^2; ± *SE*)	0.13 ± 0.01	0.13 ± 0.01	0.14 ± 0.01	0.11 ± 0.01

determine its dry mass (biomass in g—Ebensperger and Hurtado 2005). We used the same sampling pattern to record soil penetrability as an index of soil hardness (Lacey and Wieczorek 2003). Soil penetrability was recorded with the use of a handheld soil compaction meter (Lang Penetrometer Inc., Gulf Shores, Alabama). The penetrometer expressed pressure in units of pounds (of force) per square inch (psi), which we converted to SI pressure units, kPa. We 1st used the equivalence of 1 psi = 87.55 × spring elongation reading (inches), obtained from load and elongation data (available at http://www.langanalytical.com/). Then, we converted psi units into kPa with the equivalence of 1 psi = 6.894 kPa (Pennycuick 1988). Density of burrow openings (number/m^2) at each burrow system was determined by quantifying the number of burrow openings in a circular area with a radius of 9 m from the center of burrow systems.

Reproductive status of females.—Females were categorized as reproductive (gravid or lactating) or nonreproductive. We categorized as gravid those females with an increase in body mass of about 50–100 g between August and September. The transition from pregnancy to lactation was detected easily, as females lost body mass between consecutive captures and milk was present in the nipples. The total number of adult females in this analysis was 53, 43, 45, and 38 in 2005, 2006, 2007, and 2008, respectively.

Statistical analysis.—Before we analyzed data we ranked yearly estimates of degu population density from 1 to 4, with 1 the lowest density and 4 the highest. We then conducted nonparmetric correlation analysis (Spearman rank correlation, r_s) between ranks of increasing degu density and percentage of burrows systems that were vacant, that is, our population-level estimate of available burrows. Given the overall low sample size involved (1 data point per year of study), we treated this analysis as qualitative. Assumptions of normality and homoscedasticity, assessed with the use of Kolmogorov–Smirnov tests and Cochran *Q*-tests, respectively, were not met for data on burrow use, so we used Kruskal–Wallis analysis of variance (*H*), followed by nonparametric multiple comparison tests (Siegel and Castellan 1988) to examine whether burrow use changed across an increasing rank of yearly density. We then used a nonparametric Spearman rank correlation test to verify whether burrow use was influenced by ecological attributes of burrow quality: food abundance, soil hardness, and density of burrow openings.

We used 1-way parametric analyses of variance to examine variation in total group size and number of females per social group across yearly density conditions. Variation in the number of males per social group was examined using the Kruskal-Wallis test, followed by nonparametric multiple comparisons tests. The Kruskal–Wallis test also was used to verify whether the proportion of females that bred within their social groups changed across years. All data are reported as means ± *SE*. Analyses were conducted using Statistica 9.0 (StatSoft Inc., Tulsa, Oklahoma).

RESULTS

Burrow quantity and quality.—Population density varied from 63 to 215 individuals and was unrelated to quantity or quality of burrows that were in use. At a population level the proportion of burrows used was highest in 2007 at 88% and lowest in 2006 at 40% (Table 2). However, no association was found between the proportion of burrows used each year and degu density ($r_s = 0.40$, $n = 4$, $P = 0.60$). Additionally, no trend was apparent from scanning of data. Similarly, at a level of individual burrows we found no overall association between yearly population density and burrow use. Although burrow use in 2008, the year with the lowest degu density, was significantly lower than burrow use in 2005 and 2007, it was similar to burrow use in 2006, the year with the 2nd highest population density ($H_{3,167} = 17.87$, $P < 0.001$, and nonparametric multiple comparison tests, $P < 0.05$; Table 2).

The number of entrances to burrow systems for all years combined ranged from 6 to 71 per burrow system. Density of burrow openings had a range of 0.024–0.283 openings/m^2 and did not differ significantly with year of study ($H_{3,157} = 6.37$,

$P = 0.095$). Food abundance at 3 m from individual burrow systems was variable, ranging from 0 to 347 g/m^2. The mean value in 2006 was significantly lower than in 2005 but similar to means for 2007 and 2008 ($H_{3,157} = 9.87$, $P = 0.0197$; and for all nonparametric multiple comparison tests, $P < 0.02$; Table 2). At 9 m from main burrow systems food abundance ranged from 0 to 355 g/m^2. Mean value for food at 9 m was higher in 2005 than in 2006 and 2007 but similar to mean for food in 2008 ($H_{3,157} = 21.20$, $P = 0.0001$, and for all nonparametric multiple comparison tests, $P < 0.04$; Table 2). Hardness of soil at 3 m from main burrow systems ranged from 502,287 to 695,130 kg/m^2. This measure was significantly lower in 2005, higher in 2008, and intermediate in 2006 and 2007 ($H_{3,157} = 43.40$, $P < 0.0001$, and for all nonparametric multiple comparison tests, $P < 0.02$; Table 2). Hardness of soil at 9 m from main burrow systems ranged from 511,557 to 690,645 kg/m^2. This measure was significantly lower in 2005 than in 2006, 2007, and 2008 ($H_{3,157} = 43.01$, $P < 0.0001$, and nonparametric multiple comparison tests, $P < 0.001$; Table 2).

We found no statistically significant associations between burrow use and food (at 3 or 9 m), soil hardness (at 3 or 9 m), or density of burrow openings in 2006, 2007, and 2008 ($P > 0.06$ for all correlations). In 2005 burrow use decreased with increasing abundance of green herbs at 3 m from main burrows ($r_s = -0.39$, $n = 32$, $P = 0.028$). No other associations examined in 2005 were statistically significant ($P > 0.15$ for all correlations).

Size of social groups and female breeding.—Population density did not predict size of social groups nor number of breeding females per social groups. Size of social groups (including females and males) ranged from 2 to 12 adults throughout the study. Groups contained 1–8 females and 0–5 males. Neither number of females ($F_{3,39} = 0.77$, $P = 0.518$) nor total group size ($F_{3,39} = 1.50$, $P = 0.230$) changed across yearly estimates of degu density (Fig. 1). In contrast, number of males per social group was significantly lower in 2008, the year with the lowest degu density, than in 2005, the year with the 3rd highest degu density recorded, but similar to males in 2006 and 2007 ($H_{3,43} = 9.49$, $P = 0.024$, and nonparametric multiple comparison tests, $P < 0.05$; Fig. 1).

All female members of social groups bred in 2007 and 2008. The proportion of females that bred within their social groups reached 0.981 ± 0.015 in 2005 and 0.977 ± 0.016 in 2006. Statistically, proportions across years were not different ($H_{3,43} = 1.65$, $P = 0.649$).

DISCUSSION

Contrary to our predictions, our population measure of available burrows did not vary with degu density. Burrow use did not clearly increase or decrease with density; burrow use was similarly high in 2005 and 2007, yet density conditions differed by 38% during these years. In contrast, burrow use was similar in 2006 and 2008, yet density differed by 68%. Second, we found little evidence that variation in the quality of burrows affected their use by degus. Only in 1 year (2005) did burrow use decrease with increasing abundance of food (as measured 3 m from main burrow systems), a pattern that contradicted the predicted influence of food abundance on burrow use. Although we cannot eliminate the possibility that relatively high burrow use depleted food at formerly food-abundant main burrows, this trend was noted only in 2005, and for no other measure of burrow quality examined. Moreover, these findings paralleled the observation that abundance of food at burrows used is a poor predictor of group size in degus (Hayes et al. 2009). Third, neither total group size nor number of females per social group (2 related proxies of degu sociality) varied predictably with annual changes in density. Males were less numerous in 2008 (i.e., the year with the lowest density) than in other years, whereas number of females did not differ among years. Fourth, the fraction of females within social groups that bred was close to 100% irrespective of variation in social group size or population density. Pending additional long-term data, these results suggest that limitations in availability of breeding sites do not influence group living in our study population. Based on Mitchell and Dill (2005), we suggest that future studies examine other potentially relevant indicators of quality of breeding habitat in degus, specifically the inner space of underground burrows and its associated physical conditions (e.g., ambient temperature, humidity, and oxygen concentration of air).

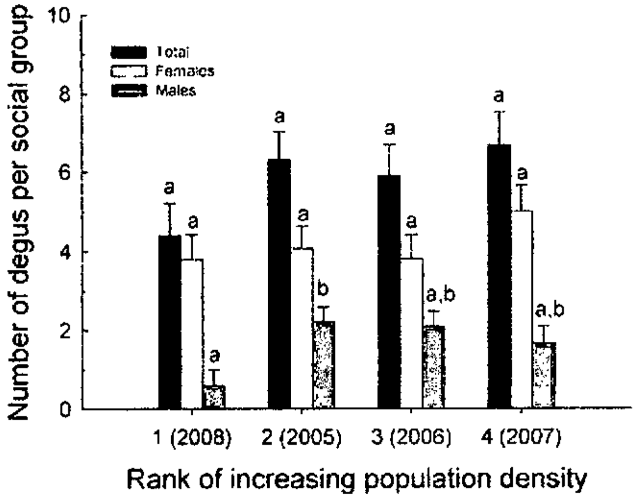

FIG. 1.—Size of social groups in years of different population density in a natural population of *Octodon degus* in central Chile. Bars indicate number of adult members (total, females, and males) of social groups, arranged by rank of increasing population density. Yearly estimates of degu density were obtained from 2 trapping grids and were 133, 199, 215, and 63 degus/ha in 2005, 2006, 2007, and 2008, respectively. A total of 13, 11, 9, and 10 social groups were identified and examined in 2005, 2006, 2007, and 2008, respectively. Bars with the same lowercase letters indicate no statistically significant difference in group size within totals, females, or males. Data are means ± *SE*.

From a proximate perspective the seemingly low importance of ecological limitations on burrow availability is consistent with previous findings in degus. Theory predicts that when population density is high and burrows are limited, offspring delay dispersal and remain philopatric at natal sites, resulting in the formation of kin groups (Emlen 1995). Although natal philopatry occurs in degus, immigration of adult males and females also plays a major role in group formation and maintenance (Ebensperger et al. 2009), possibly explaining why social groups consist of both kin and nonkin (Ebensperger et al. 2004). Greater kinship among group members would be expected if offspring followed the expected pattern of delayed dispersal and natal philopatry at high density (Emlen 1995). In this context, observed variation in number of males in social groups remained puzzling. In 2008, the year with the lowest degu density, number of males per group was lower than in years with higher population density (2005–2007). This finding is consistent with males being less constrained in 2008 to remain in social groups. However, juvenile and adult males are known to disperse and emigrate from their natal social groups (Ebensperger et al. 2009), implying that males generally are not forced to remain in their groups of origin. The absence of a relationship between dispersal and density also has been reported in other rodents (Maher 2006).

A potential alternative to the ecological limitations hypothesis is that social groups occur in species with predictable life-history variation. In particular, species characterized by relatively low annual mortality could reach high densities and then saturate the breeding habitat (Arnold and Owens 1998; Hatchwell and Komdeur 2000). Under these conditions low turnover of social groups, and consequently natal philopatry of most offspring, is expected. In contrast to this prediction offspring mortality in degus (based on disappearance) is extremely high (Ebensperger et al. 2009; Le Boulengé and Fuentes 1978), and typically, 80–90% of adults die after 1 breeding season (Meserve et al. 1993). Consequently, social groups are short-lived and characterized by an extensive turnover of members across years (Ebensperger et al. 2009). Second, dispersal and immigration both play important roles in group dynamics compared to adult fidelity and offspring philopatry (Ebensperger et al. 2009). Thus, life-history traits such as annual mortality and density do not hold much explanatory power for social group formation in degus.

Among social mammals, species generally can be categorized as facultative or obligate social breeders depending on their tendency to form groups. For example, facultatively social species of *Peromyscus* are solitary at low to moderate densities but delay dispersal and form social groups at high density (Wolff 1994). Other taxa such as some canids and other carnivores are obligate social breeders, forming groups regardless of ecological variation (Moehlman 1979). Our results, in combination with previous observations at our study site (Ebensperger et al. 2004, 2007; Hayes et al. 2009), suggest that most female degus live in social groups regardless of ecological variation. Variation in the size and composition of degu social groups is still evident. Our current long-term study is aimed at testing some alternative explanation to this variation, namely that fitness consequences to females are not the same within groups (e.g., breeding success is skewed), or that other ecological factors (such as parasitism) play roles.

Regarding ultimate causation, evidence is accumulating to suggest that fitness consequences of group living vary both within (Brown and Brown 1996; Harrington et al. 1983) and among (Cant 2000; Hoogland 1995; Randall et al. 2005) social species. In particular, negative or neutral fitness consequences are expected in social groups that form due to habitat or other limitations. A density-dependent formation of social groups coupled to neutral fitness consequences of group size supports a role for habitat limitations in some rodents (Randall et al. 2005; Travis et al. 1995; Wolff 1994). Studies on degus have provided little support for this expectation. Although negative and neutral fitness consequences characterize degu social groups (Hayes et al. 2009), the size of these groups does not appear to be influenced by density-driven burrow limitations. However, our estimates of fitness are based on a per capita number of offspring per female. Under habitat limitations direct reproduction might not be shared equally among all group members, a hypothesis that we are currently evaluating with microsatellite tools (Quan et al. 2009). Although >95% of adult females captured appeared to breed during all years of this study, preliminary molecular evidence from 10 social groups observed in 2005 suggests that reproductive success is highly skewed (L. D. Hayes, pers. obs.; P. Quan, pers. comm.). Understanding the relationship between ecological variation, group size, and direct fitness (based on molecular tools) could be the key to understanding degu sociality.

Aside from ecologically based explanations, sociality in degus could represent a case of phylogenetic inertia. Group living seems common within Octodontidae, particularly in the most derived forms, which include degus (Ebensperger et al. 2008). Given that group living is also common within other hystricognath families basal to Octodontidae (Ebensperger and Blumstein 2006; Opazo et al. 2005), comparative studies are needed to determine whether sociality in degus evolved independently or represents an ancestral trait that arose in a context different from that faced by current degu populations.

Overall, the role of ecological limitations as a cause of vertebrate sociality remains largely unresolved. Although correlative and experimental evidence support an effect of ecological limitations in some cooperatively breeding birds, fishes, and mammals (Bergmüller et al. 2005; Carrete et al. 2006; Lucia et al. 2008; Moreira 2006; Woolfenden and Fitzpatrick 1984), controversy persists (Doerr and Doerr 2006; Hatchwell and Komdeur 2000). Existing evidence about the role of habitat limitations among less-studied communal (or plural) breeders also is not consistent (Lucia et al. 2008; White and Cameron 2009).

RESUMEN

La vida en grupos (o sociabilidad) puede evolucionar ya sea porque confiere ventajas netas en adecuación, o porque los

individuos se ven forzados a vivir socialmente producto de condiciones de alta densidad que limitan la cantidad de recursos necesarios para su reproducción independiente. La influencia de limitaciones ecológicas ha sido poco estudiada en especies donde la reproducción al interior de los grupos está repartida más equitativamente. Estudios previos en el roedor caviomorfo *Octodon degus* (un histricomorfo del Nuevo Mundo) indican que el uso comunitario del madrigueras no es ventajoso, y que limitaciones relacionadas a la disponibilidad de estas estructuras podrían influir la formación de grupos sociales en esta especie. El objetivo de nuestro estudio fue examinar estas limitaciones en una población silvestre de *O. degus* entre 2005 y 2008. Nuestro estudio de 4 años no detectó ninguna asociación entre densidad de degus y uso de sus sistemas de madrigueras. El uso de estas estructuras tampoco fue afectado de manera importante por indicadores de su calidad. No hubo cambios en el número de hembras ni el número total de adultos por grupo con la densidad de degus entre años. Aunque el número de machos por grupo fue menor en 2008, esta variación no estuvo relacionada a cambios en densidad. El porcentaje de hembras lactantes al interior de cada grupo fue cercano al 99% el que no fue afectado por variaciones en densidad. Por ahora, estos resultados indican que la sociabilidad en *O. degus* no es consecuencia de limitaciones de hábitat (madrigueras) necesarias para su reproducción.

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On the Relationship between Herbaceous Cover and Vigilance Activity of Degus (*Octodon degus*)

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Abstract

A number of studies demonstrate that plant cover provides prey animals with refuges to decrease vulnerability to predators. However, others suggest plant cover to visually obstruct detection of predators or conspecifics. We suggest these seemingly conflicting results can, to some extent, be resolved if overhead vs. lateral cover are distinguished. We recorded seasonal variation in vigilance activity of a natural population of degus (*Octodon degus*), a diurnal, semi-subterranean and social rodent from central Chile. We used these data to determine whether cover provided by herbaceous vegetation is mostly obstructive. The height of herbaceous vegetation in the habitat of degus varied seasonally, and the ability of degus (estimated from human observers) to detect potential predators decreased when herbaceous vegetation was high. This effect was more important for degus using quadruped postures and when dealing with terrestrial simulated predators. Accordingly, degus adjusted the quality rather than the quantity of their vigilance activity: male and female degus allocated similarly more time to bipedal vigilance when the height of herbs was high. Such increase in bipedal vigilance seemed to occur at the expense of quadruped vigilance instead of foraging time. Collectively, these results support the hypothesis that cover of herbaceous vegetation is mostly obstructive to degus when active above ground, a finding that contrasts with previous evidence supporting that shrub cover provides refuges against predators. The differential effects of shrubs and herbs on degu vigilance are likely linked to differences in the costs and benefits associated with each cover type. For degus, shrubs may provide more overhead (protective) than lateral (obstructive) cover.

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Introduction

Evidence generally supports a link between the amount of plant cover (shrubs, trees) and the vigilance activity of animals. For instance, several studies have documented changes in the allocation of time to vigilance under varying amounts of cover. Thus, small mammals and birds spend more time alert when foraging away from shrub or tree cover (Barnard 1980; Leger et al. 1983; Cassini 1991; Otter 1994; Tchabovsky et al. 2001). In addition, the influence of plant cover on the allocation of time by animals has been examined in the context of patch use and foraging decisions. The observation that ground squirrels, porcupines, and mice forage less in patches away from bush cover (Newman et al. 1988; Brown & Alkon 1990; Brown et al. 1992; Hughes & Ward 1993; Orrock et al. 2004), or spend more time out of their nests when in patches with overhead cover (Jensen et al. 2003) also provide support for the hypothesis that plant cover may be protective. Collectively, this evidence suggests that tree canopies and shrubs function as refuges for prey animals that decrease their vulnerability to predators.

More direct evidence for the protective function of plant cover comes from studies showing that mice use more densely vegetated patches in areas with more predators (Dickman 1992), and that gerbils limit their activity to bush as opposed to open habitat upon being exposed to frequent owl flights or sightings (i.e. high predation risk; Kotler et al. 1991; Abramsky et al. 1996). More interesting, some studies that directly estimated predation risk found that risk increases in open habitats compared with bush habitats (Longland & Price 1991), as well as in patches without grass cover (Wywialowski 1987). Again, this evidence suggests that prey animals reduce vulnerability to aerial predators by using patches with overhead shrub or tree cover.

However, despite the above evidence, the link between vegetation cover and vigilance is far from simple (Lazarus & Symonds 1992; Pöysä 1994). Vegetation may not only provide individuals with hiding places, but also obstruct vision, reduce detection of predators, and hinder escape (Lima 1987, 1990; Schooley et al. 1996; Sharpe & Van Horne 1998; Blumstein et al. 2004). Accordingly, other studies have recorded animals to increase rather than decrease vigilance activity near or in patches with high plant cover. Thus, some birds, rodents, and ungulates increase their vigilance (or feed less) in patches with reduced long-range visibility (Underwood 1982; Metcalfe 1984; Carey 1985; Carey & Moore 1986; Lagory 1986; Lima et al. 1987; Lima 1987; Goldsmith 1990; Loughry 1993; Sharpe & Van Horne 1998; Burger et al. 2000). Rodents in tall vegetation are less tolerant of an approaching human 'predator' than those in short vegetation (Blumstein et al. 2004).

The seemingly contradictory results regarding the effect of plant cover on animal vigilance may, to some extent, be related to differences in the relative costs and benefits associated to overhead and lateral obstruction to visibility. Thus, animals might benefit from use of overhead cover to hide from aerial predators at no major cost regarding their ability to detect conspecifics or food sources

(Duncan & Jenkins 1998). In contrast, lateral cover can not only provide concealment to prey animals, but also make terrestrial predators, food patches, and conspecific competitors more difficult to detect. Some terrestrial predators (e.g. felids) use short to medium height vegetation cover to stalk prey (Branch 1995; Murray et al. 1995). More intriguingly, experiments have revealed that ground squirrels modify their vigilance in response to varying conditions of lateral visual occlusion (Arenz & Leger 1997a), and that these animals spend less time in patches with lateral occlusion as compared with patches with overhead occlusion (Lima 1987; Arenz & Leger 1997b). Likewise, birds increase their vigilance when closer to obstructive lateral cover (Lazarus & Symonds 1992).

Degus are small- to medium-sized (ca. 180 g), diurnal, social and semi-subterranean Hystricognath rodents of the semiarid and Mediterranean environments of north-central Chile (Fulk 1976; Yáñez 1976; Le Boulengé & Fuentes 1978; Ebensperger et al. 2004). In this habitat, degus inhabit a mosaic of open areas interspersed with small- to large-sized shrubs. Both open and bush microhabitats include herbaceous vegetation whose height varies seasonally: the height of herbs is low from late summer to early winter, and tall from late winter until late spring and summer (Fig. 1). Previous evidence supports that overhead shrub cover is protective to degus (Jaksic et al. 1979; Ebensperger & Wallem 2002; Vásquez et al. 2002), but no data are available regarding the role of herbaceous cover. We used observational data to examine the hypothesis that the cover of herbaceous vegetation is obstructive rather than protective to degus. Herbs, particularly annual grasses, are likely to obstruct lateral rather than overhead visibility. If so, we expected degus to adjust their vigilance seasonally in response to changes in the height of herbs. More specifically, if the height of herbaceous vegetation decreases the efficiency of degus to detect predators (or competitors), these rodents should allocate more time to vigilance, particularly in high quality high cost (Lima & Bednekoff 1999), bipedal vigilance. On the contrary, if tall herbs provide degus with places to hide from predators (or competitors), degus should allocate less time to vigilance. Time saved from vigilance could be allocated to more energy maximizing activities such as foraging (Vásquez 1997).

Methods

Study Area and Time of Observations

The study population was located at the Estación Experimental Rinconada de Maipú (33°23′S; 70°31′W, altitude = 495 m), a field station of the Universidad de Chile located 30 km west of Santiago, Chile. The study site was characterized by a Mediterranean climate, with warm, dry summers and cold, wet winters. The site consisted of open matorral with scattered shrubs (*Proustia pungens*, *Acacia caven* and *Baccharis* spp.) and annual grasses. Shrub cover, as assessed from nine 200 m linear transects, reached 14.5 ± 1.2% ($\bar{x}$ ± SE). Animals were monitored in an area of 1.13 ha. This area was chosen based on evidence of degu activity, including the presence of recently used burrow entrances and direct visual

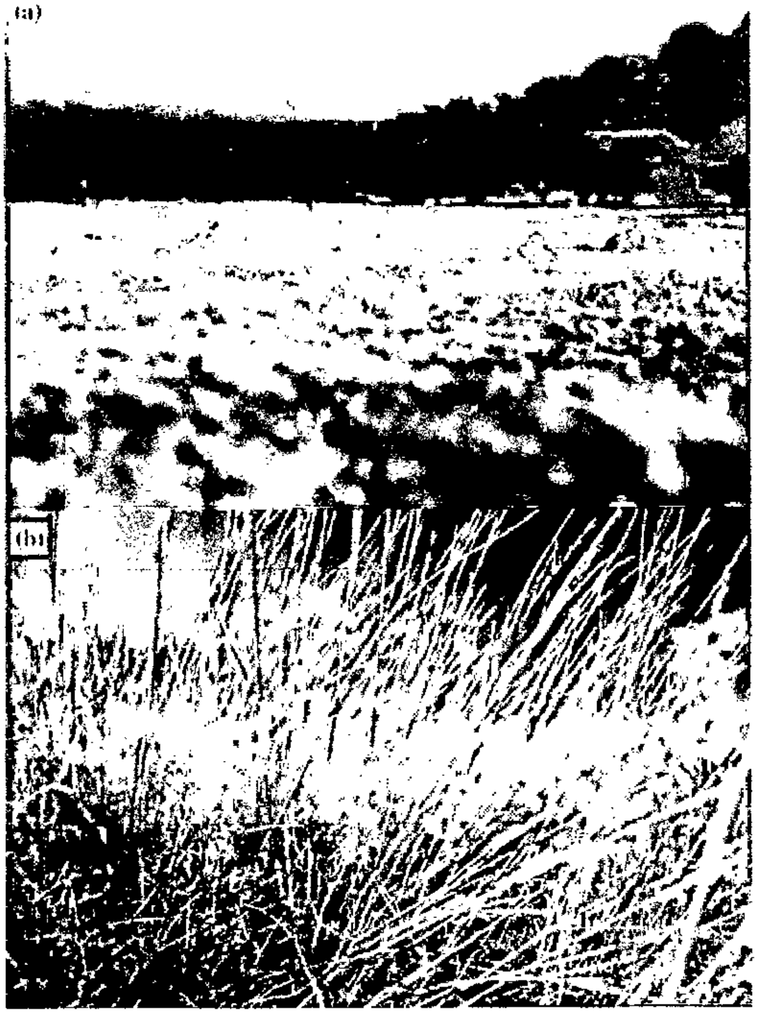

Fig. 1: Ground level views of representative differences between seasons with (a) low and (b) high herbaceous cover in our study site. Pictures were taken at the same randomly selected spot and direction

sightings of animals. General climatic conditions in the Santiago area from mid 2002 to early 2004 fluctuated from rainy to moderately dry, although no major El Niño or La Niña events took place.

Observations were carried out seasonally (i.e. once every 3 mo) between Jul. 2002 and Jan. 2004, and were part of an ongoing study on the behavioural ecology of these rodents. In particular, we conducted our observations within 10–15 d in Jun. (early Austral winter), Oct. (mid Austral spring), Jan. (mid Austral summer), and Apr. (mid Austral autumn). Degus of our study population typically mate in late autumn–early winter (Jun.–Jul.), with parturitions in early spring (Sep.–Oct.) (Ebensperger & Hurtado 2005). For the purposes of this study, we restricted our analysis to data obtained during the non-breeding period of these animals (i.e. summer, autumn). By doing so, we aimed at partially controlling for the potential influences of mate competition and the presence of vulnerable infants on degu vigilance activity.

Capture and Marking of Degus

Members of the study population were captured using Sherman live traps (H.B. Sherman Traps Inc., Tallahassee, FL, USA) baited with rolled oats. As degus are strictly diurnal (Kenagy et al. 2002; Ebensperger et al. 2004), traps were placed near active burrow entrances during mornings and evenings, when the animals were active above ground. Traps were checked approximately every 30 min. Typically, trapping was conducted continuously for 5–7 d per season. Trapping effort per season ranged from 1100 to 1540 trap-days. The estimated density of degus at the study site averaged 22 ± 1 adults per hectare. For all individuals captured, we recorded the animal's body weight, sex, and breeding condition of females (perforated, pregnant, lactating). We used body weight of animals to estimate their relative age. We restricted our behavioural observations to non-breeding adult-sized male and female degus (i.e. females > 130 g; males > 140 g). All adults captured were individually marked with neck collars (made of plastic cable ties wrapped in colored tape) to allow visual identification during behavioural observations. The number of degus that were individually marked (or remarked) before any behavioural sampling period ranged from 15 to 43 animals (28 ± 2 animals).

Behavioural Observations

We observed degus above a portable tower-blind at a distance of 30–80 m, depending on the location and height of surrounding shrubs. Observer height (ground to eye level) was approx. 4.3 m. Observations were completed between 07:30–12:00 and 18:00–20:00 h, which matches the animals' daily activity above ground (Kenagy et al. 2002). Animals were identified on the basis of collar colour; identification was facilitated by the use of a 10 × 50 pair of binoculars. As soon as a collared degu was sighted, we recorded its behaviour with a Sony digital video camera (model DCR-TRV330, Sony Corporation, Tokyo, Japan). Video recordings were terminated after about 40 min or when the focal subject went out of sight during more than 3 min. All recordings were of subjects in open patches (i.e. between shrubs). The length of focal observations averaged 11 ± 8 min, and ranged from 1 to 41 min. In the laboratory, one of us (MJH) played back the videos and recorded the percentage of time that individual degus spent in different activities when above ground. Specifically, we recorded vigilance when the animal remained motionless with its head raised upward and either supported by its four legs (quadruped) or on its rear legs (bipedal). Given that time allocated to vigilance can be traded-off with time spent in foraging (Bachman 1993; Sharpe & Van Horne 1998), we also quantified this activity.

As degus are social rodents and grouping influences their behaviour (Vásquez 1997; Vásquez et al. 2002), we quantified the number of individuals located near each focal animal from video recordings. To do so, we included all degus being at a distance of 2–3 m or less from our focal individual. The use of such criteria ensured that all putative group members were in visual contact of each other and made our results comparable with previous studies. Group membership was not constant as degus regularly leave or join the groups freely within seconds. Thus, when the size of the group that included the focal animal changed within a particular focal observation, we distinguished activity performed by the focal animal under different group size conditions. We then used these data to calculate a time-weighed mean of grouping that reflected the proportion of time spent by the focal animal under varying conditions of grouping. Overall, we continuously monitored the behaviour of degus during 140 h. Observations were carried out on days with similar weather conditions. We avoided conditions that might affect the ability of degus to detect approaching predators (i.e. no observations were made on days with fog, heavy winds, or rain).

To examine the possibility that any seasonal changes in vigilance detected were due to changes in the abundance of local predators or of degu density rather than to changes in the height of herbs, we also used scan sampling to record the total number of degus and the number of predators observed in the area. Direct counts of degus and predators were conducted during similarly favourable weather conditions (Greenwood 1996). We standardized degu counts to the total area scanned. When recording our focal observations, and every 30 min, we monitored the area over a 6.7 ± 0.1 min circular sweep. During these visual sweeps, we noted the presence of each and every predator. As data on predator abundance were not gathered from the video recordings of our focal subjects, we pooled such data per sampling season to match the focal behavioural data (i.e. sampling size equalled the number of focal observations). Our initial aim was to distinguish aerial from terrestrial predators during the analysis, but terrestrial predators were less abundant in the area and this rendered statistical analyses more difficult. Therefore, we pooled data and considered total abundance of predators.

Height of Herbaceous Vegetation, Number of Burrows, and Detectability of Predators

We recorded the height of herbaceous vegetation from 60 randomly chosen points throughout our study site. At each point, we recorded the height of dominant herbs, represented by annual grasses. Simultaneously, we placed ten 50-m linear transects equally spaced trough at our study site. Every 10 m, we recorded all open burrow entrance that was within 1 m of each side in each transect. Degus use burrow entrances as refuges to escape predators, and the availability of open burrows has been noted to influence the antipredator behaviour of other ground-dwelling semi-fossorial rodents (e.g. Leger et al. 1983; Loughry 1993; Bonenfant & Kramer 1996).

We used Sharpe & Van Horne's (1998) method to estimate the maximum distance at which a degu could potentially detect predators. We selected random points (10 in autumn 2003, 10 in summer 2004) and extended a 200-m tape along a random bearing from each point. One person moved slowly along each transect while carrying a 4-m height aluminium pole with an attached brown coloured rectangular cardboard (15 × 100 cm), representing the frontal view of a raptor. We depicted the frontal view of a mammalian predator with a 30 × 30 cm brown coloured cardboard held at a height of 50 cm. While lying on the ground, one of us (LAE) viewed the predator forms from the opposite end of each transect through 6 mm diameter (10 mm deep) cylindrical openings drilled through a wooden board at 5 and 20 cm heights. These heights corresponded to the eye level of a degu in quadruped and bipedal vigilant postures respectively. We recorded the distance (≤ 200 m) that each predator form could be seen from each of the two viewing heights.

Data Independence and Statistical Analyses

All focal observations were carried out on individually marked degus, and observations of the same individuals within a given sampling season were pooled. After doing so, 17% of all focal observations corresponded to individuals whose behaviour was recorded in more than one season, but we assumed data to be statistically independent across seasons. The length of observation time per focal degu did not differ across seasons examined (Kruskal–Wallis ANOVA by ranks, $H_{2,42} = 3.86$, $p = 0.145$).

Before conducting statistical analyses, we arcsine-square root-transformed proportions of time spent in vigilance, and $\text{Log}_{10}\,x + 1$ transformed (Zar 1984) abundance of predators (sightings per 30 min), grouping (number of degus), and degu density (animals per hectare). Normality of data was assessed by means of Kolmogorov–Smirnov tests. As maximum detection distance could not be normalized, we used the non-parametric multi-way factorial analysis of variance suggested by Zar (1984). Briefly, we subjected the ranks of distance data to a parametric factorial three-way ANOVA to obtain sums of squares for each source of variation, and then used these squares to compute Kruskal–Wallis H-values. Differences in the height of herbaceous vegetation through seasons were examined through a one-way ANOVA test. As percentages of time allocated to quadruped vigilance, bipedal vigilance, and foraging are likely to be interrelated, we examined each simultaneously through MANOVA under the GLM procedure with sex (male or female) and season (summer 2003, autumn 2003 and summer 2004) as main effects, and predator abundance, grouping, and degu density as covariates. For descriptive purposes, we also reported the mean values (±SE) for total (quadruped + bipedal) vigilance. We used Tukey HSD test for multiple comparisons of mean values of sex and season. We used partial regression analysis to further examine potential trade-offs for those elements of degu activity recorded to vary seasonally.

All statistical analyses were performed using STATISTICA 6.0 (StatSoft Inc., Tulsa, OK, USA). All statistical tests were two-tailed, and data are presented as $\bar{x} \pm$ SE.

Results

Height of Herbaceous Vegetation, Number of Open Burrows, and Predator Detectability

The height of herbaceous vegetation differed across seasons examined (Kruskal–Wallis ANOVA by ranks test, $H_{2,180} = 115.02$, $p < 0.001$) (Fig. 1). Height of herbs in summer 2003 (1.1 ± 0.3 cm, $n = 60$) was similar to that in autumn 2003 (0.4 ± 0.1 cm, $n = 60$; multiple comparisons by ranks, $p = 0.984$), but both values were shorter as compared with the height of herbs in summer 2004 (12.5 ± 1.0, $n = 60$; $p < 0.001$).

The number of open burrows available to degus did not differ in summer 2003 (12.8 ± 3.6 burrows per 100 m^2, $n = 10$), autumn 2003 (12.9 ± 3.1 burrows per 100 m^2, $n = 10$), or in summer 2004 (11.3 ± 1.5 burrows per 100 m^2, $n = 10$; Kruskal–Wallis test, $H_{2,30} = 0.20$, $p = 0.904$).

The height of herbs interacted significantly with simulated degu posture to influence maximum distance to detection (Kruskal–Wallis ANOVA by ranks test, $H_{1,72} = 6.88$, $p = 0.0087$). Thus, maximum distance to detection was significantly shorter when the height of herbaceous vegetation was high, but mostly for quadruped simulated degus (Fig. 2). No further interactions were recorded as statistically significant ($p > 0.20$). The type of predator simulated did influence maximum distance to detection (Kruskal–Wallis test, $H_{1,72} = 21.96$, $p < 0.001$). This variable was significantly shorter for mammalian than avian simulated predators (Fig. 2).

Predator Abundance, Degu Density and Grouping

Our scan sampling data revealed only a marginally significant trend for the number of predators sighted to be higher in summer 2004 (1.2 ± 0.2 predator sightings, $n = 40$ scans) and autumn 2003 (1.1 ± 0.2 predator sightings, $n = 35$ scans) as compared with summer 2003 (0.6 ± 0.2 predator sightings, $n = 34$ scans) (one-way ANOVA on $\mathrm{Log}_{10}\, x + 1$-transformed data, $F_{2,106} = 2.66$, $p = 0.074$). Sightings of aerial predators included the black-chested eagle (*Geranoaetus melanoleucus*; 17% of all predator sightings), the Harris's hawk (*Parabuteo unicintus*; 18%), the aplomado falcon (*Falco femoralis*; 8%), the American kestrel (*F. sparverius*; 17%), and the burrowing owl (*Athene cunicularia*; 36%). Terrestrial predators were represented in the area by the long-tailed snake (*Philodryas chamissonis*; 1% of all predator sightings), and the culpeo fox (*Pseudalopex culpaeus*; 3%).

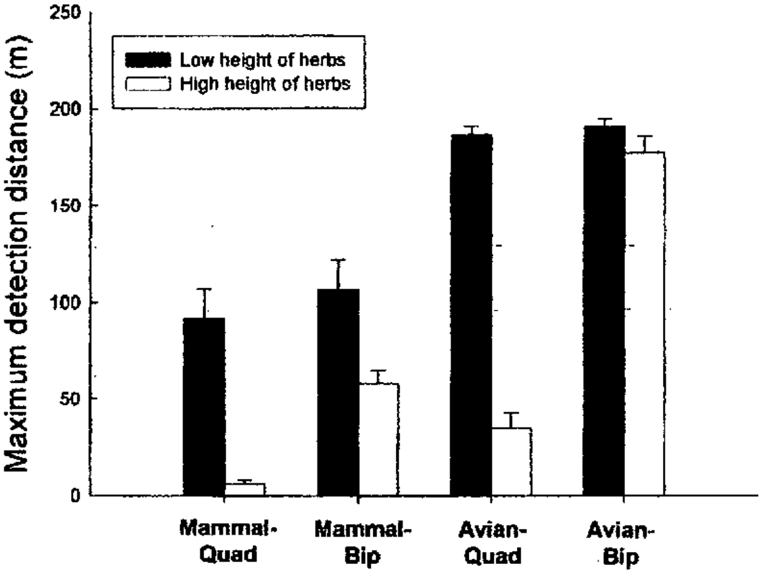

Fig. 2: Maximum predator-detection distance for degus in central Chile estimated using human observers. Distance was estimated for avian (diurnal raptors) and mammalian (foxes) predators and for two vigilant postures (quadruped and bipedal) of degus in seasons when height of herbaceous vegetation was high (Summer 2004, white bars) and low (Autumn 2003, black bars). Data are $\bar{x}$ ± SE, and were recorded from 10 random transects in each season

Our scan sampling also revealed that density of degus varied with season (one-way ANOVA on Log_{10} x + 1-transformed data, $F_{2,106} = 67.52$, $p < 0.001$). Degus were more abundant in summer 2003 (44 ± 2 individuals per hectare), intermediate in autumn 2003 (19 ± 2 individuals per hectare), and less abundant in summer 2004 (14 ± 2 individuals per hectare) (Tukey HSD test, $p < 0.05$).

When active above ground, degus were solitarily or in groups of up to 10 individuals. Typically, however, groups were small. Our metric of grouping revealed that degus performed their activities in groups of 1.5 ± 0.1 individuals (n = 42 focal observations). No differences in the tendency of degus to group were noted across seasons (one-way ANOVA on Log_{10} x + 1-transformed data, $F_{2,39} = 1.70$, $p = 0.196$).

Overall Vigilance Activity

A total of 42 focal observations representing 35 different individuals were recorded during the three seasons analysed (i.e. summer 2003, autumn 2003 and summer 2004). These data revealed that degus allocated 34.9 ± 2.8% of their time to vigilance. Of this, 26.9 ± 2.6% corresponded to quadruped vigilance and 8.0 ± 1.7% to bipedal vigilance.

Influences of Sex and Height of Vegetation on Degu Vigilance

The MANOVA revealed a significant overall main effect of the height of herbs (Wilks' $\lambda = 0.71$, $F_{4,33} = 3.43$, $p = 0.019$) on degu activity budget, but not of sex (Wilks' $\lambda = 0.93$, $F_{4,33} = 0.60$, $p = 0.668$). Likewise, sex did not interact with the height of herbs to influence activity budget of degus (Wilks' $\lambda = 0.88$, $F_{4,33} = 1.13$, $p = 0.359$). Of all variables examined, only bipedal vigilance was affected significantly ($F_{5,36} = 6.68$, $p < 0.001$). Thus, degus increased their bipedal vigilance with the height of herbaceous vegetation (Fig. 3). In contrast, neither quadruped ($F_{5,36} = 0.55$, $p = 0.738$), total vigilance ($F_{5,36} = 1.06$, $p = 0.399$), nor foraging ($F_{5,36} = 0.69$, $p = 0.636$) did vary significantly with the height of herbaceous vegetation (Fig. 3).

The MANOVA did not detect significant overall effects of covariates, namely predator abundance (Wilks' $\lambda = 0.94$, $F_{4,33} = 0.50$, $p = 0.738$), grouping (Wilks' $\lambda = 0.97$, $F_{4,33} = 0.24$, $p = 0.917$), and degu density (Wilks' $\lambda = 0.94$, $F_{4,33} = 0.50$, $p = 0.738$).

Our multiple regression analysis revealed that bipedal vigilance varied inversely with quadruped vigilance (partial $R = -0.92$, $t_{38} = -14.95$, $p < 0.001$), but positively so with total vigilance (partial $R = 0.93$, $t_{38} = 16.41$, $p < 0.001$). In contrast, no association was recorded between bipedal vigilance and foraging activity (partial $R = 0.11$, $t_{38} = 0.70$, $p < 0.489$).

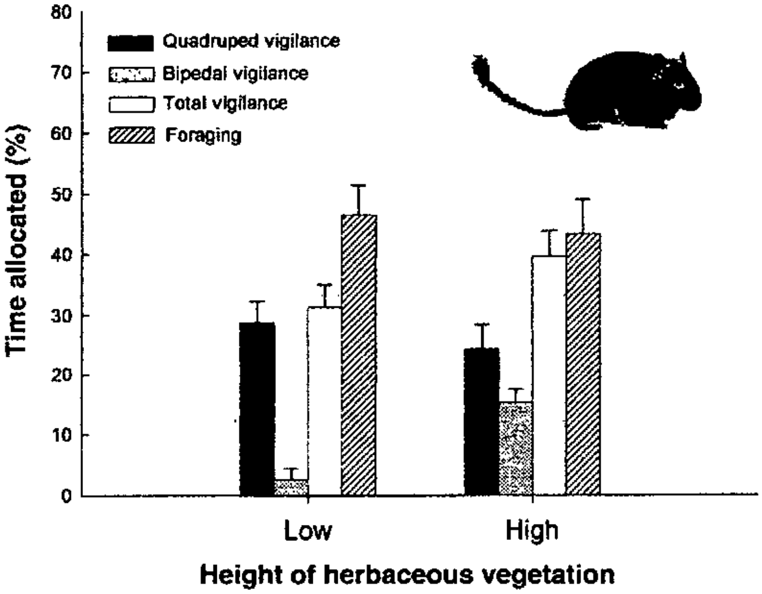

Fig. 3: Untransformed percentages of time allocated to quadruped vigilance (black fills), bipedal vigilance (grey fills), total vigilance (white fills), and foraging (hatched fills) by degus when the height of herbaceous vegetation was low (Summer 2003, Autumn 2003) and high (Summer 2004). Data are $\bar{x} \pm SE$, and were recorded to a total of 42 focal observations

Neither of the above major results differ if analyses are based on a single observation per animal subject.

Discussion

Our study revealed five major points. We first showed that the height of herbaceous vegetation in the habitat used by degus varies seasonally. Secondly, the ability of degus to detect potential predators (estimated from human observers) decreases when herbaceous vegetation is high. Thirdly, this effect is particularly important when degus use quadruped postures and when dealing with mammalian simulated predators. Fourthly, degus adjust the quality rather than the quantity of their vigilance activity to track seasonal changes in the height of herbaceous vegetation. More specifically, male and female degus similarly allocated more time to bipedal vigilance when surrounded by tall herbs. Our regression analyses suggested that increases in bipedal vigilance seemed to occur at the expense of quadruped vigilance, but not foraging activity. Finally, changes in bipedal vigilance as degus moved through different types of herbaceous cover were uninfluenced by the tendency of degus to group above ground, degu density, the number of predators sighted, or by the number of refuges (open burrows) available nearby. Our estimates of snake abundance may have been underestimated by our counting method, particularly when vegetation was tall. However, more frequent use of bipedal postures by degus in response to the presence of the more difficult to detect, snake predators, particularly when height of herbaceous vegetation was high, is expected (see below).

As predicted, vigilance of degus was sensitive to changes in the height of herbaceous vegetation. Although degus dig and use underground burrows for shelter and pup rearing, these animals forage entirely above ground (Vásquez 1997; Ebensperger & Bozinovic 2000; Ebensperger et al. 2004). Two aspects of our results suggest that herbaceous vegetation is mostly obstructive to degus when active above ground. First, bipedal simulated postures increase potential maximum distance to predator detection. Secondly, degus increase bipedal vigilance at the expense of quadruped vigilance when the height of herbaceous cover is high. In contrast to quadruped vigilance, the use of bipedal postures benefits the user with the highest level of alertness, but at the expense of a foraging cost (Lima & Bednekoff 1999; Tchabovsky et al. 2001). The recorded effect of herbaceous cover contrasts with that of shrub cover where several lines of evidence support that shrubs provide degus with refuges against predators, including patterns of patch and runway use, grouping, social vigilance, and pausing behaviour (Jaksic et al. 1979; Lagos et al. 1995; Ebensperger & Wallem 2002; Vásquez et al. 2002). We suggest that the differential effect of shrubs and herbs on degu vigilance relates to differences in the costs and benefits associated to each type of cover, and where shrubs would provide more overhead (i.e. protective) than lateral (i.e. obstructive) cover.

Changes in the vigilance behaviour of other ground-dwelling rodents in response to varying conditions of lateral occlusion further support our findings.

Thus, ground squirrels spend less time in patches with lateral occlusion as compared with patches with overhead occlusion (Arenz & Leger 1997a,b). In birds, starlings and sparrows (but see Lima 1987) increase their vigilance when closer to obstructive lateral cover (Lazarus & Symonds 1992), while towhees, juncos, and buntings feed away from or out of cover containing visual obstructions (Lima et al. 1987; Lima 1990). In contrast, sparrows seem to prefer feeding in covered patches, and decrease vigilance in the presence of 7 cm height obstructive cover (Lima 1987). Taken together, the available evidence suggests that protective and obstructive effects of plant cover may vary across species, and that such variation may be related to costs and benefits of anti-predator or social strategies used by each species (e.g. Lima 1990; Blumstein & Daniel 2002).

What is the cause of degu wariness when herb cover is high? At least two non-mutually exclusive hypothesis are possible. A first explanation relates to enhanced predation risk. Degus are preyed upon by aerial (diurnal raptors), and terrestrial (foxes) predators (Jaksic et al. 1981, 1993), and vigilance activity seems involved in several anti-predator strategies. First, degus in exposed microhabitats devote a greater percentage of their aboveground activity time to vigilance than degus in shrub microhabitats after controlling for group size (Vásquez et al. 2002). Secondly, degus adjust their grouping behaviour in response to habitat conditions; degus group more in exposed patches than in shrub patches. As a result, degus increase collective vigilance (Vásquez 1997) and predator detection (Ebensperger & Wallem 2002). Thirdly, degus spend more time pausing (a behaviour that seems to improve anti-predator vigilance) when away from shrub cover than when travelling back towards shrub cover (Vásquez et al. 2002). In short, herb cover would make predator detection more difficult and decrease the overall efficiency of vigilance-based anti-predator strategies used by these rodents.

An alternative is that herb cover may hamper detection of competitors (i.e. social monitoring) or food resources (Elgar 1989; Duncan & Jenkins 1998). Although no pertinent data are available to further support or reject this hypothesis, both empirical and theoretical considerations make this explanation less likely. First, interference competition in degus seems more related to mating than to foraging opportunities. This is supported by the observation that degus (especially males) spend significantly more time in aggressive interactions and chases during breeding than during non-breeding time, and that high quality food of these rodents (green leaves of annual grasses) is less limited during the breeding season (Ebensperger & Hurtado, 2005). Males actively defend a territory that includes the burrow system used by a group of females, but only during breeding time (Soto-Gamboa 2004). However, food-based territoriality is less likely in degus that rely on grass, a less depletable food resource (Ostfeld 1986). More recently, models suggest that scramble competition is unlikely to influence animal vigilance when group size changes rapidly (Bednekoff & Lima 2004), a situation that characterizes degu activity above ground.

Is the potentially obstructive effect of lateral cover of special concern to group-living species? Many social species use social vigilance to detect approaching predators and to monitor conspecifics from rival groups. More importantly, lateral cover may obstruct visual (and acoustic) perception of group mates (Elgar et al. 1984; Gerkema & Verhulst 1990), which may decrease social coordination. That vegetation cover represents a visual obstruction to other social animals also is supported by studies documenting that overall vigilance changes under varying conditions of cover in ground-dwelling rodents (Carey & Moore 1986; Loughry 1993) and ungulates (Underwood 1982; Lagory 1986; Goldsmith 1990; Burger et al. 2000). However, reports showing that both social and solitary rodents are less wary when in patches with high plant cover do exist (Cassini 1991; Sharpe & Van Horne 1998). Moreover, vigilance of some social species may also be insensitive to distance from cover (Blumstein et al. 2003). Thus, studies are needed to examine how vigilance activity changes across species (e.g. Blumstein & Daniel 2002), and whether this variation is linked to different types of habitats and social strategies. We suggest that emphasis should be placed to distinguish habitats with mostly overhead vs. lateral cover.

Despite the convincing evidence that group size plays a role in degu vigilance (Vásquez 1997; Ebensperger & Wallem 2002; Vásquez et al. 2002), there was no effect of grouping or degu density on vigilance in this study. Currently, we are examining a larger data set that includes focal observations on a larger number of seasons to address this rather puzzling result, and to see whether the influence of group size on vigilance varies seasonally (M.J. Hurtado and L.A. Ebensperger, in prep.).

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Grouping increases the ability of the social rodent, *Octodon degus*, to detect predators when using exposed microhabitats

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Ebensperger, L. A. and Wallem, P. K. 2002. Grouping increases the ability of the social rodent, *Octodon degus*, to detect predators when using exposed microhabitats. – Oikos 98: 491–497.

We examined the hypothesis that a main benefit of group-living in the hystricognath rodent, *Octodon degus* (common degu), is to decrease individual risk of predation. During a first series of field observations, we contrasted group size of degus when using covered microhabitats with that of degus using exposed patches. During a second set of field observations, we assessed how distance to detection and to escape by degus varied with group size upon the approach of a potential human predator. Degus in exposed patches formed larger groups than degus in covered microhabitats. After excluding the influence of nearest burrow to focal subjects, we found that degus of larger groups detected an approaching human predator at a greater distance than degus of smaller groups. Likewise, degus of larger groups escaped to nearby burrows at a greater distance from the approaching predator than degus of smaller groups. All these pieces of evidence support the predatory risk hypothesis according to which group-living in degus functions to reduce the risk of predation.

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Understanding the functional aspects of group-living (or sociality) is one main research goal of sociobiology and behavioral ecology (Krebs and Davies 1993). To accomplish this, it is useful to consider that several factors may prevent the formation of groups, imposing fitness costs to group members. Such costs may include increased transmission of parasites and diseases, increased aggression and competition for resources, infanticide, and cuckoldry (Krebs and Davies 1993, Alcock 1998). Thus one would predict the existence of benefits acting to overcome these inherent disadvantages, or constraints, that allow individuals to live socially. One such benefit is that individuals may live in groups to reduce their risk of predation (Alexander 1974, Treisman 1975, Van Schaik 1983). Reduction of predation risk may occur by different mechanisms, including an enhanced ability of grouped individuals to detect predators (i.e. the 'many eyes effect'), individuals locating themselves such that other group members become more vulnerable to attacks (the 'selfish herd effect'), and grouped individuals repelling predators more efficiently than solitary-living animals (i.e. group defense), among others (Hamilton 1971, Pulliam 1973, Romey 1997).

Among rodents (Rodentia), social systems range from solitary-living species to colonial (gregarious) and social species (Nowak 1999), in which several individuals interact frequently, share feeding areas, a territory, and often a den or a burrow system (Rayor 1988, Waterman 1995). The behavior of murid (mice, rats, voles) and sciurid (squirrels, marmots) rodents generally support the generalization that predatory risk favors group-living. For instance, grouped bank voles, *Clethrionomys glareolus*, and yellow-necked mice, *Apodemus flavicollis*, seem to be attacked less often by weasels than solitary individuals, and individual voles and mice are killed less often when in groups (Jędrzejewski et al. 1992). Solitary voles (*Microtus*

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epiroticus) are killed faster by kestrels than grouped voles (Hakkarainen et al. 1992). Among sciurid rodents, large-sized groups of black-tailed (*Cynomys ludovicianus*) and white-tailed (*Cynomys leucurus*) prairie dogs detect simulated predators sooner than prairie dogs of smaller groups (Hoogland 1981), and red-tailed squirrels (*Sciurus granatensis*) respond more quickly to human predators when foraging in groups than when foraging solitarily (Heaney and Thorington 1978).

Data relevant to the predatory risk hypothesis from species other than murid and sciurid rodents could be particularly informative as it may provide evidence of behavioral convergence, and support the hypothesis that predation is a widespread pressure favoring the evolution of rodent group-living. One group of rodents that may provide such data is the New World hystricognaths (Branch 1993a, Ebensperger 1998), which includes species found in almost every type of habitat, and with social structures ranging from solitary-living to highly gregarious species (Redford and Eisenberg 1992, Nowak 1999). Although less known than their murid and sciurid counterparts, evidence revealing that predators strongly influence the behavior of hystricognath species is not uncommon (Rood 1972, Cassini 1991, Cassini and Galante 1992, Branch 1993a, Marquet et al. 1993, Yáber and Herrera 1994).

One hystricognath species whose behavior is influenced by predators is the common degu (*Octodon degus*; Octodontidae). Degus inhabit the semi-arid areas of matorral in central Chile (Yáñez 1976, Contreras et al. 1987). In these habitats, degus live socially where groups construct and share an elaborate system of burrows (Fulk 1976, Yáñez 1976, Mann 1978). Preliminary data suggest that degu groups include one to two adult males and from two to five adult females (Fulk 1976, Yáñez 1976). More commonly, groups range from two to four individuals (Vásquez 1997, L. A. Ebensperger unpubl.). Members of different groups generally intersperse freely except during breeding time when they seem more territorial (Fulk 1976, L. A. Ebensperger unpubl.). While aboveground, degus use both exposed (between shrub) and covered (under shrub) microhabitats (Lagos et al. 1995a, b) where they spend most of their time foraging on green leaves of grasses, forbs, and shrubs (Meserve et al. 1984, L. A. Ebensperger unpubl.). Therein, degus are frequent prey of local raptors and foxes (Jaksic et al. 1993). Available evidence supports that shrub habitats provide lower predation risk than exposed areas (Meserve et al. 1984, Lagos et al. 1995b, Vásquez et al. 2002).

The purpose of this study was to examine the hypothesis that predatory risk influences group-living of common degus. In particular, we hypothesized that degus should group more when using exposed, riskier microhabitats, and that the ability of degus to detect human predators should increase with grouping.

Methods

This study was conducted at the Fundo Rinconada de Maipú, (33°29'S; 70°54'W), a field station of the Universidad de Chile, located 30 km west of Santiago, central Chile. Therein, the study area consisted of two sites (Polvorines, and El Litral), 3–4 km apart from each other, both with clear signs of degu activity, as indicated by the relatively high frequency of burrow openings and from directly observing the animals. The area has a Mediterranean climate characterized by warm dry summers and cold wet winters and is located within the biogeographical zone known as matorral. Shrub cover in the area, as assessed from nine 200 m linear and parallel transects, reached $14.5 \pm 10.5\%$ ($\pm$ SD). Dominant shrubs in the study area included *Baccharis* spp., *Proustia pungens*, and *Acacia caven*. Herbs were represented by several species of grasses and forbs, including *Clarkia tenella*, *Erodium* spp., *Helenium aromaticum*, *Madia sativa*, *Matricaria chamonilla*, *Oxalis* spp., and *Senecio adenotrichius*.

During a first period of observation, we assessed the frequency with which degus perform their activities aboveground in solitude and in groups of different size (i.e. grouping behavior), and while in two microhabitats: an exposed microhabitat comprising almost exclusively bare ground and herbs, and a covered microhabitat comprising medium (*Baccharis* spp.; height ranged from 0.5–1.0 m) to large shrubs (*Proustia pungens*, *Acacia caven*; height ranged from 1.0–3.0 m). Covered microhabitats included patches of 1–3 isolated shrubs, and more continuous matrixes of several shrubs. Degu predators such as culpeo foxes (*Pseudalopex culpaeus*), and black-chested buzzard eagles (*Geranoaetus melanoleucus*) were frequently sighted in the area. To quantify grouping behavior at these two microhabitats, we observed degus from a portable blind-tower (modified version of Rodenhouse and Best 1983), and with 10×50 binoculars. Height from ground level to the eyes of an observer was ca. 2.8 m. We located our blind tower such that both exposed and covered microhabitats were in similar proportions around the tower. Distance from the tower to degu subjects ranged from 30–150 m, depending on the location and height of surrounding shrubs. We used scan sampling (Lehner 1996) to quantify grouping by degus while active aboveground. To do so, we made a 360° visual scan at a rate of 24–30 angles per min every 15 min. During each scanning episode, we recorded the behavior of every detected degu and the grouping condition it was in. To quantify grouping condition (including solitary animals), we considered a degu to be part of a given group if located at a distance of 2 m or less from any other individual. The use of such stringent criteria ensured that all putative group members were in visual contact of each other (particularly while in covered patches) and made our results comparable

Ethology

Vigilance and Collective Detection of Predators in Degus (*Octodon degus*)

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Abstract

Individuals of social and partially social species typically reduce their vigilance activity when foraging in groups. As a result, per capita risk of predation decreases and individuals allocate more time to foraging and other fitness rewarding activities. Reduction of per capita risk is hypothesized to occur because there are more individuals to detect potential predators. If so, collective (i.e. total) vigilance is expected to increase with foraging group size. Increased surveillance during group foraging may occur if group members scan independently of one another, or sequentially to avoid the overlapping of their vigilance bouts. Intriguingly, such coordinated vigilance assumes that individuals monitor not only the presence, but the vigilance behaviour of group mates. We used seasonal records on time budget and grouping patterns of individually marked degus (*Octodon degus*), a social rodent, to examine if (a) individual vigilance decreases and/or foraging increases with group size, (b) collective vigilance increases with group size and (c) foraging degus coordinate their vigilance. When foraging, degus decreased their individual vigilance and increased their foraging time when in larger groups. Despite this, degus in larger groups increased their collective vigilance, supporting the hypothesis that socially foraging degus decrease predation risk through an improved ability to detect and escape potential predators. Additionally, patterns of collective vigilance suggested that degus scan independently of each other and so, they do not coordinate their vigilance to prevent its temporal overlapping. This finding does not support that foraging degus monitor the vigilance activity of group mates.

Introduction

The observation that individuals of social and partially social species typically reduce their vigilance activity when foraging in groups is common (Elgar 1989). However, the hypothesized causes of this 'group-size effect' on vigilance vary (Roberts 1996; Beauchamp 2001, 2003; Barbosa 2002). One major hypothesis states that, as group size increases, per capita risk of predation decreases and individuals allocate more time to foraging and other fitness rewarding activities (Elgar 1989; Quenette 1990; Roberts 1996). Reduction of per capita risk may occur because there are alternative prey (i.e. the dilution hypothesis; Foster & Treherne 1981) or because there are more individuals to detect potential predators (i.e. the detection or 'many eyes' hypothesis; Pulliam 1973). In both cases, the group-size effect reflects a net benefit derived from variations in predation risk (Blumstein et al. 2001).

Although dilution and detection effects are likely to interact in affecting an individual's risk of predation (Bednekoff & Lima 1998a), the degree to which dilution and detection are influencing the evolution of anti-predator vigilance is difficult to examine, mostly because both benefits predict individual scanning should decrease with increasing group size (Childress & Lung 2003). Nevertheless, if individuals in a group benefit primarily by detection rather than dilution, collective (i.e. total) vigilance is expected to increase with group size, a prediction supported in a bird (Bertram 1980) and some mammals (Jarman 1987; Childress & Lung 2003) where collective vigilance has been measured directly (but not in others: Quenette & Gerard 1992; Fernández et al. 2003). As a consequence, individuals in groups improve their ability to detect and escape potential predators (Lima 1995a), a prediction supported in some birds (Powell 1974; Siegfried & Underhill 1975; Kenward 1978; Lazarus 1979; Møller 1987; Boland 2003) and a few small mammals (Hoogland 1981; Ebensperger & Wallem 2002). This prediction assumes, in turn, that foragers share information perfectly and instantly when they detect predators. Although such an assumption may seem unrealistic in some cases (Lima 1995b), individual foragers may gather information from predator detection quickly, particularly so in species where individuals give alarm calls.

Increased surveillance during group foraging may result if group members scan independently of one another (Pulliam 1973; Bednekoff & Lima 1998b), a frequently untested assumption in studies assessing collective vigilance (Barnard 1980; Monaghan & Metcalfe 1985; Yáber & Herrera 1994; Vásquez 1997). However, increased group vigilance also may result if individuals within groups scan sequentially to avoid overlapping vigilance bouts (e.g. McGowan & Woolfenden 1989). Such coordinated vigilance assumes that individuals monitor not only the presence, but the vigilance behaviour of group mates (Pulliam et al. 1982; Lima 1995a), a debated issue (e.g. Bednekoff & Lima 1998b). On the one hand, some recent experimental evidence supports that starlings (*Sturnus vulgaris*) monitor group mates' vigilance during social foraging (Fernández-Juricic et al. 2004, 2005). In contrast, other studies failed to support visual monitoring of vigilance in three other species of birds (Lima 1995a; Beauchamp 2002; Fernández et al. 2003). From a theoretical point of view, the monitoring of group mates' vigilance would be unlikely given the relatively low benefits expected compared with the costs (Ward 1985; Bednekoff & Lima 1998a; but see Ferriere et al. 1996). Therefore, additional empirical evidence assessing whether foragers alter their vigilance in response to the vigilance of group mates is needed.

We collected seasonal records on time budget and grouping patterns of degus (*Octodon degus*), a caviomorph rodent, to examine how collective vigilance varies with group size. Degus are small- to medium-sized (approx. 180 g), diurnal and social rodents of the semiarid and seasonal environments of north-central Chile (Fulk 1976; Yáñez 1976; Le Boulengé & Fuentes 1978). In these habitats, degus construct underground burrows and galleries that are used communally (Ebensperger et al. 2004). When above ground, degus forage (mostly on grasses and forbs) solitarily or in small groups (mean = 2 individuals, range = 1–10; Ebensperger & Hurtado 2005a, this study). A previous study recorded degus to decrease their individual vigilance with group size (i.e. the typical group-size effect on vigilance) and predicted collective vigilance to increase with group size (Vásquez 1997). The observation that group-foraging degus detect the approach of a simulated predator at a greater distance than solitary foraging degus is consistent with this prediction (Ebensperger & Wallem 2002). Both anecdotal and systematic data support degus use predator-specific alarm calls to warn conspecifics against aerial and terrestrial predators (Fulk 1976; Yáñez 1976; Cecchi et al. 2003), suggesting degu foragers share information when they detect these predators. Taken together, these lines of evidence suggest predation risk is a major influence on degu behaviour and that these rodents are an adequate subject to examine the extent of cooperative vigilance during foraging.

In short, we examined whether (i) individual vigilance decreases with group size, leaving more time available to foraging, (ii) collective vigilance increases with group size and (iii) whether socially foraging degus cooperate through synchronizing their vigilance, implying they monitor the behaviour of group mates.

Materials and Methods

Study Area and Time of Observations

The study population is located at the Estación Experimental Rinconada de Maipú, (33°23′S; 70°31′W, altitude = 495 m), a field station of the Universidad de Chile located 30 km west of Santiago, Chile. The study site is characterized by a Mediterranean climate, with warm, dry summers and cold, wet winters. The site consists of a flat area dominated by scattered shrubs (*Proustia pungens*, *Acacia caven* and *Baccharis* spp.) and containing grasses and forbs. Shrub cover, as assessed from nine 200 m linear transects, is low and reaches 14.5 ± 3.5% ($\bar{x} \pm$ SE). Animals were monitored in an area of 1.13 ha, chosen for study based on evidence of degu activity, including the presence of recently used burrow entrances and direct visual sightings of animals.

Observations were carried out seasonally (i.e. once every 3 mo) and as part of a more general field study conducted between June 2002 and January 2004. Every year, we spent 10–15 d in Jun. (early Austral winter), Oct. (mid Austral spring), Jan. (mid Austral summer) and Apr. (mid Austral autumn). Overall, two winter, two summer, two spring and one autumn seasons were monitored (but see below). This sampling schedule follows major events of degus' life cycle. Degus are seasonal breeders: in our study site, degus typically mate in late autumn (May to Jun.), with parturitions in late winter to early spring (Sep. to Oct.; Ebensperger & Hurtado 2005a).

Capture and Marking of Degus

Members of the study population were captured using Sherman live traps (H.B. Sherman Traps Inc., Tallahassee, FL, USA) baited with rolled oats. As degus are strictly diurnal (Kenagy et al. 2002; Ebensperger et al. 2004), traps were placed near active burrow entrances during morning and evening hours, when the animals were most active above ground. Traps were checked approximately every hour; captured animals were removed from traps as soon as they were encountered. We sexed and marked all adults captured (i.e. above 120 g) with neck collars (made of plastic cable ties wrapped in coloured tape) to allow visual identification during behavioural observations (see below). We used a colour key where two to three of seven different tape colours (including black and white) were combined in a single animal. Typically, trapping was conducted for 5–7 d per season. Trapping effort per season ranged between 1100 and 1540 trap-days.

Behavioural Observations

We observed degus above a portable tower-blind at a distance of 30–80 m, depending on the location and height of surrounding vegetation. Observer height (ground to eye level) was 4.3 m. Animals were identified on the basis of collar colour; identification was facilitated by the use of a 10 × 50 pair of binoculars. As soon as a collared degu was sighted, we recorded its behaviour with a Sony digital video camera (model DCR-TRV330, Sony Corporation, Japan). Video recordings were terminated after approx. 40 min or when the focal subject went out of sight for more than 3 min. The length of focal observations averaged 11 (±8) min and ranged from 1 to 41 min. In the lab, one of us (MJH) played back the videos and recorded the percentage of time that individual degus spent in different activities when above ground.

Degus were considered to be vigilant when they remained motionless with their heads raised and either supported by four legs (quadruped) or on rear legs (bipedal) (Vásquez 1997). Foraging degus adopted a crouching posture with the head lowered to ground level (Vásquez 1997). On average, vigilance and foraging accounts for 78 ± 2% of degus' time budget (Ebensperger & Hurtado 2005a). Therefore, we included focal observations of degus only if foraging and vigilance activity accounted for at least 70% of estimated activity budget. This criterion made our observations comparable with previous studies (e.g. Vásquez 1997). Other elements of behaviour were recorded and reported elsewhere (Ebensperger & Hurtado 2005a). We quantified the number of degus located near each focal animal from video recordings. To do so, we included all degus being at a distance of 2–3 m from our focal individual. We used this criterion because (i) it ensures that all putative members of foraging groups are in visual contact of each other, a condition needed to detect group-size effects on vigilance (Blumstein 1996) and (ii) because previous studies have recorded that this distance significantly influences vigilance activity of degus (Vásquez 1997; Ebensperger & Wallem 2002; Vásquez et al. 2002). Degus leave or join the groups freely and continuously during social foraging. Thus, when the size of the foraging group that included the focal animal changed during our focal observations (because an animal either moved in or left the group), we distinguished activity performed by the focal animal under different group size categories. Ongoing observations at our study site revealed that 14% (n = 51) of all focally recorded degus were animals from five different and well-identified social groups (Ebensperger et al. 2004); the remaining focal degus were of unknown social units.

Collective vigilance was assessed directly rather than estimated. Following others (Bertram 1980; Fernández et al. 2003), we recorded collective vigilance as the proportion of time that at least one individual of the group was vigilant.

To control for some potentially confounding variables (Elgar 1989), we restricted our behavioural records to adult sized individuals that were active in similarly open, exposed habitat, monitored density of open burrows (i.e. refuges), distinguished male from females and did not include data from spring season when pups and young individuals were present (i.e. two seasons were discarded). All these variables, including age-differences, habitat openness, sex-differences and the presence of young individuals influence vigilance and foraging activity of ground-dwelling rodents (Holmes 1984; Loughry 1993; Yáber & Herrera 1994; Armitage et al. 1996). We confirmed that density of open burrows did not vary during the realization of this study (Ebensperger & Hurtado 2005b). Observations were completed between 07:30 and 12:00 hours during warm seasons and between 09:30 and 15:00 hours during cold seasons, which matches the animals' daily activity above ground through seasons (Kenagy et al. 2002). Observations were carried out on days with similar weather conditions and we avoided conditions that might affect our ability to detect degus (i.e. no observations were conducted on days with dense fog, heavy winds, or rain). To homogenize any potential effect of trapping on degu behaviour, observations always took place 3 d after trapping ended.

Data Independence and Analysis

All focal observations were carried out on individually marked degus. Scan sampling data carried out simultaneously (Ebensperger & Hurtado 2005a) revealed that the mean number of degus that were present in our study area ranged from 14 (±1 individuals, summer 2004) to 44 (±1 individuals, Summer 2003). Of these, the number of degus that were individually marked (or remarked) before any behavioural sampling period ranged from 15 to 43 animals (28 ± 2 animals).

For each degu observed at each group size (1–10 individuals), we calculated the mean proportion of time allocated to individual vigilance. To avoid pseudoreplication, focal degus contributed with a single behavioural record to any given group size category (Fernández et al. 2003). However, two sources of data dependency persisted. First, same individuals contributed to more than one group size category within seasons, an acceptable limitation given that temporal composition of degu foraging groups changes rapidly. Secondly, data across seasons were partially dependent because 12 of 51 (24% of all focal) individuals were recorded in two different seasons; one more subject was recorded in three of five seasons sampled; no degus were recorded in more than three seasons. Nevertheless, our data pooling was limited and unlikely to have biased our overall analysis (Leger & Didrichsons 1994). Inter-individual differences in vigilance of solitary recorded degus were smaller than intra-individual differences (one-way ANOVA on individual vigilance, $F_{12,14} = 0.88$, $p = 0.581$).

To analyse the effect of group size on individual and collective vigilance we used multi-way analysis of covariance (Blumstein et al. 1999, 2001; Fernández et al. 2003). Thus we examined the proportion of time in sight allocated to vigilance and to the proportion of time that at least one individual of the group was vigilant (i.e. dependent variables). Seasonality was entered as a discrete random factor with five levels (one per season) and sex was entered as a discrete (two levels) fixed factor. We examined the influence of group size as a covariate instead of as a categorical variable because not all factor-level combinations (i.e. season *x*, sex *y*, group size *z*) were represented in the data set. Data on proportions of time spent in foraging and vigilance, and proportion of time at least one degu was vigilant were arsine squared-root transformed to fit the assumptions of normal distribution (Kolmogorov–Smirnov test, $p > 0.20$) and homogeneity of variances (Levene's test, $p > 0.20$). Data on group size were $\mathrm{Log}_{10}(x + 1)$-transformed (Zar 1996).

We examined the possibility that degus monitor the vigilance of group mates by means of comparing patterns of observed collective vigilance with that expected from random and sequential bouts (Fernández et al. 2003). For each group size n, we took values for individual vigilance (V_i) from a normal distribution with parameters (mean and standard deviation, after arcsine of squared-root data transformation) equal to the observed values at each group size. As we obtained only one record for group of sizes of 7, 8 and 10 individuals, we pooled these data into a group size of 6 or more during this analysis. Expected random collective vigilance (V_c^r) was calculated by:

$$V_c^r = 1 - \prod_{i=1}^{n}(1 - V_i)$$

and expected sequential collective vigilance through:

$$V_c^s = \sum_{i=1}^{n} V_i$$

where n is the number of individual of the group and the values of V_c^s were constrained to a maximum of 1. We ran 2000 simulations for each group size and the mean values were used as an estimate of collective vigilance, to be compared with the observed data.

Statistical analyses were performed using STATISTICA 6.0 (StatSoft Inc., Tulsa, OK, USA). We tested the fit of observed values of collective vigilance to those expected under the random and sequential models with the use of Bonferroni corrected one-sample Student's t-tests. All statistical tests were two-tailed. We followed Nakagawa & Foster (2004) in reporting the size of statistical effects and p-values, instead of reporting post hoc (retrospective) power analysis. Data are presented as $\bar{x} \pm$ SE.

Results

Individual Vigilance and Foraging

The data set consisted of a total of 132 focal observations recorded on 47 degus (26 females and 21 males). Neither seasonality ($F_{4,121} = 0.91$, $p = 0.538$) nor sex of focal degus ($F_{1,121} = 4.46$, $p = 0.100$) influenced this aspect of degu vigilance significantly. In contrast, group size did influence degu vigilance negatively ($\beta = -0.213 \pm 0.085$) and significantly so ($F_{1,121} = 6.21$, $p = 0.014$), meaning that degus decreased their individual vigilance when in larger groups (Fig. 1a).

In the case of time allocated to foraging by degus, neither seasonality ($F_{4,121} = 0.53$, $p = 0.722$) nor sex ($F_{1,121} = 4.40$, $p = 0.101$) of focal degus influenced foraging time again. Similarly, group size did influence degu foraging directly ($\beta = 0.189 \pm 0.087$) and significantly so ($F_{1,121} = 4.74$, $p = 0.031$), meaning that degus increased their foraging when in larger groups (Fig. 1b).

Collective Vigilance

When collective vigilance was examined, neither seasonality ($F_{4,121} = 0.93$, $p = 0.528$) nor sex of focal degus ($F_{1,121} = 5.93$, $p = 0.070$) influenced collective vigilance significantly. As expected, group size did influence degu vigilance positively ($\beta = 0.305 \pm 0.081$) and significantly ($F_{1,121} = 14.01$, $p < 0.001$), meaning that degus experienced increased levels of collective vigilance when in larger groups (Fig. 1c).

Collective vigilance in groups of three, five and six (or more) degus did not differ from random expectations (Bonferroni corrected $p > 0.005$). In contrast, collective vigilance of degus when foraging in pairs

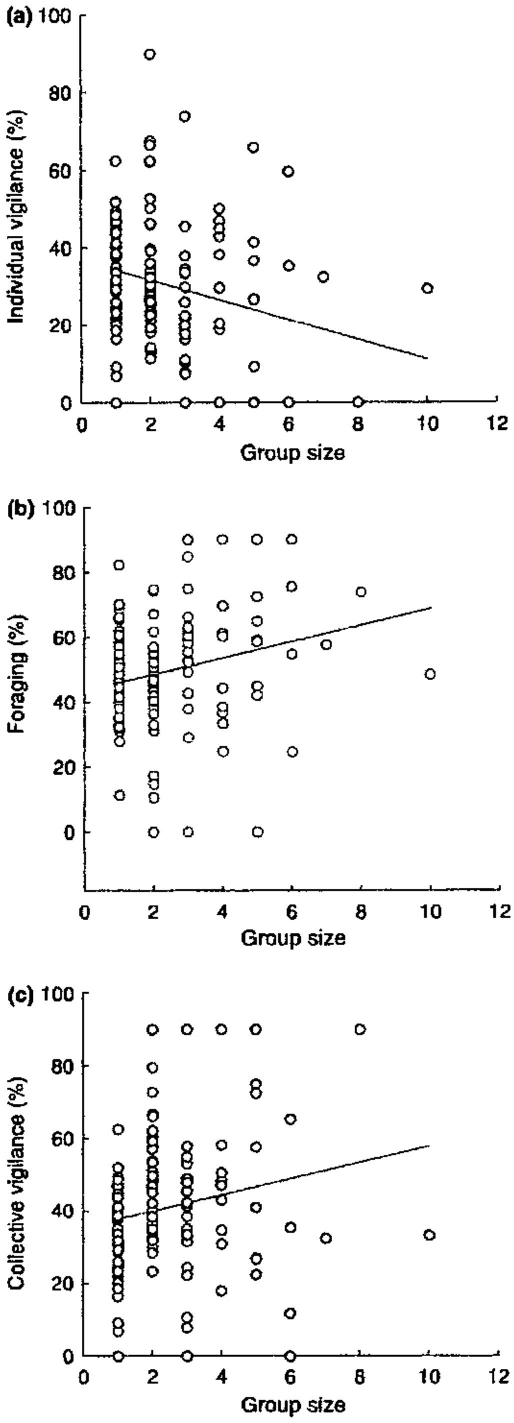

Fig. 1: Time (arcsine squared-root transformed %) allocated to individual vigilance (a) and foraging (b) in degus alone and in groups of up to 10 individuals; (c) time that at least one degu of the group was vigilant (i.e. collective vigilance, open circles). The data set consisted of a total of 132 focal observations recorded to 47 degus

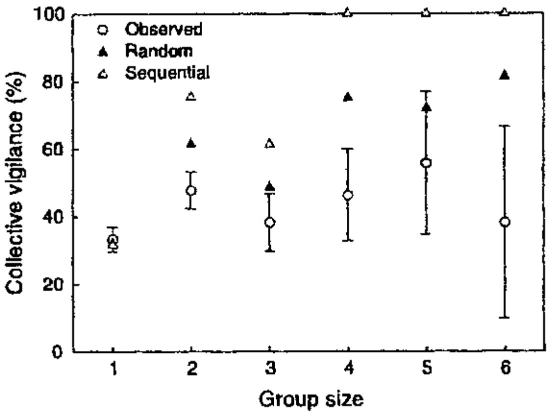

Fig. 2: Observed (open circles), randomly expected (filled triangles) and sequentially expected (open triangles) mean values of collective vigilance in degus (% time that at least one degu of the group was vigilant). Error bars represent ±95% confidence intervals

and in groups of four individuals was lower than expected from random ($p < 0.001$; Fig. 2). Collective vigilance of degus in groups was always lower than that expected from the sequential model ($p = 0.002$ or lower; Fig. 2).

Discussion

Individuals of socially foraging species typically reduce their vigilance activity when foraging in groups (Elgar 1989) and one major explanation of this 'group-size effect' on vigilance states that per capita risk of predation decreases in larger groups; as a consequence, individuals allocate more time to foraging and other fitness rewarding activities (Elgar 1989; Quenette 1990; Roberts 1996). Reduction of per capita risk may occur because there are alternative prey (i.e. the dilution hypothesis; Foster & Treherne 1981) or because there are more individuals to detect potential predators (i.e. the detection hypothesis; Pulliam 1973). Although dilution and detection effects are difficult to tease apart (Childress & Lung 2003), the detection effect clearly predicts collective vigilance should increase with group size. Our study supported this expectation. When foraging in groups (mostly of two to five individuals), degus decreased individual vigilance, increased their foraging activity and modestly enhanced collective vigilance, findings that confirmed previous suggestions (Vásquez 1997). Increased group vigilance may benefit group foraging degus through enhancing their ability to detect approaching predators, a possibility supported by the observation that degus detect and escape simulated predators at a larger distance when in larger groups (Ebensperger & Wallem 2002). That individuals in groups improve their ability to detect and escape potential predators assumes foragers share information perfectly and instantly when they detect predators, an assumption that seems unrealistic (Lima 1995b). However, that foragers may share information instantly may be more realistic in species where individuals give alarm calls such as degus (Fulk 1976; Yáñez 1976; Cecchi et al. 2003). Currently, we lack most basic information about degu calls, but calls in other ground-dwelling and social rodents elicit quick (i.e. within a few seconds or less) anti-predator responses by non-callers such as heightened vigilance and running to nearby burrows (Blumstein 1998; Randall & Rogovin 2002).

Theoretically, increased collective surveillance during group foraging may result from individuals within groups scanning sequentially to avoid the overlapping of their vigilance bouts (e.g. McGowan & Woolfenden 1989). An intriguing consequence of such coordinated vigilance is that individuals monitor not only the presence, but the vigilance behaviour of group mates (Pulliam et al. 1982; Lima 1995a). Recent experimental evidence supports starlings (*S. vulgaris*) can monitor group mates' vigilance while foraging as they are capable of synchronizing their vigilance and target group mates when interrupting their foraging to scan (Fernández-Juricic et al. 2004, 2005). However, the social monitoring of vigilance has been questioned by other theoretical and empirical studies. Thus, Bednekoff & Lima (1998a) considered the monitoring of group mates' vigilance as highly unlikely given the relatively low theoretical benefits involved compared with the costs. This is particularly expected in the case of relatively large groups (Ward 1985). Regarding experimental evidence, no evidence of visual monitoring of vigilance was recorded in dark-eyed juncos (*Junco hyemalis*) where foraging individuals do not alter their vigilance in the presence of less vigilant group mates (Lima 1995a). Similarly, socially foraging zebra finches (*Taenopygia guttata*), subjected to partial obstructions that made social monitoring of group mates more difficult, did not change their own behaviour (Beauchamp 2002). Observational studies also have provided negative evidence: patterns of collective vigilance revealed either randomness or no synchronization in greater rheas (*Rhea americana*; Fernández et al. 2003), house sparrows (*Passer domesticus*; Elcavage & Caraco 1983), ostriches (*Struthio camelus*; Bertram 1980) and wild boars (*Sus scrofa*; Quenette & Gerard 1992). Patterns of collective vigilance measured to degus adds to most previous evidence in that individuals scan independently of each other (i.e. randomly) and do not coordinate their vigilance to avoid time overlapping. However, the prevalence of random scanning still causes collective vigilance to be enhanced in some socially foraging species. Most importantly, enhanced collective vigilance increases predator detection in doves (*Streptopelia senegalensis*; Siegfried & Underhill 1975), emus (*Dromaius novaehollandiae*; Boland 2003), starlings (*S. vulgaris*, Powell 1974), red-billed weavers (*Quelea quelea*; Lazarus 1979), swallows (*Hirundo rustica*; Møller 1987), woodpigeons (*Columba palumbus*; Kenward 1978), degus (Ebensperger & Wallem 2002) and prairie dogs (*Cynomys* spp.; Hoogland 1981). Thus, collective detection of predators in most socially foraging species seems an emergent property of groups.

Collective vigilance of degus when foraging in pairs or in groups of four animals was lower than expected from individuals scanning at random (Fig. 2), suggesting degus under these social conditions were scanning rather simultaneously. Fernández et al. (2003) suggested simultaneous vigilance may result if vigilance events are elicited by stimuli of common interest, a pertinent hypothesis in the case of degus. When active above ground, degus frequently alarm call at real aerial predators (Fulk 1976; Cecchi et al. 2003), but also at other medium sized birds that fly over at low altitude (i.e. lapwings, *Vanellus chilensis*; L. A. Ebensperger pers. obs.). Alarm calls at both stimuli cause most individuals around callers to scan simultaneously.

In short, our study adds to the large amount of evidence demonstrating the group-size effect on vigilance (see Elgar 1989 for a review), but also adds to the less common body of evidence demonstrating that directly measured collective vigilance increases with group size in some social foraging animals (Bertram 1980; Jarman 1987; Childress & Lung 2003). In addition, patterns of collective vigilance in degus suggest individuals scan independently of each other, an observation providing no evidence for the social monitoring of group mates' vigilance.

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SHORT COMMUNICATION

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Communal nesting and kinship in degus (*Octodon degus*)

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Abstract Communal nesting is a fundamental component of many animal societies. Because the fitness consequences of this behavior vary with the relatedness among nest mates, understanding the kin structure of communally nesting groups is critical to understanding why such groups form. Observations of captive degus (*Octodon degus*) indicate that multiple females nest together, even when supplied with several nest boxes. To determine whether free-living degus also engage in communal nesting, we used radiotelemetry to monitor spatial relationships among adult females in a population of *O. degus* in central Chile. These analyses revealed that females formed stable associations of > 2–4 individuals, all of whom shared the same nest site at night. During the daytime, spatial overlap and frequency of social interactions were greatest among co-nesting females, suggesting that nesting associations represent distinct social units. To assess kinship among co-nesting females, we examined genotypic variation in our study animals at six microsatellite loci. These analyses indicated that mean pairwise relatedness among members of a nesting association (r=0.25) was significantly greater than that among randomly selected females (r=–0.03). Thus, communally nesting groups of degus are composed of female kin, making it possible for indirect as well as direct fitness benefits to contribute to sociality in this species.

Introduction

Females in numerous rodent species engage in communal nesting, meaning that they live and rear their young together in a single nest (Hayes 2000). Potential benefits of this behavior include protection of young from infanticide or predation, improved thermoregulation, and adoption of young whose mothers die (Lewis and Pusey 1997; Hayes 2000). Both the nature and the magnitude of these benefits may be influenced by the degree of kinship among female nest mates, with indirect fitness benefits and kin selection expected to occur only when co-nesting females are related to one another (Hamilton 1964). As a result, determining the degree of kinship among co-nesting individuals is critical to understanding the adaptive bases for nest sharing by females. In the absence of genealogical data, genetic estimates of kinship can be used to assess relatedness among nest mates and, hence, to determine the potential for indirect fitness benefits to contribute to communal nesting (Hughes 1998).

Degus (*Octodon degus*) are medium-sized diurnal rodents that occur in semiarid environments in north-central Chile (Woods and Boraker 1975). Although degus use underground burrows and nests, the animals forage exclusively above ground (Fulk 1976; Kenagy et al. 2002). Previous studies have suggested that degus are social, occurring in groups of 1–2 adult males and 2–5 adult females (Fulk 1976; Yáñez 1976). In the field, burrows contain more young than can be reared by a single female, implying that burrow systems and, possibly, nest sites are shared by multiple adults (Fulk 1976). In the laboratory, lactating females nest together and nurse each other's offspring, despite being provided with enough nest boxes that each female could rear her young alone (Ebensperger et al. 2002). Collectively, these observations suggest that free-living female degus may engage in communal nesting and allonursing of young.

Although these data are intriguing, direct evidence that female degus share nest sites has not been obtained for free-living animals. Further, kinship among potentially co-nesting females has not been characterized. Therefore,

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(Jesseau and Holmes 2002). As a result, future studies of this species will explore the role of kinship in shaping the fitness consequences of group living and communal nesting.

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Ethology

Ecological Predictors of Range Areas and Use of Burrow Systems in the Diurnal Rodent, *Octodon degus*

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Abstract

Variation in animal space use patterns may be linked to numerous ecological factors affecting survival and reproduction. We examined the relationship between ecology and above- and below-ground components of space use by *Octodon degus*, a semi-fossorial rodent in Chile. We monitored the daytime minimum convex polygon and adaptive kernel range areas of 26 individuals and determined the number of burrow systems used by degus during night-time radiotelemetry and trapping of burrow systems on two study grids at Rinconada de Maipú, a semi-arid Matorral in central Chile. We quantified food biomass, soil hardness, distance to overhead vegetative cover, and density of burrow openings at putative nest burrows. Degus living on the grid with more shrub cover had larger range areas than degus living on the grid with less cover. The range areas of degus decreased with increasing distance from overhead vegetative cover. There was a weak (but statistically significant) negative relationship between the number of burrow systems used by degus and the distance to vegetative cover and density of burrow openings at burrow systems. Male and female degus had similar range areas. Our results suggest that overhead cover decreases the risk of predation to male and female degus. Degus probably balance the benefits of numerous burrow openings (reduced predation risk) with time and energy requirements of burrow construction and maintenance. Models of space use that consider the effect of multiple ecological variables should measure different dimensions of space use.

Introduction

Intraspecific variation in animal space use patterns may be linked to numerous factors, including variation in the availability of critical resources for survival and reproduction (Emlen & Oring 1977; Lott 1991). Potential ecological factors affecting animal space use patterns include the availability of food, protective cover, and suitable breeding sites (Emlen & Oring 1977; Lott 1991; Brashares & Arcese 2002). Indeed, there is considerable empirical evidence that the space use of animals is affected by the dispersion of food (Boutin 1990; Schradin & Pillay 2006), humidity (Endries & Adler 2005), vegetative cover (Beck & Watts 1997), habitat structure (Bronson 1979), and predation pressure (Suhonen 1993; Lagos et al. 1995a,b). Moreover, space use patterns are linked to seasonal variation in ecology (e.g. Madison & McShea 1987; Frank & Heske 1992; Steinmann et al. 2005; Edelman & Koprowski 2006; Schradin & Pillay 2006) and to increased competition for resources because of high population density (Komdeur et al. 1995). Thus, understanding the relationship between ecology and animal space use is an important step to understanding the ecological causes of variation in animal mating systems and sociality (Emlen & Oring 1977; Brashares & Arcese 2002).

Semi-fossorial rodents use multiple dimensions of space, digging burrows for nests and refuges from predators and environmental stress (Kinlaw 1999), and spending time above ground to forage, defend ranges, and seek potential mates (Daly et al. 2000). Thus, the spatial and temporal activity patterns of semi-fossorial rodents might be affected by variation in soil conditions (Kinlaw 1999) and conditions above ground (e.g. food availability: Schradin & Pillay 2006). This complexity is typically not addressed in studies aimed at quantifying the influence of ecological factors on the space use of semi-fossorial rodents as they typically examine below- and above-ground components separately (e.g. Abramsky et al. 1996; Hubbs & Boonstra 1998; Getz et al. 2005; Moorhouse & Macdonald 2005; Solomon et al. 2005; for a recent exception see Schooley & Branch 2006). An additional caveat to the evidence available is that it comes mostly from sciurid and murid species from the northern hemisphere (e.g. Tew et al. 2000). Thus, studies that examine below- and above-ground components of space use of more distantly related species that face similar ecological problems are needed. Such model species include the New World hystricognaths, an ancient group of rodents that includes species with semi-fossorial habits and diverse patterns of space and habitat use (Redford & Eisenberg 1992). A primary objective of this study was to determine the below- and above-ground components of space use patterns of a South American, semi-fossorial rodent in relation to ecological variation.

The degu (*Octodon degus*) is a semi-fossorial, caviomorph rodent found in central Chile (Meserve et al. 1984; Ebensperger 1998). Field studies indicate that degus live in social groups consisting of several closely related breeding females and one or more adult males (Fulk 1976; Ebensperger et al. 2004). Group mates share underground burrow systems during night-time (Ebensperger et al. 2004), emerging from them to forage above ground during the daytime (Kenagy et al. 2002; Ebensperger et al. 2004; Soto-Gamboa 2004). Although previous studies have shown that activity is linked to intraspecific habitat variation (Lagos et al. 1995a,b; Ebensperger & Hurtado 2005a), detailed telemetric studies of degu range areas and burrow use patterns in relation to ecological variation are not available. Understanding the relationship between ecology and degu space use patterns is critical to developing a better understanding of degu sociality and mating systems. Likewise, these data would shed light on the impact of ecological variation on the space use of other semi-fossorial and diurnally active species.

A first step in understanding the space use patterns and eventually mating systems of social rodents is to correlate space use patterns with ecological variation. Thus, we assessed the relationship between two important dimensions of space use (above-ground daytime range areas and night-time use of burrow systems) with the availability of preferred food, overhead protective cover, soil hardness, and density of burrow openings at burrow systems. Based on previous studies that linked space use or behavioral activity to food availability (Travis & Slobodchikoff 1993), we predicted that range areas and number of burrow systems used would decrease with increasing abundance of primary foods (monocots and dicot green herbs; Meserve et al. 1983, 1984). Secondly, as burrow openings and overhead vegetative cover may provide semi-fossorial rodents with critical refuges to evade predators in open areas (Ebensperger & Wallem 2002; Ebensperger & Hurtado 2005b), we predicted that range areas would decrease and the number of burrow systems used would increase with increasing distance from shrubs or trees. Given that there is a high energetic cost of burrow digging (Ebensperger & Bozinovic 2000), we also expected that the number of burrow systems used would decrease with increasing soil hardness and density of burrow openings

Methods

Study Site

This study was conducted during the austral winter and spring months of June–November 2005 at the Estación Experimental Rinconada de Maipú (33°23′S, 70°31′W, altitude 495 m), a field station of the Universidad de Chile. The site is characterized by a Mediterranean climate with cold, wet winters and warm, dry summers. The habitat, known as Chilean matorral, is dominated by scattered shrubs and containing grasses and forbs. In June 2005, we established two study grids approximately 150 m from each other. The grids were placed in areas where degus were abundant. Grid 1 was 0.72 ha (120 m × 60 m) and grid 2 was 1.0 ha (100 m × 100 m).

Grid Trapping and Burrow Location

Grid trapping was conducted on the two study grids during early June 2005 to estimate density and to capture degus for radio-collar tagging. Adult degus were captured using locally-produced metal live-traps (30 × 10 × 9.5 cm, similar to Sherman traps) baited with rolled oats. Traps were set at fixed stations at 5-m intervals on two grids resulting in 91 traps on grid 1 and 121 traps on grid 2. Traps were opened for 5 d during the morning prior to emergence of animals from burrows. We determined the sex, body mass, reproductive condition (e.g. whether females were perforated, pregnant or lactating) and identification of captures.

To find used burrow systems, we first radio-collared n = 16 adult females with 8 g (BR transmitters, AVM Instrument Co., Colfax, CA, USA). We chose to radio-collar females because they are the main component of degu social groups (Fulk 1976; Ebensperger et al. 2004). We then conducted trapping at burrow systems (see below for details) that these females used and we fitted radio-collars (BR radio-collars, AVM Instrument Co. or RI-2D transmitters, Holohil Systems, LTD, Carp, ON, Canada) to a total of 34 females (including the original 16 radio-collared females) and 15 males. Collared individuals were all adults and stable members of social groups and thus, likely residents of the population.

Daytime Range Areas

Degus are diurnally active, foraging above ground during the day (Kenagy et al. 2002; Ebensperger et al. 2004). Thus, estimates of daytime activity are required to assess the range areas of degus. During mid-August and early September 2005, we determined the daytime range areas of n = 20 female and n = 6 male degus fitted with BR radio-collars (AVM Instrument Co.). We were unable to determine the daytime ranges of 14 females and nine males fitted with radio-collars because some collars were not tuned to the same frequency as the antenna towers used to determine daytime locations. Daytime ranges were determined by locating the position of animals through triangulation (Kenward 2001) at hourly intervals between 09:30–12:30 and 14:30–17:30 hours (seven locations per day) for 5 d during a 5-d period on grid 1 and 6 d during an 11-d period on grid 2. Every hour, two teams (two observers per team) simultaneously recorded bearings of every radio-collared subject (±0.5°) using the same, previously defined, subject sequence. Readings were taken by each observer team each operating a seven-element null peak antenna system (AVM Instrument Co.) and tuned to the 150.000- to 151.999-MHz frequency range. Antenna stations were located at fixed positions at the edges of grids (grid 1, location 1: X = 45.6, Y = 103.9, grid 1, location 2: X = 145.3, Y = 114.8, grid 2, location 1: X = 389.7, Y = 107.4, grid 2, location 2: X = 256.9, Y = 86.8). Pairs of bearings were then converted to X–Y, north/east coordinates with the software Locate II (Pacer Software, Truro, NS, Canada) for further analyses.

We report two estimates of range areas, 95% minimum convex polygon (MCP) and 95% adaptive kernels (AK) to allow for more comparisons with other studies (Hayes et al. 2004). Using the Ranges VI software program (Kenward et al. 2003) and all fixes for which we could determine points of crossover (males: 33.5 ± 3.3 locations, range 19–40; females: 34.3 ± 1.3 locations; range 17–40), we determined MCP range areas based on kernel cores and 95% AK range areas (tail-weighted) based on a 40 × 40 matrix. When analyzing AK ranges, we set the fixed multiplier to '1.'

Use of Burrow Systems

An important component of the space use and sociality of degus is the location of burrows where individuals remain during inactivity. Degu burrow systems consist of tunnels that are 8–10 cm in diameter and a major chamber (20 cm in diameter); they have a total length of 1–2 m and are dug to a depth that ranges from 15 to 50 cm underground (Fulk 1976; Yáñez 1976). For this study, we defined a burrow system as a group of burrow openings surrounding locations where degus were repeatedly found during night-time telemetry and usually spanning approx. 2–3 m in diameter. Thus, we determined the number of burrow systems that male and female degus used on each grid. Burrow locations were determined with two methods, night-time telemetry and burrow trapping.

Night-time telemetry

We determined the number of burrow systems used by male and female degus at night during night-time telemetry conducted during June–September 2005, when females were pregnant and lactating. A previous study of degus at Rinconada confirmed that night-time locations represent nest sites where degus remain underground (Ebensperger et al. 2004). Locations were determined through 'homing' (Kenward 2001) once approx. 1 h after sunset using a LA 12-Q receiver (for radio-collars tuned to 150.000–151.999 MHz frequency) or FM-100 receiver (for radio-collars tuned to 164.000–164.999 MHz; Advanced Telemetry Systems, Isanti, MN, USA) and a hand-held three-element Yagi antenna (AVM Instrument Co. or Advanced Telemetry Systems). We located the burrows on at least eight evenings for all individuals ($\bar{x}$ ± SE: 23.7 ± 3.1 locations per individual; range: 8–37 locations per individual).

Burrow trapping

Burrow trapping conducted at putative nest sites was used as an additional estimate of the number of burrow systems used by males and females. Trapping occurred during one period before females were parturient and three periods after females gave birth to pups. We set Sherman-like and Tomahawk-live traps at n = 11 burrow systems on grid 1 and n = 10 burrow systems on grid 2 for 9–12 d during mid-July to early August. Traps were set prior to the emergence of adults during the morning. After 2 h, we determined the identity and location of all captures and closed the traps until the next trapping event. No juveniles were captured during this period. The second round of trapping corresponded to the time when females were lactating (mid-September until early November). We set 8–14 Sherman-like and Tomahawk-like traps at putative burrows for four to five consecutive days during three trapping periods for each grid. Traps were set after degus entered burrows for the evening and opened approx. 2 h after sunrise the next morning when we determined the identity and burrow location of all adults.

Because of logistical issues and poor weather, some burrow systems were not trapped equally. Additionally, some burrows were added to the trapping effort after night-time telemetry. Altogether, we trapped burrow systems for 12–27 d (grid 1: 23.1 ± 1.6 d per system; grid 2 19.4 ± 1.4 d per system).

Ecological Predictors

To track changes in the abundance of primary food (Meserve et al. 1983, 1984), we collected samples of monocot and dicot green herbs at 3 and 9 m from the center of each burrow system in the north, east, south and west directions. At each sampling point, we placed a 250 × 250-mm^2 quadrant and removed the above-ground parts of all green herbs found. Samples were immediately stored inside 2-kg capacity paper bags. In the laboratory, we oven-dried each plant sample at 60°C for 72 h to determine its dry mass (biomass in g). We used the same sample pattern to record soil penetrability as an index of soil hardness (Lacey & Wieczorek 2003). Soil penetrability was recorded with the use of a hand-held soil compaction meter (Lang Penetrometer Inc., Gulf Shores, AL, USA). The number of burrow openings per m^2 (burrow density) was determined within the area encompassed by the 18-m diameter circle used to sample food and soil. The distance (m) to nearest tree or shrub (cover) was estimated for each burrow system with a 100-m measuring tape. We included shrubs and trees as indicators of cover because previous studies have indicated that they provide protective overhead cover from predators (Ebensperger & Hurtado 2005b). We did not include patches of tall grass as protective cover because tall grass obstructs the view of degus (Ebensperger & Hurtado 2005b).

Statistical Analyses

We present data as $\bar{x}$ ± SE. We used Student t-tests to test for differences in ecological conditions (food biomass, soil hardness, distance to cover, burrow density) at n = 13 and n = 16 burrow systems on grids 1 and 2 respectively (Table 1). Prior to assessing the relationship between range areas and ecological conditions, we used an ANOVA with sex and grid as fixed factors to determine if there were statistically significant grid and sex differences in MCP and AK range areas. Likewise, we compared the mean number of burrow systems used by captured male and female degus with an ANCOVA with the number of times individuals were captured entered as a covariate, and sex and grid

Table 1: Mean (±SE) estimates and statistical comparisons of four ecological variables (food biomass, soil hardness, distance to cover, and burrow density) measured at n = 13 burrow systems on grid 1 and n = 16 burrow systems on grid 2 at Rinconada de Malpú, central Chile

	Grid			
Predictor variable	1	2	t-value	p-value
Food biomass (g)	27.3 ± 3.3	21.9 ± 2.4	1.33	0.19
Soil hardness (kg/m^2)[a]	599,000 ± 7176	599,000 ± 10,763	0.05	0.96
Distance to cover (m)	49.2 ± 2.8	15.3 ± 2.4	9.24	<0.0001
Burrow density (number per m^2)	0.12 ± 0.01	0.14 ± 0.01	1.27	0.21

[a] To convert lbf/in^2 into kg/m^2 we used 1 lbf/in^2 = 703.07 kg/m^2 (Pennycuick 1988).

entered as fixed factors. Raw values of range areas were $\log_{10}$ transformed because they did not meet the assumptions of normality. All these analyses were run with SPSS software (version 12.0, SPSS, Inc., Chicago, IL, USA).

To determine significant ecological predictors of space use, we conducted separate multiple regression analyses for the following dependent variables: (1) MCP range areas; (2) AK range areas; (3) number of burrow systems determined during telemetry; and (4) trapping. The independent variables included soil hardness, food biomass (monocots + dicots), burrow density, and distance to nearest shrub or tree. We did not include grid in the model because variation in ecology between grids was accounted for by our ecological measurements. We followed the rule that sex would only be included in the model if ANOVAS indicated sex differences. All continuous dependent and independent values were $\log_{10}$ transformed. Multiple regression analyses included diagnostic tests for linearity, autocorrelation, homoscedasticity, and collinearity assumptions as well as tests for outliers. To test the assumption that the model was linear, we visually inspected a plot of standardized residuals. To test for autocorrelation, the Durbin–Watson statistic (d) had to range between 1.5 and 2.5. To test for homoscedasticity, we visually inspected the spread of plots showing the regression standardized residual vs. the regression standardized predicted value. Variables were considered collinear if the variability inflation factor was greater than 3.0. Finally, values were removed as outliers if the SD of the residual was greater than three units. These assumptions were met in each analysis. Statistical significance was determined at $p = 0.05$ (two-tailed tests).

Results

Space Use vs. Ecological Conditions

Grid comparisons

The estimated density of degus, based on grid trapping was relatively high (28 animals per ha and 38 animals per ha on two study grids) compared with previous estimates of density at this site (8–25 animals per ha; Ebensperger & Hurtado 2005a). The mean distance from burrows to the nearest tree or shrub (m) on grid 1 was significantly greater than that of grid 2 (Table 1). In contrast, mean food biomass (g), soil hardness (kg/m^2) and burrow density (number per m^2) were statistically similar between grids (all $p > 0.19$, Table 1).

Range areas

The daytime range areas of females (MCP: 0.14 ± 0.04 ha; AK: 0.24 ± 0.06 ha) were statistically similar to daytime range areas of males (MCP: 0.14 ± 0.03 ha; AK: 0.24 ± 0.06 ha) (MCP: $F_{1,26} = 0.012$, $p = 0.91$; AK: $F_{1,26} = 0.064$, $p = 0.80$). There were no statistically significant sex × grid interactions for both the MCP ($F_{1,26} = 0.03$, $p = 0.87$) and AK analyses ($F_{1,26} = 0.006$, $p = 0.94$). Consequently, the subsequent regression analysis did not include sex in the model.

Individuals on grid 2 exhibited significantly larger MCP ($F_{1,26} = 5.72$, $p = 0.03$) and AK ranges ($F_{1,26} = 5.40$, $p = 0.03$) than individuals on grid 1. The MCP and AK range sizes of individuals on grid 1 were 0.07 ± 0.01 and 0.13 ± 0.03 ha respectively. The MCP and AK range sizes of individuals on grid 2 were 0.21 ± 0.05 and 0.34 ± 0.07 ha respectively. A multiple regression analysis including burrow density, soil hardness, food biomass, distance to cover explained a significant fraction of variability in MCP ($r^2 = 0.64$, $F_{4,25} = 9.15$, $p < 0.001$) and AK range areas ($r^2 = 0.66$, $F_{4,26} = 10.14$, $p < 0.001$). Distance to cover was the only significant predictor of both MCP and AK range areas, where degus exhibited greater range areas when in patches far from overhead cover (Table 2, Fig. 1).

Number of burrow systems used

The number of burrow systems that individuals used based on trapping increased with the number of times that they were captured ($F_{1,93} = 23.97$, $p < 0.001$). Thus, the number of times that

Table 2: Multiple regression statistics for minimum convex polygon (MCP) and adaptive kernel (AK) daytime range areas of n = 26 degus at Rinconada de Maipú, central Chile

Predictor variable	Partial r	Beta	t-value	p-value
Food biomass (g)				
MCP	0.10	0.07	0.45	0.66
AK	0.01	0.01	0.05	0.96
Soil hardness (kg/m^2)				
MCP	0.09	0.06	0.40	0.70
AK	0.37	0.27	1.83	0.08
Distance to cover (m)				
MCP	−0.78	−0.82	5.62	<0.001
AK	−0.76	−0.75	5.31	<0.001
Burrow density (number per m^2)				
MCP	−0.02	−0.01	0.08	0.94
AK	0.08	0.06	0.38	0.71

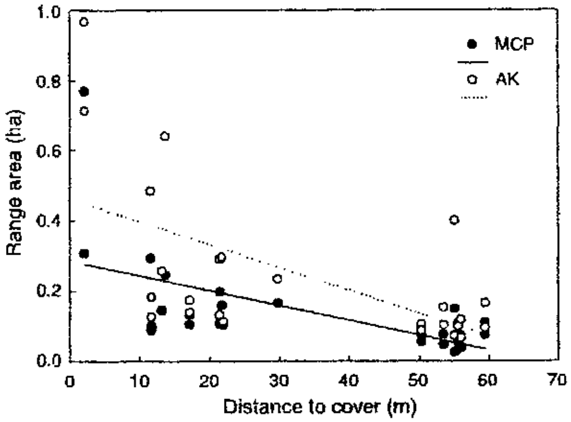

Fig. 1: Relationship between minimum convex polygon and adaptive kernels (n = 26 individuals) range areas and distance to cover at Rinconada de Maipú, central Chile. Statistics are shown in Table 2

individuals were captured was included as a covariate in the analysis. Burrow trapping indicated that degus on grid 1 (n = 52 individuals) used significantly fewer burrow systems than degus (n = 41 individuals) on grid 2 ($F_{1,93} = 14.49$, $p < 0.001$; Fig. 1b). Females (n = 57) used 2.46 ± 0.11 burrow systems and males (n = 36) used 2.33 ± 0.16 burrow systems. Females used a statistically similar number of burrow systems as males ($F_{1,93} = 0.012$, $p = 0.91$). There was no statistically significant sex × grid interaction on the number of burrows used ($F_{1,93} = 0.012$, $p = 0.91$). Consequently, sex was not included in the subsequent regression analysis.

A multiple regression analysis of the relationship between the number of burrow systems used based on trapping and four variables (burrow density, soil hardness, food biomass, distance to cover) reasonably met the regression model assumptions. Although model-level significance was detected ($F_{4,92} = 5.02$, $p = 0.004$), the model explained a relatively low amount of variation ($r^2 = 0.16$). Density of burrows and distance to vegetative cover were significant predictors of the number of burrow systems used by degus during burrow trapping; degus used more burrow systems when at places far from cover (Table 3; Fig. 2a), and when burrow systems had more openings (Table 3; Fig. 2b).

Females (n = 34) were radio-tracked to burrow systems on significantly more evenings than males (n = 15; females: 23.7 ± 1.7, males: 16.5 ± 1.4; Student's t-test for unequal variances, $t_{45} = 3.26$, $p = 0.002$). However, the proportion of burrow systems used per number of nights surveyed was similar for

Table 3: Multiple regression estimates for the number of burrow systems used by degus during trapping and night-time telemetry at Rinconada de Maipú, central Chile

Predictor variable	Partial r	Beta	t-value	p-value
Food biomass (g)				
Trapping	−0.08	−0.09	0.74	0.46
Telemetry	−0.05	−0.05	0.17	0.72
Soil hardness (kg/m^2)				
Trapping	−0.18	−0.19	1.68	0.10
Telemetry	−0.29	−0.31	2.04	0.05
Distance to cover (m)				
Trapping	−0.32	−0.32	3.21	0.002
Telemetry	−0.20	−0.18	1.34	0.20
Density of burrow openings (number per m^2)				
Trapping	−0.26	−0.29	2.38	0.02
Telemetry	−0.45	−0.55	3.38	0.002

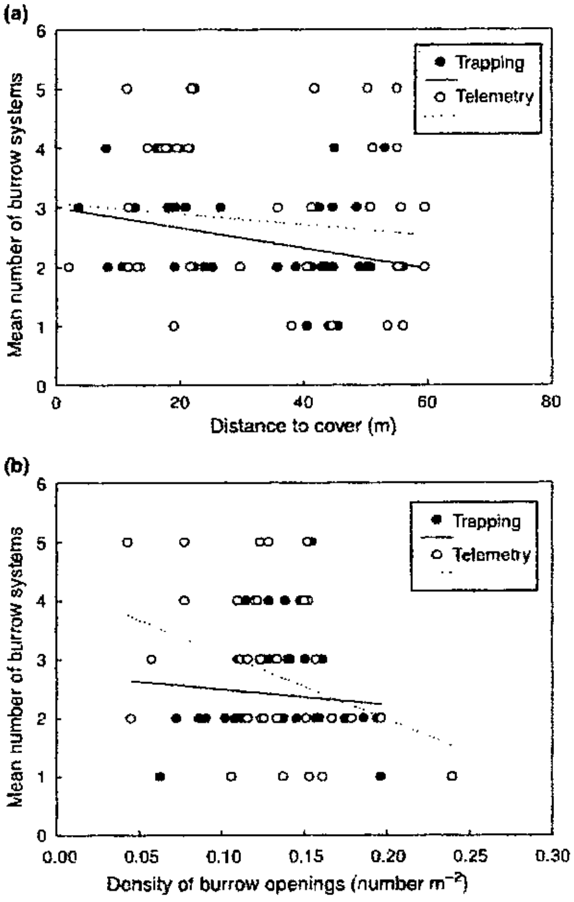

Fig. 2: Relationship between the number of burrow systems and (a) distance to cover and (b) density of burrows at Rinconada de Maipú, central Chile. Dark circles and lines indicate trapping whereas open circles and dotted lines indicate night telemetry data. Statistics are shown in Table 3

males and females (females: 0.17 ± 0.01, males: 0.13 ± 0.02; Student's t-test for equal variances, $t_{47} = 1.51$, $p = 0.14$), indicating that differences in sampling effort did not affect estimates of burrow system use. The number of burrow systems that individuals used increased with the number of times they were located ($F_{1,49} = 14.85$, $p < 0.001$). Thus, the number of times that individuals were located was included as a covariate in the analysis. Telemetry indicated that degus on grid 1 (n = 24 individuals) used a similar number of burrow systems as degus on grid 2 (n = 25 individuals) ($F_{1,49} = 0.75$, $p = 0.39$). Females used 2.9 ± 0.2 burrow systems and males used 2.6 ± 0.3 burrow systems, a difference that is not statistically significant ($F_{1,49} = 0.42$, $p = 0.52$). There was no statistically significant interaction between sex and grid ($F_{1,49} = 1.05$, $p = 0.31$). Thus, sex was not included in a subsequent regression analysis.

A multiple regression analysis of the relationship between the number of burrow systems used based on night-time telemetry and four variables (burrow density, soil hardness, food biomass, distance to cover) reasonably met the regression model assumptions. While the overall model was statistically significant ($F_{4,48} = 3.23$, $p = 0.02$), the model only explained a modest amount of variation ($r^2 = 0.23$). Density of burrows was the only significant predictor of the number of burrow systems used by radio-collared degus, where fewer burrow systems were used when such burrow systems had more openings (Table 3, Fig. 2b).

Discussion

Distance to shrub cover and density of burrow openings were the most important predictors of space use by both male and female degus at Rinconada de Maipú. First, MCP and AK range areas decreased with increasing distance from overhead vegetative cover. Similarly, degus on the grid with greater shrub cover (grid 2) had larger home ranges than degus on the grid with lower shrub cover (grid 1). Trapping, but not night telemetry data, suggested that the number of burrow systems used by degus decreased with increasing distance from vegetative cover. The number of burrow systems used by degus decreased with increasing density of burrow openings. Food biomass and soil hardness were not significant predictors of range areas or burrow systems.

Our observation that range areas decreased with increasing distance from overhead vegetative cover supports the hypothesis that overhead cover decreases the risk of predation to degus (Jaksic et al. 1979; Ebensperger 2001; Ebensperger & Hurtado 2005b). Several lines of evidence suggest that shrubs provide degus with refuges against predators, including patterns of patch and runway use, grouping, vigilance, and pausing behavior (Jaksic et al. 1979; Lagos et al. 1995b; Ebensperger et al. 2002; Vásquez et al. 2002; but see Yunger et al. 2002). These potential benefits may be critical at our study site, where degus are preyed upon by predators, including several birds of prey (Ebensperger & Wallem 2002; Ebensperger & Hurtado 2005b). In other rodent species, including mice, gerbils, and desert heteromyids, individuals occurring in patches with less overhead vegetative cover are at greater risk of predation than individuals occurring in patches with more protective cover (Kotler et al. 1991; Longland & Price 1991; but see Schooley et al. 1996). Under these conditions, the behavior and space use patterns of semi-fossorial rodents should also be linked to shrub or tree cover. Indeed, numerous rodents spend less time foraging in patches with less plant cover (Lima et al. 1985; Newman et al. 1988; Kotler et al. 1991; Barnum et al. 1992; Brown et al. 1992; Hughes et al. 1994; Abramsky et al. 2004). Moreover, shrub cover decreases the need for vigilance (Tchabovsky et al. 2001; Vásquez et al. 2002), allowing individuals to be more active when predators are abundant (Lagos et al. 1995a,b). We suggest that degus originating from burrow systems near shrubs had larger ranges because: (1) shrubs blocked them from the view of aerial predators; (2) shadows cast by shrubs and trees camouflaged individuals; or (3) aerial predators have greater difficulty hunting near shrubs and trees than in open areas.

An alternative interpretation for our observation of greater degu range areas at locations closer to shrub or tree cover is that individuals living near shrubs range farther from their burrows to find abundant sources of preferred foods. We examined this hypothesis preliminarily through testing for a correlation between food biomass and distance to cover. While food biomass at 3 and 9 m from burrow centers and distance to shrub cover did not covary (both $p > 0.05$; n = 29 burrow systems), the average food biomass from these areas significantly increased with increasing distance from vegetative cover (Pearson $r = 0.75$, $p < 0.001$; n = 29 burrow systems). This result supports the hypothesis that the abundance of primary foods is reduced because of intense foraging activity (Jaksic 1986).

Semi-fossorial species, such as degus (Ebensperger & Bozinovic 2000), use burrows for many purposes (Reichman & Smith 1987; Kinlaw 1999). Some species, including degus, dig complex burrow systems with multiple entrances and exits (Reichman & Smith 1987; Kinlaw 1999). One major function of these structures is to confuse pursuing predators and provide places to escape approaching predators (Kinlaw 1999). Burrow systems and their burrow openings may, therefore, be critically important to survival in open areas where predators can more easily detect prey. However, we found a weak but negative association between distance to overhead cover and the number of burrow systems used, implying that degus at locations far from cover use less burrow systems. Moreover, and in contrast to Yáñez (1976), we found no association between density of burrow openings and distance to cover ($n = 29$ burrow systems) suggesting that the density of openings per burrow system does not change with the distance of burrow systems to vegetative cover (Pearson $r = -0.03$, $p = 0.87$). Thus, the number of burrow systems used by degus is likely driven by factors other than predation risk.

We recorded a negative association between the number of burrow systems and density of burrow openings, implying that degus that used more burrow systems had fewer burrow openings (Fig. 2b). We suggest that this reflects a cost–benefit balance between benefits of having more refuges to evade predators and the time and energy costs of burrow construction and maintenance (Ebensperger & Bozinovic 2000). Thus, a sufficient number of burrow openings can be achieved either through constructing a few burrow systems with more burrow entrances or through digging (and using) more burrow systems with fewer openings.

Our observation that food availability was not a significant predictor of space use was surprising. Ecological models predict that animal ranges, especially those of females, are as large as necessary to gain access to sufficient food resources (Emlen & Oring 1977; Brashares & Arcese 2002). For example, female oribi (*Ourebia ourebi*) maintain smaller home ranges in areas where food is abundant (Brashares & Arcese 2002). Similarly, some North American rodents exhibit smaller ranges in areas where food is abundant (Travis & Slobodchikoff 1993) or is added experimentally (Hubbs & Boonstra 1998). Similar patterns have also been observed in primates (e.g. Masaaki & Hiroo 1999). It is possible that the patchiness of food (Travis & Slobodchikoff 1993; Travis et al. 1995), a variable that we did not measure, is a more important predictor of space use in degus. This hypothesis predicts that degus have smaller range areas in areas of patchily distributed food than in areas where food is more uniformly distributed. We are currently testing this hypothesis at Rinconada de Maipú.

Most likely, multiple ecological variables interact to affect the space use of animals (Brashares & Arcese 2002; Yunger et al. 2002; Bacigalupe et al. 2003). For example, animals probably make trade-offs between predation risk, food availability, and energetic costs of foraging to maximize fitness (Bacigalupe et al. 2003). In terms of range areas, our results suggest that the risk of predation is an important predictor of space utilization by degus. However, post hoc correlations suggest that degus living under protective cover range farther into areas of high food density (Jaksic 1986), implying that predation risk and food availability play roles in degu space use patterns (Lagos et al. 1995a,b). Moreover, our study suggests that ecological models for space use should also consider multiple features or dimensions of space use. For example, whereas Lagos et al. (1995a,b) focused on the above-ground daytime space use of degus, we assessed the relationship between ecology and above- and below-ground space use. Our study indicates that the use of different spatial dimensions may be affected by different ecological factors. Thus, future models of space use should measure different dimensions of space use, building upon existing models that consider the effect of multiple ecological variables affecting space use (Lagos et al. 1995a,b; Torres-Contreras & Bozinovic 1997; Brashares & Arcese 2002; Yunger et al. 2002).

Directions for Future Study

Our results suggest that variation in vegetative cover and the density of burrow openings, but not the abundance of food, affects the space use of a semi-fossorial rodent. This is an interesting result because it suggests that both below- and above-ground components of space use are influenced by variations in ecology. Future manipulations of soil conditions and overhead cover are needed, therefore, to determine the relative importance of these factors on the space use of semi-fossorial rodents. Our results also suggest that males and females have similar space use patterns when most females are pregnant or lactating, a pattern that likely would differ when most individuals are mating (Schwagmeyer 1988). More information is needed to understand the link between space use, sociality and mating systems of degus, and other semi-fossorial rodents. There are excellent field data showing that variability in ecology affects the spacing behavior (a reasonable indicator of mating systems) in some species (e.g. Schradin & Pillay 2005). However, advances in the ornithological literature (Griffith et al. 2002) suggest that the use of molecular genetic tools is necessary to distinguish between social and genetic mating systems, an aspect needed for semi-fossorial rodents.

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Seasonal changes in the time budget of degus, *Octodon degus*

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Summary

The activity budget of an individual is the allocation of time to all its activities, and is expected to vary in response to both internal and environmental factors that influence its energy acquisition, breeding success, and survival. We recorded seasonal variation in individual and social behaviour of a natural population of degus (*Octodon degus*), a diurnal, semi-subterranean and social rodent from central Chile. We related changes in degu activity to differences in sex, seasonality (breeding activity, abundance of high quality food), and abundance of degu predators. On average, degus allocated most of their time while active above ground to foraging (46%) and alertness (32%); activities such as resting (8%), locomotor activity (7%), self-grooming (3%), burrow digging (0.2%), dust-bathing (1%), and social interactions (3%) occupied a relatively small percentage of degus' time budget. Time spent in foraging and total vigilance did not vary seasonally, but they were inversely related, reflecting a trade-off. Degus adjusted bipedal vigilance and locomotor activity partially to the presence of predators. Sex interacted with seasonality to influence degu behaviour. Male degus dust-bathed more and were more aggressive toward conspecifics than females during breeding time. We hypothesize that breeding activity is a more important predictor than abundance of high quality food to account for these interactions.

Keywords: activity, foraging, vigilance, predation risk, degu breeding, seasonality.

Introduction

The allocation of time to different kinds of activity, or activity budget, is one major aspect of the temporal behaviour of animals (Halle & Stenseth,

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2000). Given that organisms must perform their activities within constraints imposed by daily or seasonal cycles (Bartness & Albers, 2000), time is limited to them. As a consequence, how an animal allocate its time budget to different activities usually is influenced by conflicting demands. Thus, time must be assigned to activities that increase nutritional and breeding objectives, but also to activities that minimize costs and risks imposed by environmental conditions (Alkon & Saltz, 1988; Armitage et al., 1996; Halle, 2000; Weiner, 2000).

Among animals, activity of model organisms such as rodents is influenced by several individual (energy requirements, sex-specific breeding activity) and environmental (weather, predators, food abundance) factors, some of which interact and result in activity trade-offs to individuals. Thus, foraging-related activities are typically traded off against those that decrease the risk of predation (Kotler et al., 1991; Abramsky et al., 1996; Vásquez, 1996; Hendrie et al., 1998), or the risk of hyperthermia (Melcher et al., 1990; Cotton & Parker, 2000; Kenagy et al., 2002). On the other hand, breeding-related activities may force individuals to expand their daily activity to gather enough food (Corp et al., 1997), and sex-linked differences or similarities in activity tend to be related to sex differences or similarities in breeding strategies (Behrends et al., 1986; Loughry, 1993; Armitage et al., 1996; Sharpe & Rosell, 2003). Sex-specific parental duties and breeding-related activities may interact with predation risk to modulate overall activity (Daly et al., 1990; Sommer, 2000). Other factors such as food availability may cause changes in overall activity and re-allocation of time to different activities (Lacki et al., 1984; Kenagy et al., 1989).

The allocation of time to different, and often conflicting, activities might be of special concern to rodents that breed once per year in seasonal environments. Herein, we used observational data to examine how male and female degus, *Octodon degus* (Rodentia; Octodontidae), adjust their activity time throughout seasonal changes in their annual life cycle and environmental conditions. In particular, our objective was to examine how degus allocate time seasonally among essential activities such as foraging, vigilance, and social behaviour.

Several aspects of degu biology and ecology predict that these rodents should adjust their seasonal activity in response to sex-linked changes in breeding activity, food abundance, and predator abundance. First, degus are small to medium sized (ca. 180 g), diurnal, social, and semi-subterranean

Hystricognath rodents of the semiarid and Mediterranean environments of north-central Chile (Fulk, 1976; Yáñez, 1976; Le Boulengé & Fuentes, 1978). In this environment, degus typically breed once per year in late autumn (May-June), with conceptions in late winter to early spring (September-October) (Contreras & Bustos-Obregón, 1977; Rojas et al., 1977). During this time, males aggressively exclude other males from the communal burrows used by groups of 2-4 females, but not at other times of year (Ebensperger et al., 2004; Soto-Gamboa, 2004). Thus we hypothesized that males rather than females should adjust their activity during breeding time to, for instance, patrol, scan, and chase conspecifics.

Not only breeding activity varies seasonally in degus. Degus rely mostly on green parts of grasses and forbs, a high quality food, but secondarily on shrub foliage, a low quality food (Meserve et al., 1983, 1984). The characteristic concentration of precipitation in winter months in the Mediterranean habitats used by degus causes young leaves and herbs to be available during winter and spring (breeding time), but not in summer and autumn (non-breeding time; Rojas et al., 1977; see Results). Thus, degus are expected to adjust time allocated to foraging and to track seasonal changes in high quality food availability. In addition, we predicted that time spent in locomotor activity should increase when high quality food is less abundant (i.e., summer and autumn months) as a consequence of more time needed for food searching.

Predators are known to influence degu behaviour. Although degus construct and use underground burrows, they forage entirely above ground (Fulk, 1976; Vásquez, 1997) where they are frequent prey of raptors and foxes (Jaksic et al., 1981, 1993). As might be expected, degus adjust their spatial and social behaviour in response to varying conditions of risk (Jaksic et al., 1979; Lagos et al., 1995a, b; Ebensperger & Wallem, 2002; Vásquez et al., 2002). Thus, we hypothesized that degus should increase antipredator vigilance whenever predatory risk increases in response, for instance, to increasing predator abundance. Since locomotor activity of prey may enhance detection by predators and thus increase predation risk (Norrdahl & Korpimäki, 1998; Yoder et al., 2004), we also predicted that degus should decrease locomotor activity whenever predator abundance increases.

Previous studies addressed how daily and seasonal changes in thermal conditions influence degu overall activity and microhabitat use (Lagos et al., 1995a; Kenagy et al., 2002; Bacigalupe et al., 2003). However, effects of sex, breeding activity, food abundance, and predator abundance on the time budget of these rodents remain largely unknown.

Although experimental studies should be preferred to reveal cause-effect relationships, manipulating two or more environmental factors while keeping several others 'constant' can be a major challenge to field studies. Thus, we are confident that correlative efforts such as this study will be useful to highlight potential cause-effect relations and guide ulterior experimental studies.

Methods

Study area and time of observations

The study population was located at the Estación Experimental Rinconada de Maipú (33°23'S; 70°31'W, altitude = 495 m), a field station of the Universidad de Chile located 30 km west of Santiago, Chile. The study site was characterized by a Mediterranean climate, with warm, dry summers and cold, wet winters. The site consisted of a flat area with scattered shrubs (*Proustia pungens*, *Acacia caven* and *Baccharis* spp.), containing grasses and forbs. Shrub cover, as assessed from nine 200 m linear transects, reached 14.5 ± 1.2% ($\bar{x} \pm$ SE). Animals were monitored in an area of 1.13 ha. This area was chosen based on evidence of degu activity, including the presence of recently used burrow entrances and direct visual sightings of animals.

Observations were carried out seasonally (i.e., once every three months) between June 2002 and January 2004. We conducted our observations within 10-15 days in June (early Austral winter), October (mid Austral spring), January (mid Austral summer), and April (mid Austral autumn). Degus are seasonal breeders, and this sampling regime followed major events of their life cycle. In central Chile, degus typically mate in late autumn-early winter (June-July), with conceptions in late winter to early spring (September-October). General climatic conditions in the Santiago area from mid 2002 to early 2004 fluctuated from rainy to moderately dry, and no major events of El Niño or La Niña took place.

Capture and marking of degus

Members of the study population were captured using Sherman live traps (H.B. Sherman Traps Inc., Tallahassee, Florida, USA) baited with rolled oats. Since degus are strictly diurnal (Kenagy et al., 2002; Ebensperger et al., 2004), traps were placed near active burrow entrances during mornings and evenings, when the animals were active above ground. Traps were checked approximately every hour. Typically, trapping was conducted continuously for 5-7 days per season. Trapping effort per season ranged from 1,100 to 1,540 trap-days. For all individuals captured, we recorded body weight, sex, and breeding condition of females (perforated, pregnant, lactating). Since breeding condition of males was difficult to assess precisely (testes do not become scrotal), we inferred breeding activity of our population from the condition of females only. We used body weight of animals to estimate their relative age. Degus were considered to be newborns (pups) when weighing less than 70 g. Juveniles corresponded to individuals weighing 70-130 g (females) or 70-140 g (males), and not previously recorded in our study site within the last 2 months. All captured adults (i.e., above 130 g for females, 140 g for males) were individually marked with neck collars (made of plastic cable ties wrapped in colored tape) to allow visual identification during behavioural observations. We used a color key where 2-3 out of 7 different tape colors (including black and white) were combined in a single animal. The number of degus that were individually marked (or remarked) before any behavioural sampling period ranged from 15 to 43 (28 ± 2).

Behavioural observations

We observed degus above a portable tower-blind at a distance of 30-100 m, depending on the location and height of surrounding shrubs. Observer height (ground to eye level) was approximately 4.3 m. Observations were completed between 07:30-12:00 and 18:00-20:00 h during warm seasons, and between 09:30 and 15:00 h during cold seasons, which matches the animals' daily activity above ground (Kenagy et al., 2002). No behavioural data were collected during spring 2003 as too few adult sized individuals were present in our study site. Animals were identified on the basis of collar color; identification was facilitated by the use of a 10 × 50 binoculars. As soon as a collared degu was sighted, we recorded its behaviour with a Sony digital video camera (model DCR-TRV330, Sony Corporation, Japan). Video recordings were terminated after about 40 min or when the focal subject went out of sight during more than 3 min. The length of focal observations averaged 11 (±8) min, and ranged from 1 to 41 min. In the lab, we played back the videos and recorded the percentage of time that individual degus spent in different activities when above ground.

Elements of degu individual behaviour recorded were similar to those of other Hystricognath rodents (Smythe, 1978; Lacher, 1981), and included foraging (including short displacements, <2 m), vigilance (the animal remains motionless with its head raised and either supported by its four legs [quadruped] or on its rear legs [bipedal]), moving (moves >2 m from the original spot), resting (sits on the ground with body in full contact with the substratum), self-grooming (including scratching, nibbling, and licking), dust-bathing, and burrow digging. We classified social interactions as being amicable or neutral, versus agonistic. Neutral or amicable interactions typically included cases of brief nose to nose and mutual naso-anal contacts and allogrooming. Agonistic interactions typically involved two individuals pushing each other with their forelegs, after which one animal frequently chased the other for a few seconds. These episodes also took place without previous boxing, and they normally ended with the chaser remaining motionless and watching the chased individual flee. Rarely, degus kicked one another with their hind legs (Fulk, 1976).

Since degus are social rodents and grouping influences their behaviour (Vásquez, 1997; Vásquez et al., 2002), we quantified the number of individuals located near each focal animal from video recordings. To do so, we included all degus at a distance of 2-3 m or less from our focal individual. The use of such criteria ensured that all putative group members were in visual contact with each other and made our results comparable with previous studies. Group membership was not constant as degus regularly leave or join the groups freely within seconds. Thus, when the size of the group that included the focal animal changed within a particular focal observation, we distinguished activity performed by the focal animal under different group size conditions. We then used these data to calculate a time-weighted mean of grouping that reflected the proportion of time spent by the focal animal under varying conditions of grouping.

Overall, we continuously monitored the behaviour of degus during 140 h, restricting behavioural records to adult sized males and females.

Degu sex, breeding activity and density, abundance of high quality food and predators

Sex and breeding condition of animals were recorded from our trapping data. We inferred the breeding schedule of our study population through seasons from the condition of females, as well as from the timing of appearance of pups.

We used scan sampling to record the numbers of every predator known to prey on degus that was observed in the area. When recording our focal observations, and every 30 min, we monitored the area over a 6.7 (± 0.1) min circular sweep. During these visual sweeps, we made instantaneous recordings of every predator sighted. A total of 252 scan samplings were completed. Likewise, and in order to assure that any seasonal changes in behaviour detected were not due to changes in degu density rather than to changes in the hypothesized factor, we also used our scan sampling regime to record the total number of degus observed in the area. We standardized degu counts to the total area scanned. Since data on predator abundance and degu density were not gathered from the video recordings of our focal subjects, we pooled such data per sampling season to match the focal sampling data (i.e., sample size equaled 78 'focal' observations instead of 252). Our initial aim was to distinguish aerial from terrestrial predators during the analysis, but foxes and snakes were infrequent and highly unpredictable in the area. Therefore, we pooled data and considered total abundance of observed predators.

To track changes in the abundance of herbaceous vegetation (dry mass m^{-2}), we randomly selected 15 points in our study area per season. At each sampling point, we placed a 250 × 250 mm quadrant and removed the aboveground parts of all green herbs found. Samples were immediately stored inside 2 kg capacity paper bags. In the laboratory, we oven-dried each plant sample at 60°C for 72 h to determine its dry mass.

Given the non-experimental nature of our study, we could not statistically distinguish the effects of breeding activity from those of food abundance. Green parts of grasses and forbs, the preferred food of degus, are available during winter and spring, but not during summer and autumn (see Results). This pattern matches exactly the breeding and non-breeding periods, respectively. Despite this, we compared our results with our a priori predictions to infer which factor probably plays a greater role in explaining seasonal changes in degu activity.

Data independence and analyses

All focal observations were carried out on individually marked degus, and observations of a given individual within a given sampling period (i.e., season) were pooled. Although 26% of all focal observations corresponded to individuals whose behaviour was recorded in more than one season, we assumed data to be statistically independent across seasons.

Before statistical analyses, proportions of time spent in different activities were arcsine-square root transformed, whereas abundance of predators (sightings 30 min^{-1}), grouping (number of degus), and degu density (animals ha^{-1}) estimates were $\text{Log}_{10}(x+1)$ transformed (Zar, 1996). Normality of data was assessed by means of Kolmogorov-Smirnov tests. Some dependent variables (resting, dust-bathing, digging, neutral and aggressive interactions) deviated from normality even after data transformation ($p < 0.01$). However, and since kurtosis of all these variables was always greater than 0, violations of normality made our tests more conservative (Statistica, 2001).

Differences in the number of local predators sighted, as well as in the tendency of degus to group, were pooled per season and examined through one-way ANOVA tests. As seasonal changes in breeding activity exactly matched changes in food abundance, both factors were entered in the analysis as a joint 'seasonality' factor. Since percentages of time allocated to different activities were probably interrelated, we examined each behaviour simultaneously through MANOVA under the GLM procedure with sex (male or female) and seasonality (breeding and high quality food available versus non-breeding and no high quality food available) as main effects, and predator abundance, grouping, and degu density as covariates. This multivariate analysis was used to highlight statistically significant predictors and response variables influenced by such predictors. After that, we considered univariate results of significant predictors and variables, and used Tukey HSD tests for multiple comparisons of means of sex and seasonality. Post-hoc examination of continuous variables were carried out through Bonferroni corrected regression analyses (Hayes & Solomon, 2004). Since time allocated to foraging can be traded off against time spent in vigilance (Bachman, 1993; Sharpe & Van Horne, 1998), we also explored this possibility for degus through partial correlation analysis.

All statistical analyses were performed using Statistica 6.0 (StatSoft Inc., Tulsa, Oklahoma, USA). All statistical tests were two-tailed, and data are presented as $\bar{x} \pm \text{SE}$.

Results

Degu breeding activity, density, and grouping

A total of 268 degus (121 males and 147 females) were trapped on 699 occasions during our 18-month study. These captures revealed that pups (46 males and 34 females) were caught during spring only (Figure 1). Pregnant and lactating females were recorded from winter (15 out of 43 adult females caught) to spring (15 out of 17 females caught), whereas juveniles (59 females and 56 males) appeared from late spring to early autumn (Figure 1). Only a small number of recently perforated females were recorded ($N = 3$) during early winter. No signs of either pregnancy or lactation were recorded during summer ($N = 41$ females caught) or autumn ($N = 36$), suggesting that post-partum oestrus did not occur in our study population. Collectively, these findings indicated that breeding activity of our degu population occurred once per year during winter-spring months.

Scan sampling revealed that density of degus was significantly lower in spring (8±3 individuals ha^{-1}) (one-way ANOVA on $\mathrm{Log}_{10}\,[x+1]$ transformed data: $F_{3,74} = 25.17$, $p < 0.001$; Tukey HSD tests: $p < 0.05$) than in autumn (19±3 individuals ha^{-1}), winter (24±2 individuals ha^{-1}) and summer (25±2 individuals ha^{-1}); the latter three seasons did not differ (Tukey HSD tests: $p > 0.05$).

Degus performed their activities above ground either solitarily or in groups of up to 10 individuals. Typically, however, groups were small (2-3 degus). Degus grouped significantly less in spring when active above ground (1.1 ± 0.1 degus group^{-1}) (one-way ANOVA: $F_{3,74} = 102.98$, $p < 0.001$; Tukey HSD post-hoc tests: $p < 0.05$). Grouping was similar in autumn (1.5 ± 0.1 degus group^{-1}), winter (1.4 ± 0.1 degus group^{-1}), and summer (1.5 ± 0.1 degus group^{-1}) (Tukey HSD post-hoc tests: $p < 0.05$).

Abundance of high quality food and predators

Our scan sample data revealed that the number of predators sighted varied significantly through seasons (one-way ANOVA on $\mathrm{Log}_{10}\; x + 1$ transformed data: $F_{3,74} = 102.98$, $p < 0.001$; and Tukey HSD post-hoc tests: $p < 0.05$). The lowest number of predators was recorded in spring and averaged 0.26 ± 0.04 per scan. In contrast, the highest number of predators was recorded in autumn (1.09 ± 0.04), a fourfold increase. The numbers of

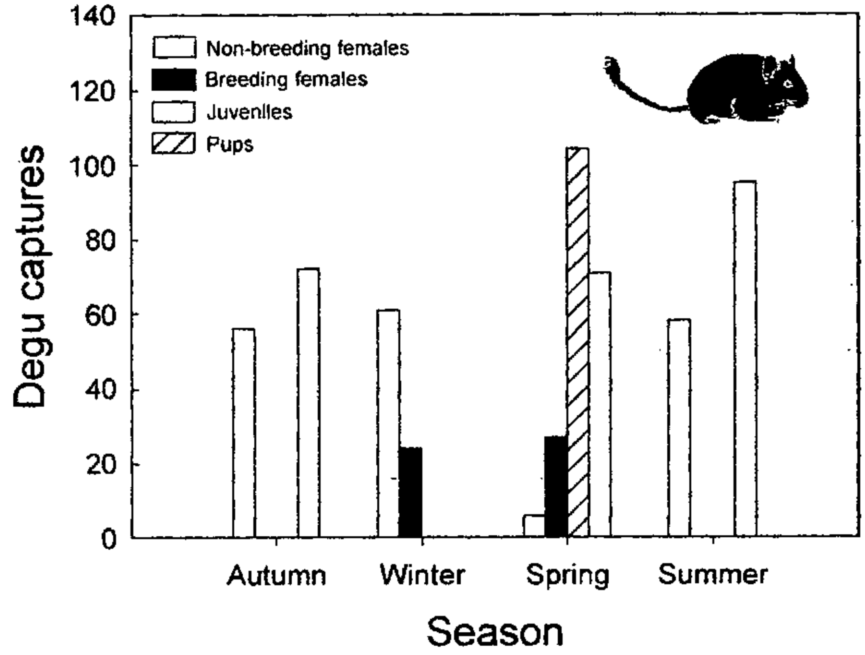

Figure 1. Number of degu captures per season: adult non-breeding females (white), breeding females (black: perforated, pregnant or lactating), female and male juveniles (grey), and female and male pups (white hatched).

predators sighted in winter (0.93 ± 0.04) and summer (0.98 ± 0.03) were similar, but higher than in spring, and lower than in autumn (Tukey HSD post-hoc tests: $p < 0.05$). Aerial predators sighted included black-chested eagles (*Geranoaetus melanoleucus*), Harris's hawks (*Parabuteo unicintus*), white-tailed kites (*Elanus leucurus*), aplomado falcons (*Falco femoralis*), and American kestrels (*Falco sparverius*). Terrestrial predators were represented in the area by culpeo foxes (*Pseudalopex culpaeus*), and long-tailed snakes (*Philodryas chamissonis*). Iguana lizards (*Callopistes palluma*) also were seen marauding degu burrows at the time of pup emergence.

As expected, availability of green herbs varied significantly across seasons (Kruskal-Wallis ANOVA by ranks test: $z = 65.33$, $p < 0.001$). Green herbs were available in winter (99.7 ± 9.9 g dry mass) and spring (64.5 ± 13.8 g dry mass), but not during summer and autumn months. Differences in the abundance of herbs during winter and spring were not statistically significant (multiple comparison by ranks test: $z = 0.92$, $p = 0.358$).

Overall activity budget

A total of 78 focal observations representing 56 different individuals were recorded. These data revealed that degus allocated the greatest amount of time while active above ground to foraging and vigilance (Table 1). Resting, moving, and self-grooming were less frequent, and digging and dust-bathing were rarer still (Table 1). On average, social degus spent 3.2% of their time interacting with conspecifics (Table 1). Of this, neutral or amicable interactions took up 2.0 ± 0.5%, whereas aggressive or agonistic interactions took up 1.2 ± 0.4%.

Influences of sex, seasonality and predator abundance

Overall, all major predictors examined influenced some aspect of degu behaviour, including sex (Wilks' lambda $= 0.57$, $F_{11,61} = 4.13$, $p < 0.001$), seasonality (Wilks' lambda $= 0.65$, $F_{11,61} = 3.02$, $p < 0.003$), predator abundance (Wilks' lambda $= 0.57$, $F_{11,61} = 4.19$, $p < 0.001$), and the sex-seasonality interaction (Wilks' lambda $= 0.65$, $F_{11,61} = 2.94$, $p < 0.004$). The influences of degu density (Wilks' lambda $= 0.74$, $F_{11,61} = 1.94$, $p = 0.051$) and grouping (Wilks' lambda $= 0.86$, $F_{11,61} = 0.91$, $p = 0.639$) were not statistically significant in the overall model.

The percentage of time degus allocated to foraging ($F_{6,71} = 1.47$, $p = 0.201$), quadrupedal vigilance ($F_{6,71} = 0.26$, $p = 0.952$), total vigilance ($F_{6,71} = 1.07$, $p = 0.386$), digging ($F_{6,71} = 1.57$, $p = 0.168$), self-grooming ($F_{6,71} = 1.50$, $p = 0.189$), and to neutral interactions ($F_{6,71} = 0.88$, $p = 0.511$) were not influenced by any of major predictors used in the analysis, including seasonality (Table 1). Sex, seasonality and predator abundance had an interactive effect on time allocated to bipedal vigilance: bipedal vigilance increased with predator abundance, but mainly in females during the non-breeding period (and when high quality food was scarce) ($R = 0.42$, $t_{21} = 2.15$, $p = 0.043$). However, this finding was not significant after Bonferroni correction for post-hoc tests (adjusted critical $\alpha = 0.0125$).

As expected, partial correlation analysis revealed that time allocated to foraging was inversely related to time allocated to both quadrupedal (partial $R = -0.62$, $t_{75} = 6.92$, $p < 0.001$) and total vigilance (partial $R = -0.64$, $t_{75} = 7.27$, $p < 0.001$) when grouping was controlled for. No such correlation was detected between foraging and bipedal vigilance (partial $R = -0.12$, $t_{75} = 1.04$, $p = 0.421$).

Table 1. Untransformed percentages of time devoted to individual and social activities by female and male degus when breeding and non-breeding. Values are mean ± SE. The number of focal observations is indicated in parentheses

Activity	Breeding females ($N = 22$)	Non-breeding females ($N = 23$)	Breeding males ($N = 10$)	Non-breeding males ($N = 23$)	Overall ($N = 78$)
Foraging	51.5 ± 4.9	48.4 ± 5.2	34.9 ± 5.9	42.7 ± 4.4	45.8 ± 2.6
Quadruped vigilance	26.2 ± 3.2	25.9 ± 4.0	21.8 ± 4.2	26.6 ± 2.9	25.7 ± 1.8
Bipedal vigilance	2.5 ± 0.6	6.8 ± 1.9	4.6 ± 1.2	9.4 ± 2.4	6.1 ± 1.0
Total vigilance	28.7 ± 3.4	32.6 ± 4.0	26.4 ± 4.2	36.0 ± 3.4	31.7 ± 1.9
Resting	10.1 ± 0.6	6.9 ± 0.2	17.0 ± 6.5	16.9 ± 2.1	7.5 ± 1.5
Moving	5.7 ± 1.7	10.6 ± 1.9	3.0 ± 1.0	6.8 ± 1.0	7.1 ± 0.9
Self-grooming	4.3 ± 1.2	2.8 ± 0.5	2.2 ± 0.7	2.7 ± 0.6	3.1 ± 0.4
Dust-bathing	0.8 ± 0.3	0.5 ± 0.3	5.5 ± 1.9	0.6 ± 0.2	1.2 ± 0.3
Burrowing	0.3 ± 0.2	0.2 ± 0.1	0.4 ± 0.3	0.1 ± 0.0	0.2 ± 0.1
Social interactions	1.7 ± 0.4	3.7 ± 1.8	9.0 ± 2.9	1.8 ± 0.4	3.2 ± 0.7

Although sex and seasonality influenced time devoted by degus to resting independently (sex-$F_{1,71} = 11.60$, $p = 0.001$; seasonality-$F_{1,71} = 5.59$, $p = 0.021$), resting time increased during breeding time, but mostly in males (Tukey HSD tests: $p < 0.030$). Predator abundance did not influence resting activity of degus ($F_{1,71} = 0.42$, $p = 0.518$).

Degus moved more during non-breeding time ($F_{1,71} = 19.63$, $p < 0.001$), and our post-hoc analysis suggested that this effect was more pronounced in females (Tukey HSD tests: $p < 0.030$). Predator abundance influenced time allocated to locomotor activity significantly ($F_{1,71} = 10.83$, $p < 0.002$). Females during breeding time moved less when predator abundance was high ($R = -0.69$, $t_{21} = 4.13$, $p < 0.001$). Although males exhibited a similar trend when non-breeding (and when high quality food was unavailable), this finding was not significant after Bonferroni correction ($R = -0.43$, $t_{21} = 2.19$, $p = 0.040$; corrected critical $\alpha = 0.0125$).

Sex and seasonality interacted significantly to influence time allocated by degus to dust-bathing ($F_{1,71} = 11.67$, $p = 0.001$). Thus, males dust-bathed more than females, but only during breeding time (Tukey HSD tests: $p < 0.002$) (Figure 2A). Degus did not adjust their dust-bathing activity in response to changes in predator abundance ($F_{1,71} = 0.002$, $p = 0.967$).

Sex and seasonality interacted to influence time allocated to aggressive or agonistic social interactions ($F_{1,71} = 24.75$, $p < 0.001$). Males were

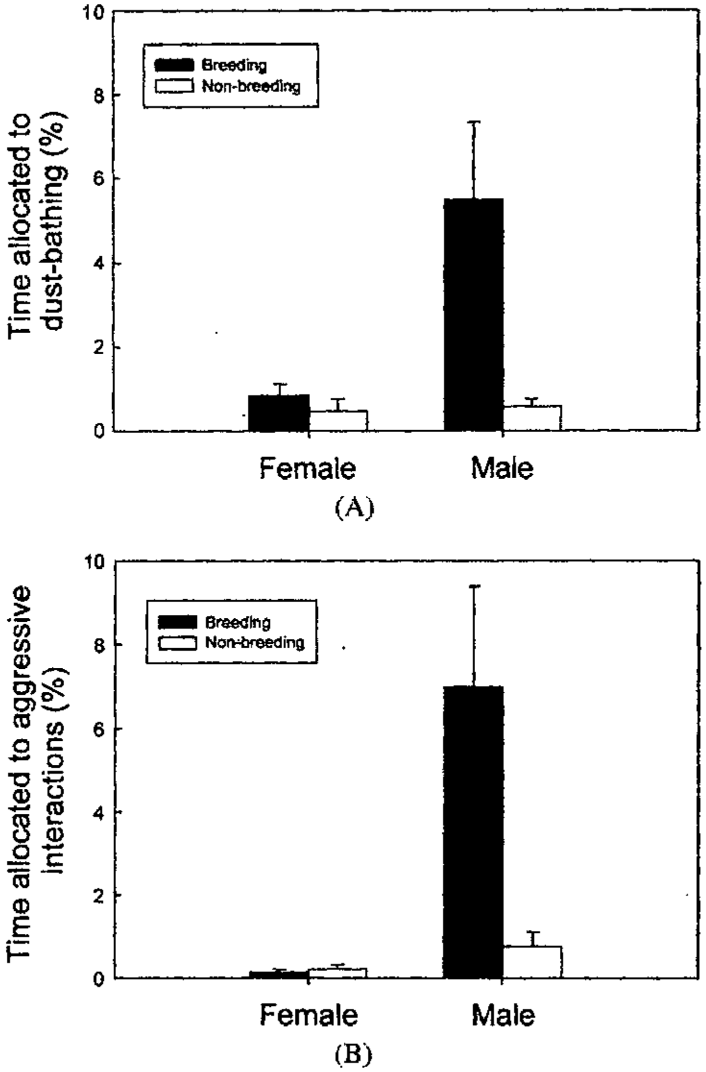

Figure 2. Time allocated to (A) dust-bathing and in (B) aggressive interactions (%) by breeding and non-breeding male and female degus. Data are $\bar{x} \pm$ SE, and were calculated from a total of 78 focal records, corresponding to 56 individually marked degus.

more aggressive than females, but only during breeding time (Tukey HSD tests: $p < 0.001$) (Figure 2B). Aggressiveness was unaffected by changes in predator abundance ($F_{1,71} = 2.60$, $p = 0.111$).

Discussion

Our study revealed three major points. First, all factors hypothesized to influence seasonal activity of degus did vary through seasons (e.g., breeding activity, predator abundance). Second, all of these factors, along with sex, did influence one or more aspects of degu seasonal activity, including time allocated to bipedal vigilance, resting, locomotor activity, dust-bathing, and agonistic social interactions. Third, aspects of degu activity such as time allocated to dust-bathing and to aggressive interactions were influenced by the factor interactions (e.g., sex and seasonality). In contrast, aspects such as time devoted to foraging, quadrupedal and total vigilance, burrow digging, self-grooming, and neutral/amicable social interactions seemed scarcely influenced by any major factor included in the analysis. We now examine our findings in more detail.

Seasonality of main factors

Breeding activity of degus occurred once per year, from winter to spring. Contrary to previous suggestions, our degu population did not undergo a second breeding event (Contreras & Bustos-Obregón, 1977; Rojas et al., 1977; Meserve et al., 1984). As hypothesized for other species (Kenagy et al., 1989), breeding seasonality of degus is probably adaptive as the energetically expensive process of pregnancy and lactation (females), or harem defence (males) matches the availability of high quality food during winter and spring.

The abundance of local predators in the area (mostly raptorial birds) also exhibited seasonal variation, with spring being the period with fewer predator sightings. The causes of such variation remain unknown to us.

Influences on degu individual activity

That foraging activity dominates degus' activity time is not surprising as it parallels the behaviour of other semi-subterranean and ground-dwelling rodents, some of which invest even more of their total activity in feeding than degus (e.g., *Marmota marmota*, *Spermophilus columbianus*: Barash, 1976; Betts, 1976), although other species (e.g., *Marmota flaviventris*, *Spermophilus saturatus*: Kenagy et al., 1989; Armitage et al., 1996) spend less time foraging. The potential causes of such variation across species are intriguing and should be the subject of future comparative analyses.

Foraging not only takes most of male and female degus' activity time, but also remains relatively constant despite strong seasonal changes in breeding activity and food abundance. Thus, and contrary to predictions, neither males nor females adjusted foraging time to cope with the relatively high energetic requirements of breeding (Veloso & Bozinovic, 2000), a finding that contrasts with the behaviour of other ground-dwelling rodents (Barash, 1980; Kenagy et al., 1989; Branch, 1993). Similarly, foraging time did not track seasonal changes in the abundance of high quality food. We suggest that foraging activity is a major and permanent constraint on degu activity budget, and most likely a major influence on individual fitness (e.g., Bacigalupe et al., 2003). However, similarly high levels of activity allocated to foraging might reflect seasonal changes in the importance of different constraints: the high energetic costs of breeding might constrain degus during winter-spring to allocate most time to foraging, but low food abundance might select for such high time allocation to foraging during summer-autumn.

Vigilance was the second most frequent activity of degus when above ground (32%). Our prediction that degus should increase antipredator vigilance in response to increasing predatory risk was partially supported. Time allocated to total and quadrupedal vigilance remained unaffected despite changes in predator abundance and breeding activity, but bipedal vigilance increased during the non-breeding period and when predator abundance was high, suggesting that degus seasonally adjust the quality rather than quantity of vigilance. We suspect that such variation may, to some extent, be related to changes in the amount of herb cover, which affects predator detection (Ebensperger & Hurtado, in press).

Several lines of evidence suggest that vigilance by degus is, partially, an anti-predator strategy (Vásquez, 1997; Ebensperger & Wallem, 2002; Vásquez et al., 2002), but the observation that vigilance did not track environmental changes in predator abundance remains puzzling. Thus, the possibility that degu vigilance serves other functions such as social monitoring needs to be assessed (e.g., Beauchamp, 2001; Barbosa, 2002).

Despite the lack of seasonal changes in time allocated to foraging and total alertness, there was an inverse relationship between these activities when grouping was controlled for. Thus degus still seem capable of fine tunings of their foraging and vigilance activities. A trade-off between foraging and vigilance has also been recorded in other ground-dwelling rodents (Betts, 1976; Bachman, 1993; Sharpe & Van Horne, 1998), and experimental studies are needed to confirm the cause-effect nature of this relation in degus.

Degus allocated 7-8% of their time to resting (sitting/lying) when above ground, a figure that contrasts with the 40-60% recorded in *M. flaviventris* (Armitage et al., 1996), or the 43-50% recorded in *Hydrochaeris hydrochaeris* (Jorgenson, 1986). The relatively low amount of time spent resting by degus suggests that the time/energy budget of these rodents is not particularly constrained by time needed to process ingested food, as has been suggested in marmots (Armitage et al., 1996). Nonetheless, caution is needed as degus might rest while in their underground burrows during day time. Whole-day follows of radio collared animals are needed to assess this possibility.

We are not certain what caused male degus to devote more time than females to resting during breeding time. One possibility is that resting and alertness are not mutually exclusive activities, as has been demonstrated when foraging birds (i.e., those with their heads down) are still capable of performing (low quality) vigilance (Lima & Bednekoff, 1999). If so, breeding male degus might use some resting time to, for instance, scan for potential intruders.

Although not quantified, it seemed to us that most locomotor activity by focal degus involved switching among different microhabitat patches. Unlike findings in some other species (e.g., Behrends et al., 1986), degus (mainly females) moved less during breeding time (and when high quality food was abundant), but also when predator abundance was high. On the one hand, this finding supports the hypothesis that degus reduce their locomotor activity to decrease predation risk, and adds to other social and spatial anti-predator responses known in this species (Lagos et al., 1995a, b; Ebensperger & Wallem, 2002; Vásquez et al., 2002). Locomotor activity increases detection by potential predators and overall predatory risk in small mammals (Daly et al., 1990; Norrdahl & Korpimäki, 1998), and birds (Yoder et al., 2004). Alternatively, however, breeding females degus may move less because of parental duties or the fact that high quality food is easily available.

Degus invest a small percentage of their time in grooming themselves, which is not different from the behaviour of other rodents (0.5-8%: Betts, 1976; Leger et al., 1983; Waterman, 1995; Chiarello et al., 1997; Blumstein, 1998). Self-grooming has been suggested to provide a means for broadcasting scents to conspecifics. In particular, self-grooming by male meadow voles (*Microtus pennsylvanicus*) increases the attractiveness of their scents to females (Ferkin et al., 1996). We failed to detect an interaction between sex and breeding-linked seasonality that would support this hypothesis in degus.

Our focal observations of degu behaviour revealed that burrow digging occurs infrequently (0.2%), and that this activity occurs in all seasons. Such lack of seasonality contrasts with previous findings based on the tally of freshly deposited mounds near burrow entrances (Ebensperger & Bozinovic, 2000). The discrepancy might be explained if most digging takes place underground and remains undetected in above ground observations. Alternatively, and since burrows have a rather permanent (historical) value for semi-subterranean mammals (King, 1984), burrow digging may be more responsive to interannual fluctuations in animal density or precipitation than to seasonal changes.

Degus spent a small amount of their activity time in dust-bathing (i.e., ~1%), a finding similar to previous reports on other semi-fossorial rodents (e.g., 0.8%: Leger et al., 1983). Interestingly, however, dust-bathing was more frequent in males during breeding time. Both male and female captive degus alter their dust-bathing activity in response to the familiarity of previous scents deposited on the substratum, but only males decrease their dust-bathing in response to same-sex unfamiliar scents (Ebensperger, 2000; Ebensperger & Caiozzi, 2002). Collectively, this evidence suggests that male degus use dust-bathing in social communication during breeding time. Whether the targets of scents deposited on the ground are potential intruders (males) and/or mates (females) needs further research.

Influences on degu social activity

That degus spend a relatively small percentage of their time in social interactions while above ground (~3%) is in agreement with the tendency of these rodents to form relatively small social groups (Ebensperger & Wallem, 2002; Ebensperger et al., 2004, this study), and fits well with previous estimates from other social and semi-fossorial rodents (Lacher, 1981; Loughry, 1993; Armitage et al., 1996). Male degus spent significantly more time in aggressive interactions during breeding time and when high quality food was easily available (see also Soto-Gamboa et al., 2005), supporting the possibility that changes in social behaviour are linked to breeding cycle rather than to varying conditions in food supply. Greater aggression of degus during breeding time most likely was caused by male-male conflicts over access to breeding females (Soto-Gamboa et al., 2005). Males actively defend a territory that includes the burrow system used by a group of females (Soto-Gamboa, 2004).

Concluding remarks

Contrary to our predictions, degus allocated a rather constant percentage of their activity time to energy acquisition (mostly foraging) and alertness, despite significant changes in breeding activity and ecological conditions (high quality food, predator abundance). However, such constancy does not preclude other seasonal and daily adjustments in their activity. Degus switch from an unimodal activity peak in winter to a bimodal peak pattern in summer, most likely in order to decrease the risk of hyperthermia (Kenagy et al., 2002). Moreover, these daily and seasonal adjustments in overall activity time can be linked to a more frequent use of patches with high vegetation cover, a strategy that can reduce exposure to thermally stressful conditions, and to aerial predators (Lagos et al., 1995a, b; Bacigalupe et al., 2003).

Our study adds to previous evidence suggesting that predators are a major influence on degu behaviour (Ebensperger & Wallem, 2002; Vásquez et al., 2002). The observed changes in time allocated to bipedal vigilance and locomotor activity are consistent with an influence of predation risk. Nevertheless, degus did not exhibit significant changes in total alertness.

As predicted, there were sex differences in seasonal patterns of time allocation by degus, including resting, locomotor activity, dust-bathing, and aggressive social interactions. We hypothesize that sex differences in breeding strategies are one main cause of such seasonal patterns. Whether our 'seasonality' predictor reflects an influence of changes in high quality food remains debatable. On the one hand, the observation that degus did not alter their foraging time despite strong seasonal changes in the abundance of high quality food does not support a major role of food abundance in influencing activity time of these rodents. Moreover, seasonal changes in activity of other hystricognath rodents inhabiting similarly seasonal environments seem related to mate acquisition and parental care duties rather than to variations in food availability (Taber & Macdonald, 1992; Branch, 1993). On the other hand, however, more intense fluctuations in the abundance of high quality food triggered by long-term (inter annual) changes in climatic conditions (e.g., precipitation) might impact degu behaviour more strongly. North and central Chile are affected by such events during El Niño or La Niña episodes.

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The influence of habitat on travel speed, intermittent locomotion, and vigilance in a diurnal rodent

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We studied effects of habitat structure on routine travel velocities, intermittent locomotion, and vigilance by the degu (*Octodon degus*), a diurnal rodent of central Chile. We predicted that travel speed, pauses during locomotion, and vigilance would be greater in open (riskier) than in shrub (safer) habitats. Video recordings of marked individuals in the wild were used to measure speed and other variables of spontaneous locomotion not triggered by predatory attack or any other noticeable stimulus during nonforaging periods. Time spent vigilant while foraging was also measured. Because degus use bare-ground runways for distant movements (e.g., between burrow openings and/or food patches), data on locomotion decisions were not confounded by effects of obstructive vegetation cover and/or resource abundance. When moving across the habitat between different feeding places, degus showed an intermittent pattern of locomotion, interrupting running events with short pauses. As predicted, travel speed and the duration of pauses between locomotion bursts were significantly greater in open habitats. Further, the duration of locomotion bursts between feeding sites or between feeding sites and burrows was significantly longer in open habitats. Our assumption that pauses and velocities are independent decisions was supported by the lack of correlation between pauses and speeds during locomotion events. During foraging, degus devoted more time to vigilance in open than in shrub habitats. The static position adopted by degus during pauses, the speeds attained during movements, and the concordance between pausing behavior and vigilance across habitats suggest that pausing has an antipredatory role and is not limited to orientation and/or physiological recovery. Our results support the view that degus perceive higher predation risk in open areas and that flexible movement behavior reflects an adaptive antipredator response. *Key words:* antipredator behavior, degus, *Octodon degus*, pausing behavior, predation risk, travel speed, vigilance. *[Behav Ecol 13:182–187 (2002)]*

Decisions about locomotion are integral to many fitness-related activities, such as foraging and predator avoidance (Djawdan and Garland, 1988; Garland et al., 1988; Houston, 1992; Swingland and Greenwood, 1983). For example, running speed has been widely described as a key attribute of escape behavior (Blumstein, 1992; Ydenberg and Dill, 1986). Smith (1995) showed that golden-mantled ground squirrels (*Spermophilus lateralis*) run faster than coexisting least chipmunks (*Tamias minimus*), which seems to allow the former species to use more exposed areas with lower predation hazard. Movement rates, distances, and changes in velocity may also influence feeding success (Gendron and Staddon, 1983; O'Brien et al., 1990). For instance, prey capture is greatly influenced by pausing behavior (i.e., pauses between movement bursts) and movement distance in flycatchers and owls (Davies, 1977; Sonerud, 1992).

The structural complexity of the habitat may affect movement behavior through (1) physically impeding locomotion (e.g., Brownsmith, 1977; Crist and Wiens, 1994; Schooley et al., 1996), (2) making movement more conspicuous and thus riskier (e.g., Brillhart and Kaufman, 1991), (3) providing a higher density of resources, hence favoring slower speeds so that resource opportunities are not missed (see Brownsmith, 1977), (4) increasing protection against predators through hiding cover (e.g., Thompson, 1982), and/or (5) increasing visual obstruction, thus reducing the ability to detect predators (Metcalfe, 1984; Schooley et al., 1996). The relationship between predation risk and habitat structure has stood out in the literature (e.g., see Lima, 1998; Lima and Dill, 1990; Ylönen and Magnhagen, 1992, for reviews). A common finding for nocturnal desert rodents is that vegetated shrub microhabitats provide safer conditions against raptors (e.g., Brown, 1988; Brown et al., 1988; Kotler, 1984; Kotler et al., 1991; Longland and Price, 1991). Despite the vast literature showing diverse effects of habitat structure over prey behavior such as foraging, refuge and space use, grouping, and vigilance (e.g., Brown, 1988; Elgar, 1989; Kotler and Blaustein, 1995; Korpimäki et al., 1996; Longland and Price, 1991), few investigations have addressed the influence of habitat structure on locomotion and running velocities. An exception is the study of Schooley et al. (1996), in which Townsend's ground squirrels (*Spermophilus townsendii*) exhibited slower escape speeds in shrub habitats than in open areas. According to these authors and contrary to the common finding that vegetation provides safer conditions, shrub vegetation obstructs movement and visual detection of predators, and hence squirrels seem to experience higher predation risk in shrub habitats. A drawback of the majority of studies that have measured running speed (e.g., Blumstein, 1992; Djawdan and Garland, 1988; Garland et al., 1988) is the measurement of velocities under laboratory or seminatural conditions, including artificial tracks, release of captive animals, and artificial stimuli to elicit running (e.g., humans, raptor models, trained animals). Moreover, there is a lack of studies measuring spontaneous or routine travel speeds under natural conditions.

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Many animals do not move continuously through their habitat but show an overall pattern of intermittent locomotion, with pauses breaking up movement bursts (see Pennisi, 2000, for a recent discussion). Pauses may allow animals to increase detection both of predators and prey (Gendron and Staddon, 1983; McAdam and Kramer, 1998; O'Brien et al., 1990). If pausing occurs between bursts of rapid locomotion among feeding sites, it may improve predator detection (e.g., McAdam and Kramer, 1998); if it occurs between events of slow locomotion within feeding sites (i.e., while foraging), it may improve prey detection and capture (e.g., Anderson et al., 1997; Gendron and Staddon, 1983; O'Brien, 1990), as well as predator detection and avoidance (Lima and Dill, 1990). Pauses might also make prey more cryptic and reduce capture ability if predators are more likely to detect or attack moving prey (Curio, 1976; Martell and Dill, 1995). Pauses also may provide orientation cues for navigation throughout the habitat (Dyer, 1998). From a physiological point of view, pausing may serve as a resting period (Weinstein and Full, 1992). However, even if pausing functions to gain navigation cues and/or physiological recovery, it may also contribute to information processing and enhanced predator detection (Dukas, 1998). Also, during foraging activities not involving locomotion, animals normally interrupt feeding with vigilance events. Higher levels of vigilance are associated with higher perceived predation risk (Elgar, 1989). Although a faster speed may increase safety, it might also imply a higher cost, for instance, associated with greater energy expenditure (Taylor et al., 1982). Further, longer pauses favoring predator detection might also increase other costs such as increased total travel time (i.e., time exposed to predators), thus decreasing time that could be spent at feeding sites or refuges.

The purpose of this study was to assess the influence of habitat structure on routine travel speed, pausing behavior, and vigilance in the caviomorph rodent *Octodon degus* (Rodentia: Octodontidae; common name: degu). *Octodon degus* is a semifossorial, herbivorous rodent that inhabits xeric habitats of central Chile. Most daytime activities take place above ground (Fulk, 1976; Vásquez, 1997). Degus use shrub and open habitats when above ground, and previous studies suggest that shrub habitats provide lower predation risk than open areas (Lagos et al., 1995, Vásquez RA, unpublished data). Degus are social rodents that live in underground galleries, connected above ground by a system of runways (Fulk, 1976; Vásquez, 1997; Yáñez and Jaksic, 1978). These runways are highly conspicuous because frequent use by degus leads to bare ground along the runways (Fulk, 1976; Vásquez, 1997; Yáñez & Jaksic, 1978). Normally, these runways connect burrow entrances of different galleries in a straight line. Degus usually use the runways to move between distant locations within their home range, and they leave the runways only to forage (or sometimes to engage in social activities), particularly away from burrow openings (Vásquez, 1997; Vásquez RA and Bozinovic F, personal observations). Close to burrow entrances, degu activity often produces an area of completely bare ground where animals normally do not forage but engage in behaviors such as agonistic interactions, play behavior, reciprocal grooming, dust bathing, prolonged vigilance, resting, and burrow maintenance (Fulk, 1976; Vásquez, 1997; Yáñez & Jaksic, 1978; Ebensperger LA, unpublished data). The degu is an interesting animal model for testing hypotheses related to locomotion because its almost exclusive use of runways for distant movements and its exploitation of localized food patches allow the investigator to exclude the influence of physical obstruction and differential resource density on movement behavior.

If predation risk increases significantly in open areas, we predicted that degus should run faster when using open habitats, particularly if vegetation and food sources do not interfere with movement behavior, in spite of greater energetic costs of faster speed. We also predicted that degus should break locomotion bursts with longer pauses in open (riskier) habitats, particularly if pausing decreases overall predation risk, albeit accepting the cost of more time away from a feeding site or refuge. Our approach assumes that travel speed and the duration of (preceding and subsequent) pauses are independent decisions. This assumption was explicitly analyzed. To further support the view that habitat structure affects perceived predation risk, we measured individual vigilance of foraging degus in open and shrub habitats. During foraging activities, we expected degus to be more vigilant in open habitats. To our knowledge, this is the first study reporting habitat effects on routine travel speed under natural conditions.

METHODS

We studied a natural population of degus inhabiting a site in the oriental slopes of the coastal range (70°53′ W, 33°28′ S, 450 m above sea level) at the field station of the University of Chile, 30 km west of Santiago, central Chile. The area has Mediterranean climate characterized by warm, dry summers and wet winters and is located within the biogeographical zone known as matorral (Rundel, 1981). The studied population inhabited an area where two conspicuous habitats were distinguished: an open habitat comprising almost exclusively bare ground and dried small herbs with 2% of plant cover, and a shrub habitat comprising small shrubs (*Senecio* sp.) and herbs (*Erodium* sp., *Hordeum* sp.). In the shrub habitat, plant cover was 31%, and most vegetation had a height range of 10–50 cm. Degu predators such as culpeo foxes (*Pseudalopex culpaeus*) and black-chested buzzard eagles (*Geranoaetus melanoleucus*) were observed regularly in the area (see Vásquez, 1997).

Degus were recorded in a site of approximately 2 ha containing similar areas of both habitats. Because speed can be influenced by the arrangement of runways and burrow openings, we took special care to choose open and shrub habitats where runways and burrows had similar characteristics and densities, runways with few or no turns, similar lengths of straight lines, and even distributions of burrow openings. This was one of the reasons that we chose a shrub habitat with low and sparse vegetation (see Lagos et al., 1995, for degu populations dwelling in more densely vegetated habitats); the other reason was visibility of the degus being observed. We selected areas with similar sizes of each habitat to reduce any possible effect of total distance, total length of runways, and/or overall abundance of food patches. Observations were eased by the fact that most diurnal activities of degus, particularly foraging, take place above ground. From midsummer through early winter, most herbs are dried, and foraging is carried out almost exclusively in specific, well-delimited feeding sites with high densities of dried herbs and/or remaining green vegetation (Vásquez RA, unpublished data). During summer, degus show a bimodal period of above-ground activity with an interruption at midday when temperatures are highest (Kenagy et al., in press).

During a given period of activity, degus normally run between different feeding sites in bouts (bursts) of locomotion that include short pauses (i.e., intermittent locomotion). These running events are not triggered by predatory attacks or by any other noticeable stimuli. Overall, running episodes account for distances of up to 50 m in short periods of time (commonly ≤ 20 s), and often degus go across both habitats. To avoid the effect of neighboring habitat edges (see McAdam and Kramer, 1998), we recorded degus at 10 m or more from the closest habitat border.

Two weeks before recording locomotion behavior, we live-trapped 14 adult degus (mean ± SE weight: 172.3 ± 5.2 g; sex ratio male:female = 6:8) and marked them individually with distinct patterns using black hair-dye. Degus were immediately released after marking. Marking appeared not have any perceptible effect on the behavior of subjects. We video recorded marked subjects in the runways. We used two video cameras (Sony CCD-TR413). Video recordings were made from four different sites, all naturally hidden places located underneath shrubs in the margins of the study area, where degu activity was low or nil. Distance between recorded subjects and observer ranged from 15 to 40 m, and we stopped recording when we noticed that subjects were affected by observers or conspecifics, when animals got off the runways, or when a predator was present in the area. In this way, we only recorded routine travel on runways rather than responses to threatening stimuli. Recordings were made between 0700 h and 1100 h on target animals observed during a continuous time period of 5–40 min. Data collection began 30 min after arrival at the hide. After each recording day and in the study site, one of us watched the video recordings from the corresponding observation points, carefully distinguishing natural marks such as rocks and plants. In this way we identified accurately the runways used by subjects and later measured the distances traveled in each movement event to the nearest centimeter. The duration of running and pausing events was measured from the video recordings using stopwatches. The locomotion part of the study was carried out during the Southern Hemisphere summer between December 1998 and February 1999.

During different periods of observations, when animals were foraging and no locomotion occurred, we measured the time that individual degus devoted to vigilance. Degus were considered to be alert when motionless with the head raised or when standing erect on their hind feet (Vásquez, 1997). Observations began upon sighting an adult-sized degu. Then one of us voice tape-recorded the subject's activity. We stopped recording when the focal degu moved to a different habitat, when group size changed, or when the focal animal went out of sight. Animals were considered to be in the same group when interindividual distances were ≤ 2 m. Total observation time for each focal degu varied between 1.4 and 35.7 min (mean ± SE, 15.1 ± 1.1 min). We repeated these observations during periodic 1–2 day sessions once during midsummer (1999), midfall, and early winter. Both marked and unmarked degus were used as focal subjects. We observed unmarked degus at different locations within our study site to minimize pseudoreplication. Group size affects vigilance of degus (Vásquez, 1997), so we controlled this effect statistically (see below).

We averaged data for each individual for analyses. Data were transformed when appropriate to meet the assumptions of each analysis (Sokal and Rohlf, 1995). We carried out paired t tests to compare locomotion variables between habitats. To examine the influence of habitat type on time allocated to vigilance, we used ANOVA with group size and season as covariates.

RESULTS

Travel speeds and pauses

Degus traveled between feeding places in an intermittent pattern of locomotion and generally crossed shrub and open habitats during long trips. Of 14 marked individuals, we obtained records of 8 subjects (5 males, 3 females); 7 subjects were recorded in both habitats. We did not detect any perceptible difference in locomotion behavior between the sexes, and hence we pooled male and female subjects for analyses. Spontaneous travel speed was 1.82 times faster in the open than in the shrub habitat (paired t test: $t_6 = -4.52$, $p = .004$; Figure 1a). The ranges of observed speeds were 0.91–3.40 m/s in the open habitat and 0.83–1.59 m/s in the shrub habitat. The fastest speed recorded for an unmarked individual was 3.8 m/s in the open habitat. When running, degus adopted at least two different gaits: trotting for slow speeds, and bounding for faster speeds.

During trips between feeding sites or between feeding sites and burrows, degus normally interrupted their movement with short pauses. Pausing accounted for 44% of the total time spent traveling (i.e., pause plus movement). During these brief intervals, degus had their feet on the ground, often in a crouching posture, with the head raised in an alert position. This posture most likely allowed visual scanning of the surroundings and hence visual detection of dangerous events.

The mean duration of pauses was 1.51 times longer in the open than in the shrub habitat ($t_6 = 2.48$, $p = .048$; Figure 1b). Pauses showed a minimum and a maximum duration of 1.07 s and 4.10 s in the open habitat, and 0.50 s and 3.01 s in the shrub habitat, respectively.

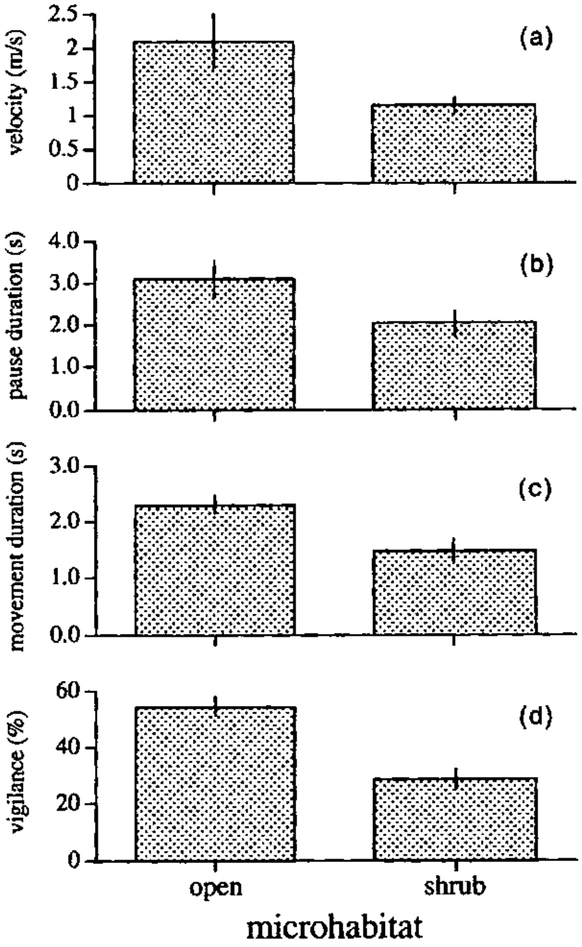

Figure 1
Results (means ± SE) on locomotion variables and vigilance of *O. degus* in open and shrub habitats. (a) Travel velocity during locomotion bursts; (b) pause duration between locomotion bursts; (c) duration of locomotion bursts ($n = 7$ for both habitats in panels a–c); (d) percentage of time devoted to vigilance by *O. degus* in open ($n = 48$) and shrub ($n = 16$) habitats.

The duration of locomotion bursts within a trip between feeding sites or between a feeding site and a burrow was also influenced by habitat. Locomotion bursts were 1.56 times longer in the open than in the shrub habitat ($t_6 = 3.52, p = .013$; Figure 1c). Locomotion bouts had a minimum and a maximum duration of 1.67 s and 2.71 s in the open habitat and 0.66 s and 2.48 s in the shrub habitat, respectively. Because degus moved faster and for longer time during locomotion bursts in the open habitat, the distance they traveled during each locomotion burst was 2.8 times greater in the open habitat ($t_6 = -7.84, p = .0002$). Mean burst distances (± SE) were 4.8 ± 1.1 m and 1.7 ± 0.3 m in the open and shrub habitats, respectively. We found no correlation between speed during a movement burst and the duration of the preceding (Spearman correlation, $r_s = .22, p > .3, n = 8$) and subsequent ($r_s = -.40, p > .1, n = 8$) pause. Therefore, the analysis of pauses and movement bursts as independent decisions seems justified.

Vigilance during foraging

Because vigilance increased during winter as compared with summer and autumn ($t_{60} = 3.05, p = .003$) and it decreased with group size ($t_{60} = 2.7, p = .009$), we entered these factors as covariates. After doing so, we found that degus in open habitats were more vigilant than degus in shrub habitats (ANOVA, $F_{1,60} = 23.4, p < .00001$; Figure 1d). The majority of degu above-ground activities are allocated to foraging not involving long travel distances (Kenagy et al., in press).

DISCUSSION

As we expected, degus adjusted their locomotion behavior according to the type of habitat used. Degus ran faster and paused longer in the open habitat. Running faster in open habitats decreases the time animals spend moving in areas of high visibility, which may reduce predation risk, particularly if predators are more likely to detect and/or attack moving prey (Curio, 1976; Martell and Dill, 1995). We noted that it was far more difficult to detect a motionless degu than a moving one, and often we could only detect animals when they were moving. Open habitats between shrubs have been reported to present higher predation risk to rodents (Bowers et al., 1993; Brown, 1988; Kotler, 1984; but see Schooley et al., 1996). In experimental, large-scale exclusions, Lagos et al. (1995) found that degus use shrub and open microhabitats in similar proportions when predators were excluded, but they select shrub microhabitats when predators were present. Further, above-ground runways between shrubs were more linear in grids with predator access, suggesting that linear runways, by being shorter than more curvy runways, reduce exposure to predators (Lagos et al., 1995).

Longer pausing may increase the efficacy of antipredatory vigilance. Although longer pauses might increase total travel time, thus increasing exposure in riskier habitats, animals seem to overcome this cost with enhanced predator detection. Recently, McAdam and Kramer (1998) reported that squirrels and chipmunks pause frequently during locomotion and that these interruptions improve antipredator vigilance. They found that animals increased their pauses of vigilance when moving toward a condition of higher predation risk. During pauses, degus often adopted a crouching posture with the head raised in alert attitude. This position may allow degus to visually scan the surroundings, increasing their visual detection of dangerous events and hence decreasing their reaction time to flee from potential predators, as occurs in other social rodents (Blumstein, 1998). The static position adopted during pauses may also improve hearing performance in comparison to running behavior, during which audition may be interfered by the noise generated by the movement of the animal. Our results on vigilance were also concordant with data on pauses. Degus devoted a greater fraction of their above-ground activity time to vigilance when in open areas, which parallels the vigilance behavior of other rodent species (Cassini, 1991; Legger et al., 1983). These results agree with our predictions and hence support the view that degus perceive higher predation risk in open areas. Of course, habitats may differ in several aspects beyond predation risk (e.g., food density and quality, obstructions, among others) that might affect locomotion, vigilance, and other behaviors (see Brown, 1988, Elgar, 1989). However, our study system excluded several of such factors, and consequently we suggest that flexibility in running velocity, pausing behavior, and vigilance among habitats reflect, to a large extent, adaptive antipredator responses. Although locomotion composes a small fraction of the daily time budget of degus (Kenagy et al., in press), it certainly can have a major impact on survival because it greatly affects predator escape ability (Swingland and Greenwood, 1983).

Shrub habitats may have two opposing effects on the predation risk experienced by a given prey animal. On the one hand, more complex vegetative structure might provide safer conditions against predators (e.g., Armitage, 1982) by increasing hiding cover or obstructing predator movement. On the other hand, visual and/or physical obstruction might also diminish the effectiveness of antipredator vigilance and/or escape (e.g., Schooley et al., 1995). For instance, Schooley et al. (1995) argued that Townsend's ground squirrels experience higher predation risk in shrub habitats because vegetation obstructs locomotion, making squirrels run slower during fleeing responses. Those findings are opposite to the most frequently reported effect of shrub habitats, particularly in arid environments where predation risk tends to be higher in open areas (e.g., Brown et al., 1988, Kotler et al., 1991). Because degus made intensive use of their runways, they should not have experienced increased physical obstruction in shrub habitats compared to open areas. In fact, we had observed that, upon a predatory attack, foraging degus flee toward the nearest runways and then run to the nearest burrow (see Vásquez, 1997). Observations revealed that degus consider runways a more familiar area compared to open terrain, where obstructions such as rocks, twigs, and herbs make locomotion more difficult.

Although our findings support the view that predation has been a major selective factor on movement behavior, pausing behavior may also function to gain orientation cues or increase physiological endurance. If habitat structures are used for orientation, longer pauses would be expected in areas with fewer physical landmarks (i.e., open habitats) in order to gain navigation cues (see Dyer, 1998). However, the concordant results between pauses and vigilance make the predation risk hypothesis a more parsimonious explanation. In any case, pauses may well play both roles, since in general, pauses increase the capacity to obtain different kinds of information (Dukas, 1998). In contrast, if animals move at sufficiently high velocities, thus using anaerobic energy, brief pauses may improve overall performance (e.g., Weinstein and Full, 1992, see also Pennisi, 2000). However, running velocities recorded are probably well below the maximum running speed of degus. Kenagy et al. (in press) have recently observed that degus can run up to 5.7 m/s after being released; this speed is greater than the maximum velocity expected from allometric considerations (see below). Although our data include acceleration and deceleration times and hence underestimate the maximum speed attained during a running event, it appears that degus run at submaximal speeds in their normal movements, especially if not being attacked by a predator.

Using allometric mammalian models (Garland, 1983), we calculated that the maximum speed for a 180-g degu should be 4.9 m/s (see also Jones and Lindstedt, 1993). Therefore, our field data show that spontaneous locomotion velocity of degus is below their observed and theoretical maximum, and below the maximum aerobic speed (2.4 m/s; following Garland, 1983). Consequently, intermittent running should not play an important role in endurance capacity of degus (see McAdam and Kramer, 1998, for a similar conclusion for squirrels). This assertion is further supported by empirical evidence showing that physiological recovery (accomplished through resting pauses) after bursts of maximal activity requires longer time than the activity itself (see Bennett and Ruben, 1979). However, recent findings provide new evidence for increased physiological performance due to intermittent locomotion (see Pennisi, 2000). This area certainly deserves further research.

The lack of correlation between pause duration and speed during running bursts supports our assumption that pauses and locomotion velocities can be considered as independent decisions. Pause patterns during movement episodes seem convergent with the data on vigilance during foraging activities: both increase with higher risk exposure, everything else being equal. If pauses increase with predation risk, one would expect more pauses when approaching a riskier area. We designed our study to reduce variability from this effect (see Methods). In their study on gray squirrels (*Sciurus carolinensis*) and eastern chipmunks (*Tamias striatus*), McAdam and Kramer (1998) found that both species increase their pauses when approaching situations of higher risk.

Flexibility in travel speeds supports the hypothesis that degus perceive greater predation risk in open habitats. Other rodent species also show flexibility in running speeds, although previous studies have assessed escape velocities, whereas we report spontaneous travel velocities not triggered by a noticeable stimulus. Escape speed might also vary with habitat and refuge location, suggesting that rodents exceptionally run at their maximum speed. For example, escape velocity in woodchucks (*Marmota monax*) increases with greater distances to burrow openings (Bonenfant and Kramer, 1996). In any case, submaximal travel speeds during spontaneous movements when animals are not being preyed upon may allow increments in escape velocity when attacks occur (Bonenfant and Kramer, 1996).

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