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Cover: an adult huemul doe reaches for a branch of one of her favourite food sources, *Fuchsia magellanica*, in Fiordo Témpano (Photograph by Daan Wensing).

Quiero volver al sur (Pablo Neruda, 1941)

Enfermo en Verazcruz, recuerdo un día
del Sur, mi tierra, un día de plata
como un rápido pez en el agua del cielo.
Loncoche, Lonquimay, Carahue, desde arriba
esparcidos, rodeados por silencio y raíces,
sentados en sus tronos de cueros y maderas.

El Sur es un caballo echado a pique
coronado levanta el verde hocico caen las gotas,
la sombra de su cola moja el gran archipielago
y en su intestino crece el carbón venerado.
Nunca más, dime, sombra, nunca más, dime, mano,
nunca más, dime pie, puerta, pierna, combate,
trastornarás la selva, el camino, la espiga,
la niebla, el frío, lo que, azul, determinaba
cada uno de tus pasos sin cesar consumidos?
Cielo, déjame un día de estrella a estrella irme
pisando luz y pólvora, destrozando mi sangre
hasta llegar al nido de la lluvia!

Quiero ir
detrás de la madera por el río
Toltén fragante, quiero salir de los aserraderos,
entrar en las cantinas con los pies empapados,
guiarme por la luz del avellano aléctrico,
tenderme junto al excremento de las vacas,
morir y revivir mordiendo trigo.
Océano, tráeme
un día del Sur, un día agarrado a tus olas,
un día de árbol mojado trae un viento
azul polar a mi bandera fría!

Foreword

It was a once in a lifetime experience to spend half a year in the Bernardo O' Higgins National Park in Chile; to walk, work and live next to the huemul that sometimes observes you with the same curiosity as you do, but twenty seconds later goes on with it's daily tasks as if you are invisible; to snooze in the field at two meters distance from a sleeping huemul; to stand on places where no man has ever stood and have a view on yet undiscovered valleys, mountains and plains; to see the shadow of a condor intercept the sunrays on the flickering bright white antlers of a yearling buck; and, above all, to do all that while contributing to the conservation of this wondrous species.

This would not have been possible without the help of many people. I would first like to thank Dr. Pita Verweij, who supported this research as my supervisor from the Utrecht University and helped during preparations and gave useful comments on earlier drafts of this report.

Michel Durand (the director of CAZ) is one of the driving forces behind the huemul project and I want to thank him for letting me participate in this project, for his hospitality when we first arrived in Santiago and for the housing and food supplies which he granted us in the research area. Mauricio Rosenfeld (CAZ) was very helpful with all the paperwork during our time in Chile. His support was much appreciated, especially during the first weeks in Punta Arenas. Alejandra Silva (CONAF) helped us during our preparations for our research. She showed a remarkable patience when we tried to explain our ideas in the few words of Spanish we could speak.

I want to thank the Utrecht University, Department of Biology and the Lucy Burgers Foundation for the financial support for the travel, housing and research expenses. Without your help this research wouldn't have been possible.

I would like to thank Dr. M. Kik of the Veterinary Department of Utrecht University and Mr. J. van Haeften for providing me with more insight in the biology of deer in my preparations. Drs. Joep Wensing gave useful comments on Patagonian flora and Prof. dr. Paul Maas helped me with the preparation and taxonomic identification of my plant collection.

Within the national park several people were of great help. First of all Mr. Coronado, the administrator of the Bernardo O' Higgins National park and captain of the yepayek. I want to thank him for letting me work in all the restricted areas we have been, and also for coordinating transportation and supplies, which is a difficult job in an area as big as the Netherlands without any infrastructure. I also want to thank all the park guards: don Manuel, don Guillermo, Juan and Ivan. I want to mention especially Aliro (Cucho), with whom I spent several weeks alone in Fiordo Bernardo. He is a very hard worker and has a very amicable personality. With Victor Zuñiga I spent most of the time in Fiordo Témpano. Without (learning from) his skills for finding deer and for reading tracks we would have never succeeded. His good humour and pleasant companionship made me forget the lack of civilisation in the surroundings. I was very pleased by the inhabitants of Puerto Edén who, after one day, stopped regarding us as tourists. They could never quite understand why two European guys would like to spend half a year in the park, but they showed us their authentic faces and we were welcomed warmly. Especially by the family Zuñiga with whom we stayed. I also want to thank Jorge Prieto M, the service manager of Navimag. He provided us with free transport from and to Puerto Edén in luxurious cabins. In return we were happy to give presentations to the tourists about our research.

In the last place I would like to thank my research companion and good friend Daan Wensing who brought me into contact with this project. His company and vision were of great value during the research, personally as well as professionally.

Summary

A field study on the habitat use and food habitats of the huemul (*Hippocamelus bisulcus*) was done in the fjords Témpano and Bernardo in the Bernardo O'Higgins National Park in Chilean Patagonia. The huemul is a deer species in danger of extinction according to the red list of threatened animals (IUCN) and the Red Book of Chile's Land vertebrates. It has been the focus of relatively few scientific studies. During this study the largest known population of the world was found in Fiordo Bernardo.

Part of this study has a descriptive character. An inventory of the flora present in Fiordo Témpano was made and habitat descriptions of both fjords were formulated. The plant collection needs more analysis, but at least two vulnerable species were found according to the 1997 IUCN red list of threatened plants (Walter and Gillett, 1998): *Pilgerodendron uviferum* and *Dacrydium fonkii*. Also three non-native plant species were found in Fiordo Témpano, the presence of these species should be considered as a warning.

Both fjords differed in (habitat) characteristics. The valley of Fiordo Témpano could best be described as grassland dominated and the valley in Fiordo Bernardo as shrubland dominated.

In Fiordo Témpano huemuls spent most time in footslope habitat, low-elevation bluffs, forest border and periglacial grassland. Correcting for the relative surface, a measure for preference, Ivlev's Selectivity Index, was computed. A preference was found for footslope habitat, low-elevation bluffs and forest border, not for periglacial grassland, although in former years a preference for grassland was found. The most likely reason for this shift is the presence of cattle in the area. In Fiordo Bernardo most time was spent in low shrub vegetation and on beaches and riverbeds. An estimated selectivity index shows that the last mentioned habitat has a strong preference.

Gunnera magellanica and, when available, *Fuchsia magellanica* are the most important species in the diet of the huemul in the research area. Species composition of the diet does not differ much during the year, but there is a shift in importance of plant species in the diet. The huemul can be classified within the concentrate selectors group, but it is not an extreme example in this regard.

Recommendations are provided in the last chapter. Further research should be done on a lot of issues, such as winter diet and winter habitat use and population dynamics. The usage of radio collars for monitoring of movements is strongly recommended.

This report contributes to the knowledge of habitat use and diet preferences in periglacial sites and can be used as a guide to find suitable habitat for reintroduction of huemul deer. Also can it be used to assess on which sites chances of finding huemuls are largest and it thus gives more direction to the efforts of conserving this wonderful species.

Contents

1. Introduction

The Huemul (*Hippocamelus bisulcus*) is an endemic deer species that can be found in the Patagonian Andes in the southern cone of South America. It is threatened with extinction according to the Red List of threatened fauna species (IUCN) and the Red Book of Chile's Land vertebrates (Cooperation Agreement, 2004). The latest estimation of the remaining Huemul world population is less than 1,000 individuals, which make up isolated and fragmented populations (Saucedo and Gill, 2004).

The species is considered an umbrella species, because it requires broad areas of habitat (Noss and Cooperrider, 1994; Hunter, 1996), and its conservation is assumed to lead to the protection of other Andean wildlife (Parques Nacionales de Argentina, 1992). It also is considered to be a flagship species symbolising the vulnerable natural heritage of the south Andes and being depicted on the national coat of arms of Chile (Povilitis, 1998).

Bernardo 'O Higgins National Park is said to contain the last viable populations of this endangered deer species (Cooperation Agreement, 2004). Especially in an area within the national park, called the 'Huemul Project area', with in its centre a fjord called Fiordo Témpano (Iceberg fjord), the presence of huemul was determined. Therefore our focus should be on this area to preserve this important deer species. And with its conservation we would also safeguard the other natural values within the project area.

To do this, the Huemul Project was started. The Huemul Project is a conservation effort of three different organisations co-operating. It consists of CONAF (Corporación Nacional Forestal), the Chilean forestry service and owner of the project area, WCS (Wildlife Conservation Society), a large international conservation organisation, with its main basis in New York, and CAZ (Centro de Aclimatación Zoológicas de la Dehesa), a private nature conservation agency from Chile. During an international meeting of the different parties co-operating in the huemul project the project goal was reformulated as: "… conserve viable populations of wildlife with emphasis on the Huemul…, …in Fiordo Témpano and its surroundings".

Because it is living in a remote area with harsh climatic conditions and rough terrain, little scientific information has been gathered on the huemul (see paragraph 2.3). But for a good conservation plan, knowledge is needed on a large number of issues. We should know for instance, what the primary habitat is during the different seasons. To what amount inbreeding is a problem in the population. What do healthy population dynamics look like and does natural predation form a threat? All these important questions are to be answered in order to plan efficient and feasible measures for the preservation of this species.

This study focussed on habitat use and food habits, because habitat and food availability are the two most important variables that determine whether an area can support huemul populations. The research area is restricted to two fjords: Fiordo Témpano and Fiordo Bernardo. Both fjords are within the Huemul project area. Fiordo Témpano forms its centre and Fiordo Bernardo forms its northern border.

The main research question is as follows:

Which habitat- and dietary preferences does the huemul have within Fiordo Témpano and Fiordo Bernardo?

I hypothesise that huemuls are not indifferent to their environment, but have clear habitat and dietary preferences. The description of these preferences can be used as a guideline to recognise areas that are promising for (future) huemul populations. It will also fill an important gap in our knowledge of this relatively unknown species.

To answer this main question, a number of sub-questions need to be answered:

- What kinds of habitat occur within both fjords?
- To what extent are these habitats used by huemuls?
- Which plant species occur in the research area?
- Which plant species do huemuls consume in both fjords and what is the relative contribution to their diet?

The habitat use and diet might be all the same in the research area, but they can also differ locally. My hypothesis is that there are local differences in habitat use and food habits, depending on the available local conditions. These differences give an idea of the plasticity of the species according to habitat use and diet preferences, but it would be even more important to find similarities in habitat use and food habits, as this would point towards overall habitat requirements. Therefore, I also hypothesise that general preconditions can be given for important huemul habitat in this area and that one or more certain plant species are important as a food source in both fjords.
This leads to the following questions:

- Is there a difference in habitat use between both fjords?
- What habitat conditions do the fjords have in common?
- Is there a difference in food habits between both fjords?
- Which plant species are common diet species for the huemul in both fjords?

In answering these questions I hope I can contribute to our knowledge of this relatively unknown species and contribute to its conservation for future generations.

2. The huemul

2.1 Introduction

The huemul (*Hippocamelus bisulcus*) is one of the two current species, belonging to the genus *Hippocamelus*. It is a member of the large subfamily Odocoileinae, the New World deer. The other species of this genus is the taruca, or *Hippocamelus artensis*. Another name for this deer is Northern Andean deer, opposite to the Southern Andean deer, as the huemul is called sometimes. The taruca is smaller compared to the huemul. Its distribution is more towards the North and it lives at higher altitudes.

This chapter first provides a short physical description of the Huemul. Then the results of a literature review on all deer species are discussed and the relevant results of a research that was carried out simultaneously and in the same research area are presented.

2.2 Physical description of the Huemul

Being well adapted to the broken terrain it lives in, the Huemul is stocky built. With its short legs it can climb easily over narrow mountain ridges and walk with ease through the rough landscapes.

Another feature that makes the huemul well adapted to its habitat is its coat. Consisting of long curled hairs (3-4 cm in summer, 5-7 cm in winter) (Díaz and Smith-Flueck, 2000) it provides protection against the cold and moist climate. The colour varies from yellowish brown to grey-brown to darker brown.

Sexual dimorphism is clear. Bucks have antlers and a black facial 'mask'. The antlers are cast away each year towards the end of winter (Montecinos, 1995) and will grow in length and diameter each following year. The black mask bucks wear, runs along the snout towards the eyes leaving the forehead in the original colour. This has a heart shaped figure as a result; giving bucks a characteristic expression. Bucks are bigger and heavier. Whereas does have an average shoulder height of 81 cm (Povilitis, 1979) and a body weight of 70 to 80 kg (Díaz and Smith-Flueck, 2000), bucks' average shoulder height is 90 cm (Povilitis, 1979), and a weight of approximately 90 kg (Serret, 2001).

There is no sexual dimorphism present in fawns and they are born unspotted (Povilitis, 1979). Bucks will grow antlers when they are around six months old (Díaz and Smith-Flueck, 2000), the facial mask will appear during the same period (own observation).

2.3 Inventory of scientific literature on deer subfamilies, genera and species

The Huemul was only subject to relatively few scientific studies. The genus *Hippocamelus* is one of the least studied genera of the Cervidae (Table 1), although most studies have been undertaken on the subfamily Odocoileinae of which *Hippocamelus sp.* is a member. To illustrate the division in research among the different deer genera and –species an inventory of available scientific literature on deer species was made. Using the Web of Knowledge database, ranging from 1988 till the date of the query (20th of May 2005), the

number of published scientific articles was determined per species. It is clear that there is not an equal division. From Table 1 one can deduct that the quantity of research done on a certain genus can be divided into four categories:

- n>1000; *Cervus sp.* And *Odocoileus sp.*
- 100<n≤1000; *Dama sp.*, *Alces sp.*, *Capreolus sp.* and *Rangifer sp.*
- 20<n≤100; *Axis sp.*, *Elaphurus sp.* And *Muntiacus sp.*
- n≤20; *Hydropotes sp.*, *Elaphodes sp.*, *Megamuntiacus sp.*, *Blastocerus sp.*, *Hippocamelus sp.*, *Mazama sp.*, *Ozotocerus sp.* And *Pudu sp.*

Figure 1: Clockwise: an adult doe, a fawn, a juvenile buck with its antlers just emerging, an adult buck (photographs by Daan Wensing) and a yearling buck (photograph by Jasper van Winden).

In the first category (n>1000) two genera are present: one genus (*Cervus sp.*) is representing the old world deer and one genus (*Odocoileus sp.*) is representing the new world deer. The bulk of the research of both genera has been done on one species, respectively the red deer (*Cervus elaphus*) and the white-tailed deer (*Odocoileus virginianus*). Both are abundant species, living in relatively accessible habitat.

In the second category (100<n≤1000) four genera are present. All are small genera, with only one or two species. In all cases only one species was researched very intensively. All these species are abundant and live in comparatively accessible habitat.

The third category (20<n≤100) holds three genera. *Elaphurus sp.* has only one species (*E. davidianus*). Four species belong to *Axis sp.*, of which one is studied more intensively than the others (*A. axis*). To *Muntiacus sp.* Belong eight species; two of them have been

studied more intensively (*M. muntjak* and *M. reevesi*). With the exception of *E. daviadianus*, none of the most researched species of the genera is endangered. They are hard to study however: *Axis axis* is very nervous and will flee at the slightest provocation. Both species of *Muntiacus sp.* Are nocturnal and have thick forest as their main habitat. *E. davidianus* is only known to live in the wild in one reserve in China where it was reintroduced in the late 1980´s. It is critically endangered.

Eight genera are in the fourth category (≤20). All of them, except for *Mazama sp.*, have only one or two species. These genera live either in remote areas with a hardly accessible habitat (*Hydropotes sp., Elaphodes sp., Megamuntiacus sp., Blastocerus sp., Hippocamelus sp.*) or are secretive or nocturnal by nature (*Mazama sp., Ozotocerus sp.* And *Pudu sp.*). *Megamuntiacus sp.* For example was not even discovered since 1994.

Hippocamelus sp., of which the Huemul is a member, belongs to the last category. Only thirteen articles were found for this genus in the query. In none of the articles was there a field study done on *H. antisensis*. For the Huemul (*H. bisulcus*) this was five times the case. This is illustrative for the lack of empirical data on both species of *Hippocamelus sp.*

2.4 Description of huemul populations in the surroundings of Fiordo Témpano and Fiordo Bernardo

Introduction

For this study observations were done in two fjords: Fiordo Témpano and Fiordo Bernardo. This study focused on habitat and food habits, the research of my travel- and research companion Daan Wensing focused on the number and composition of huemul populations and their behaviour and social organisation. He also made a conservation analysis (Wensing, 2005). In continuation I shortly summarise the most important outcomes of his study that are relevant for this present study.

Number of huemuls in both fjords

The number of huemuls differed greatly between both areas. In Fiordo Témpano the number of huemuls living in Huemul valley and the adjacent valleys was 14. On the opposite side of the fjord (Valley V, as shown in fig. 4) seven more huemuls were found. These huemuls were regarded as part of a separate population and were not observed in this research. At Fiordo Bernardo a total of 75 huemuls was found: 31 on the southern side of the valley and 44 on the northern side. These two locations were considered separate sites because of the broad water barrier in between. Together they form the largest known (sub)population in the world. For the diet study, only the data of the southern side was used.

Age- and sex structure

In both valleys roughly twice as many adult does were found as bucks (Table 2 and 3). The ratio between adult does and fawn shows that in Fiordo Témpano 12.5% of the adult females had a young at the moment of the research (Huemuls normally only get one youngster a year). The average of Fiordo Bernardo was 26.8% (Table 3).

Table 1: The number of articles found on all deer species using the Web of Knowledge database ranging from 1988 till present (date of query was 20th May 2005). The outcomes are based on searching on scientific species names, the numbers of the subfamilies and genera are the number of articles per species summed up.

Scientific name	Common name	Number of articles
Cervinae		2835
Axis sp.		**72**
Axis axis	Axis deer, Chital	67
Axis calamianensis	Calamian deer	0
Axis kuhlii	Bawean deer, Kuhl's deer	0
Axis porcinus	Hog deer	5
Cervus sp.		**2234**
Cervus albirostris	Thorold's deer, white-lipped deer	7
Cervus alfredi	Philippine spotted deer	0
Cervus duvaucelii	Barasingha, swamp deer	0
Cervus elaphus	Red deer, Wapiti, American elk	1907
Cervus eldii	Eld's deer, Thamin	1
Cervus mariannus	Philippine sambar	2
Cervus nippon	Sika deer, Japanese deer	241
Cervus schomburgki	Schomburgk's deer	0
Cervus timorensis	Rusa deer, Sunda sambar	23
Cervus unicolor	Sambar	53
Dama sp.		**489**
Dama dama	European fallow deer	476
Dama mesopotamica	Persian fallow deer	13
Elaphurus sp.		**40**
Elaphurus davidianus	Pere David's deer, milu	40
Hydropotinae		15
Hydropotes sp.		**15**
Hydropotes inermis	Chinese water deer	15
Muntiacinae		92
Elaphodus sp.		**4**
Elaphodus cephalophus	Tufted deer	4
Megamuntiacus sp.		**6**
Megamuntiacus vuquangensis	Giant muntjac	6
Muntiacus sp.		**82**
Muntiacus atherodes	Bornean yellow muntjac	0
Muntiacus crinifrons	Black muntjac	2
Muntiacus feae	Fea's muntjac	1
Muntiacus gongshanensis	Gongshan muntjac	0
Muntiacus muntjak	Indian muntjac	30

Table 1 continued		
Muntiacus putaoensis	Leaf deer	2
Muntiacus reevesi	Reeves's muntjac	46
Muntiacus truongsonensis	Truong Son muntjac	1
Odocoileinae		3509
Alces sp.		**547**
Alces alces	Moose, European elk	547
Blastocerus sp.		**13**
Blastocerus dichotomus	Marsh deer	13
Capreolus sp.		**650**
Capreolus capreolus	European roe deer	637
Capreolus pygargus	Siberian roe deer	13
Hippocamelus sp.		**13**
Hippocamelus antisensis	Peruvian guemal, taruca	2
Hippocamelus bisulcus	Chilean guemal, South Andean huemul	11
Mazama sp.		**16**
Mazama americana	Red brocket	13
Mazama bricenii	Grey dwarf brocket	0
Mazama chunyi	Dwarf brocket	1
Mazama gouazoupira	Brown brocket	1
Mazama nana	Lesser brocket, bororo	1
Mazama rufina	Little red brocket	0
Odocoileus sp.		**1591**
Odocoileus hemionus	Mule deer	438
Odocoileus virginianus	White-tailed deer	1153
Ozotoceros sp.		**12**
Ozotoceros bezoarticus	Pampas deer	12
Pudu sp.		**20**
Pudu mephistophiles	Northern pudu	2
Pudu puda	Southern pudu	18
Rangifer sp.		**647**
Rangifer tarandus	Caribou, reindeer	647
Total		6451

Table 2: Number and composition of huemul populations in Fiordo Témpano and the North and South side of Fiordo Bernardo (obtained from Wensing, 2005)

	Adult ♂	Adult ♀	Yearling ♂	Yearling ♀	Fawn♀/♂	Total
Fiordo Témpano	4	8	1	0	1	14
Fiordo Bernardo S	7	14	4	2	4	31
Fiordo Bernardo N	10	24	3	1	6	44

Table 3: Adult and total buck-doe ratio and fawn-adult doe ratio (obtained from Wensing, 2005)

	adult ♂:♀ x 100	total ♂:♀ x 100	fawn : adult♀ x100
Fiordo Témpano	50	63	12.5
Fiordo Bernardo S	50	67	28.6
Fiordo Bernardo N	42	53	25

Mortality at Fiordo Témpano and Fiordo Bernardo

In both valleys carcasses were found. In Fiordo Témpano five remains of deer were found: four of adult does, and one fawn. In Fiordo Bernardo eight carcasses were found: seven adult bucks and one adult doe. It was evident that this last one was killed by men.

Group size

Group sizes differed between both fjords. In Fiordo Témpano group size ranged from 1 to 4 individuals. The mean group size was 1.47. In Fiordo Bernardo group size ranged from 1 to 8 and the mean group size was 2.30.

3. Research area

3.1 Chile

Chile has an extraordinary geographical shape. With its length of 4,300 km it contains all possible different biomes except for tropical rainforest. It is a very narrow strip of land, lying only west of the Andes, rarely wider than 180 km. (Lonely planet, 2000). The country is so narrow and the coastal line is so insected that it is not even possible to cross the country North-South or vice versa by road, and staying within its borders (Lonely planet, 2000). To keep such a country governable it was divided in thirteen regions (I to XIII). This research took place in the two southernmost regions Aisén (XI) and Magellanes (XII), in Bernardo O'Higgins National Park.

3.2 Bernardo O'Higgins National Park

The Bernardo O'Higgins National Park (Figure 2) was created by law decree Nº264 on July 22nd 1969, covering an area of 1,761,000 hectares. By law decree Nº392 on June 14th 1989 the park surface became 3,525,901.2 hectares. About 26% of the total area is within the Aisén (XI) Region, and the rest of the area is within the Magallanes (XII) Region. The whole park is state owned and the exact location of the park is between 47º 54'59'' and 51º 41'52'' south, and 72º 59'10'' and 75º 44'50'' east. The park features: sub-Antarctic evergreen forests, temperate rainforest formations, sub-Antarctic deciduous forest and tundra (Paruelo et al., 2001; Cooperation Agreement, 2004). Within the park there is an abundance of wildlife: huemuls (*Hippocamelus bisulcus*), huillin (*Lontra provocax*), sea lions (*Otaria byronia* and also *Arctocephalus australis*), hunchback whales (*Megaptera novaeangliae*), chilla fox (*Pseudalopex griseus*) and many species of marine birds. The park is only accessible by ship/vessel, due to its physical characteristics (ice, summits and islands). These characteristics made it possible that the original landscape has been preserved (Cooperation Agreement, 2004).

The climate in the National Park is of cyclone type, just like in the rest of the Magallanes region.

3.3 Puerto Edén

There is one populated area within the Bernardo O'Higgins National Park: Puerto Edén, on Wellington Island. CONAF has its administrative office for the park in this village. Most of the people are originally from Chiloé but there are some native Kaweshkars living there as well. The people make a living as fishermen and the local economy is solely based on the extraction of shellfish. Due to the appearance of Red Tide the population of the village decreased rapidly from 258 in 1992 (Cooperation Agreement, 2004) to an estimated population of 140 at present (H. Zuñiga, personal comment). The condition of Red Tide is caused by a dinoflagelate (*Alexandium catenella*), which intoxicates molluscs with a VPM-type toxin. This toxin is deadly to people and therefore extraction of molluscs was stopped in the area. Since two years production has started again in a few sectors as the Red Tide has temporarily disappeared. Another option for extra income for the area is tourism (Coorporation Agreement, 2004).

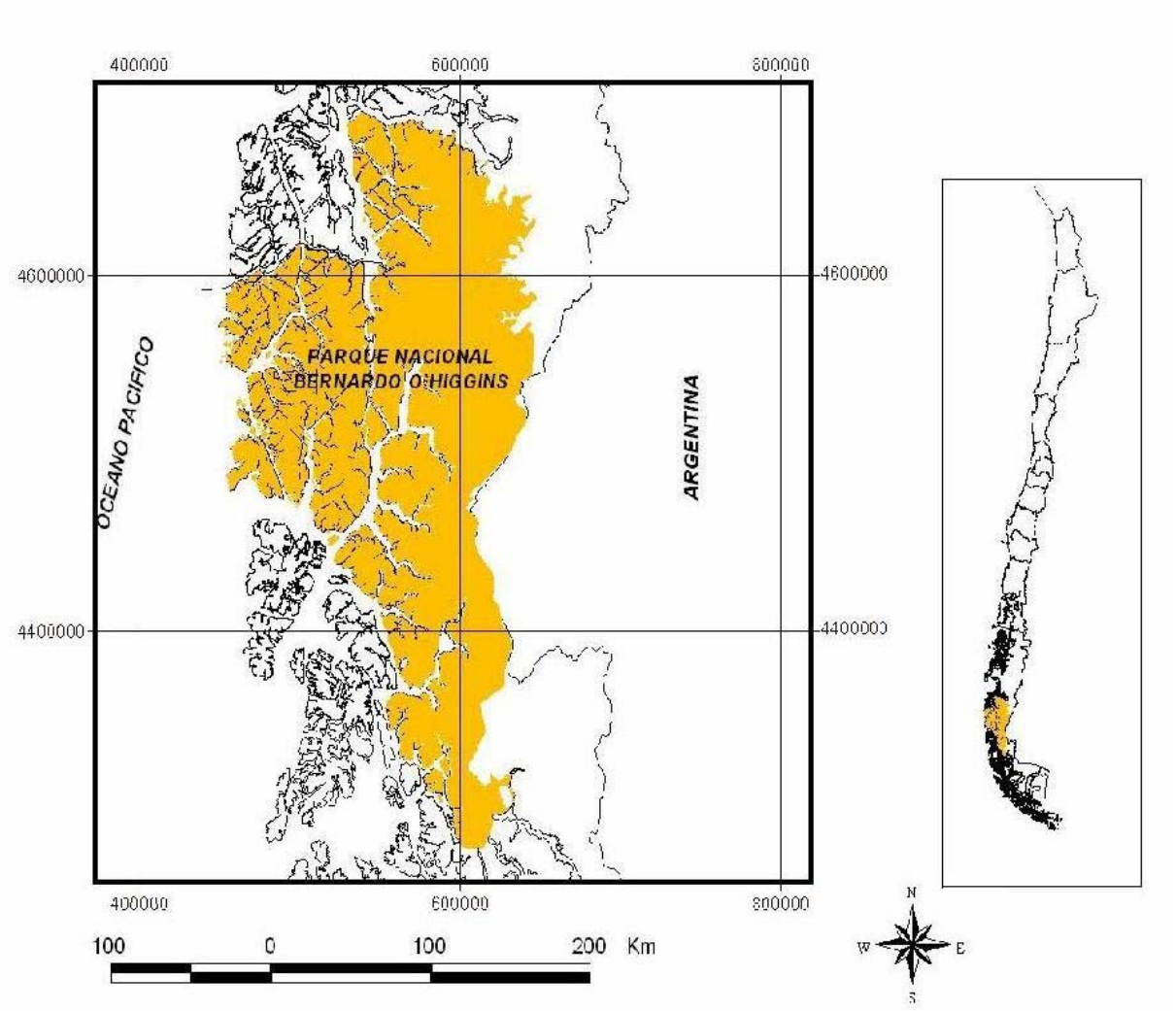

Figure 2: Bernardo O'Higgins National park (source: CONAF).

3.4 The huemul project area

The research area is located within the Bernardo O'Higgins National Park and named The Huemul project area (48º 25'55'' - 48º 58'58'' S, and 73º 51'13'' - 74º 25'31'' E). The research area has an approximate surface area of 50,000 hectares and comprises Fiordo Témpano, the main axes between the Fiordo Bernardo to the north and the Dennman Estuary to the south, which are also part of the research area (Cooperation Agreement, 2004).

In the research area (Low Patagonian subsystem) there is abundant precipitation, which can reach 4,000 mm evenly spread throughout the year. The mean annual temperature ranges between 7º and 8ºC. During summer, the average temperature reaches 11.5ºC. The temperature only occasionally drops below 0ºC in winter (Cooperation Agreement, 2004). In Figure 3 the average daily minimum and maximum temperature and average daily precipitation are shown per month for the years 2001 till 2003. Shortly after the research period a weather station was taken into use within the research area.

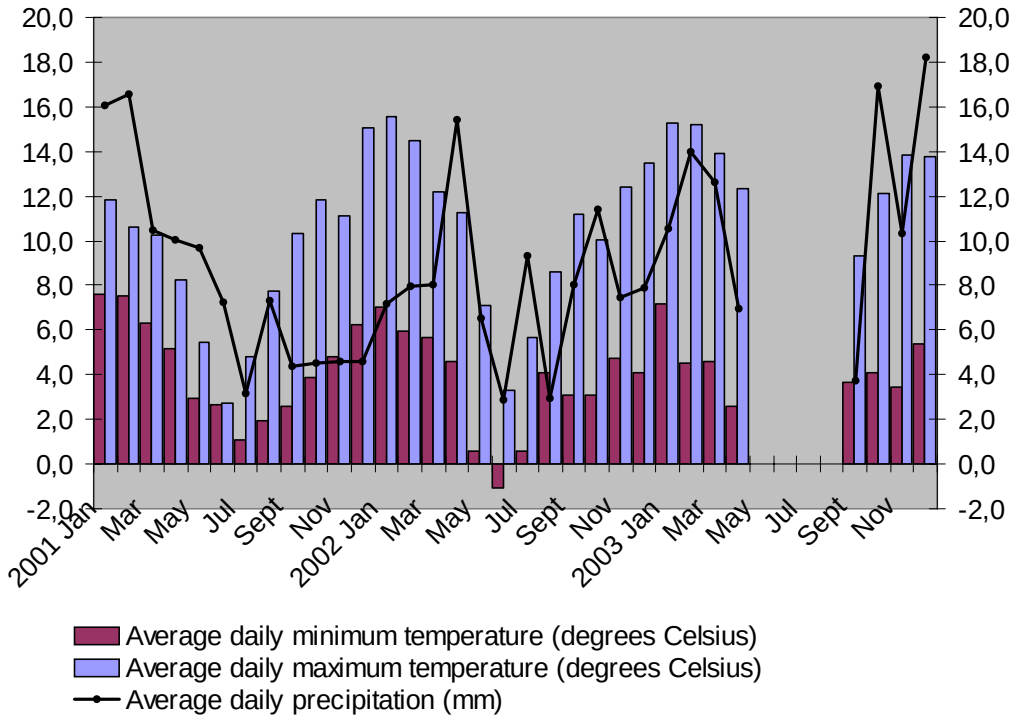

Figure 3: Average daily minimum and maximum temperature, and average daily precipitation in the period of 2001-2003 in Puerto Edén. No data were available from May till August in 2003. (Adapted from weather registration books 2001, 2002 and 2003, CONAF)

Fiordo Témpano

Fiordo Témpano forms the centre of the Huemul project Area. On the Northern side of the fjord lies the Huemul valley. At the entrance of this valley a research station is situated. The valley is located adjacent to the '*Campo Hielo del sur*', Ice field of the south. Aerial photographs of the late forties show that it was still totally covered with ice then. In the last sixty years the ice has retreated to the other side of the fjord and has no direct influence anymore on Huemul valley. Four other valleys around Huemul valley are also surveyed in this study, but most data is collected within Huemul valley (Valley I in Figure 5), an area of over 1000 hectares. Huemul valley has been studied more intensively than the other valleys. The following is a short description of the other valleys:

Valley II has poorly drained soils. The habitats found here are mainly periglacial grassland and young *Nothofagus* forest. A glacier is situated at its terminus to the east. In the north, a river borders the valley. There were at least twelve cows present during the research period.
Valley III is at its highest point situated at 300 m above sea level, but leads into the second valley at 70 m above sea level. The main habitat is Magellanic moorland. Soils are poorly drained. The presence of cows in former years was evident.
Valley IV is under more influence of the glacier than the valleys mentioned above, the main habitat is periglacial grassland. Soils are well drained.
Valley V is as Valley IV under direct influence of the glacier, its main habitat is periglacial grassland. Soils are well drained.

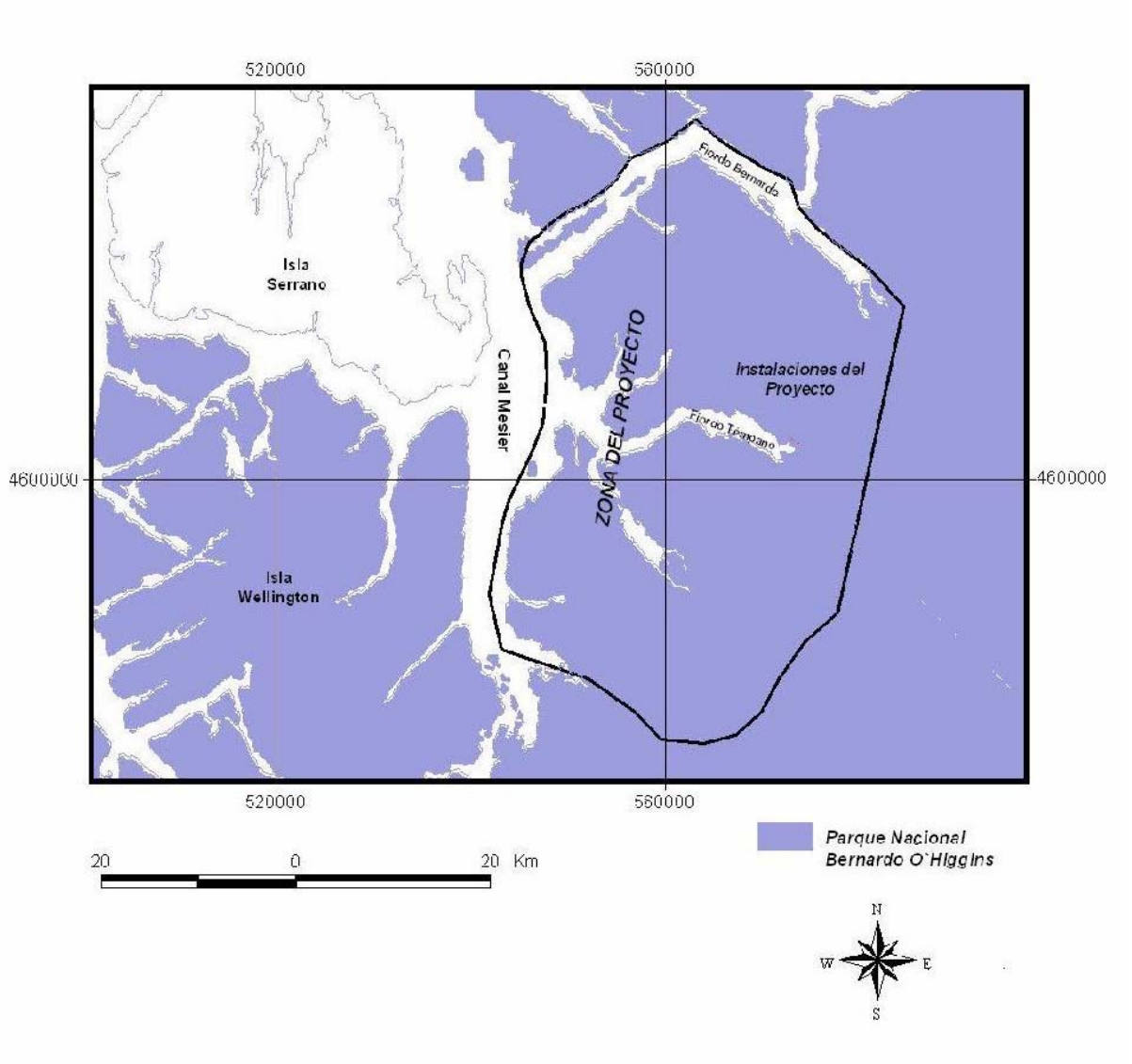

Figure 4: The Huemul project area (Source: CONAF).

Fauna

Bernardo O' Higgins National Park in general is famous for its marine wildlife. Two species of sea lions (*Otaria byronia* and *Arctcephalus australis*) and Peale's dolphin (*Lagenorhynchus australis*) were sighted during the study period in Fiordo Témpano. Outside the fjord the Chilean dolphin (*Cephalorhynchus eutropia*) and Magellanic penguin (*Spheniscus magellanicus*) were sighted. Many bird species were present. Amongst others the Magellanic flying- and flightless steamer duck (respectively *Tachyeres patachonicus* and *Tachyeres pteneres*), large flocks of ashy headed geese (*Chloephaga poliocephala*), the Magellanic woodpecker (*Campephilus magellanicus*) and the Andean condor (*Vultur gryphus*) were sighted. Next to the huemul (*Hippocamelus bisulcus*) the presence of two other larger indigenous terrestrial mammal species has been determined: the culpeo fox (*Pseudalopex culpeus*) and puma (*Felis concolor*).

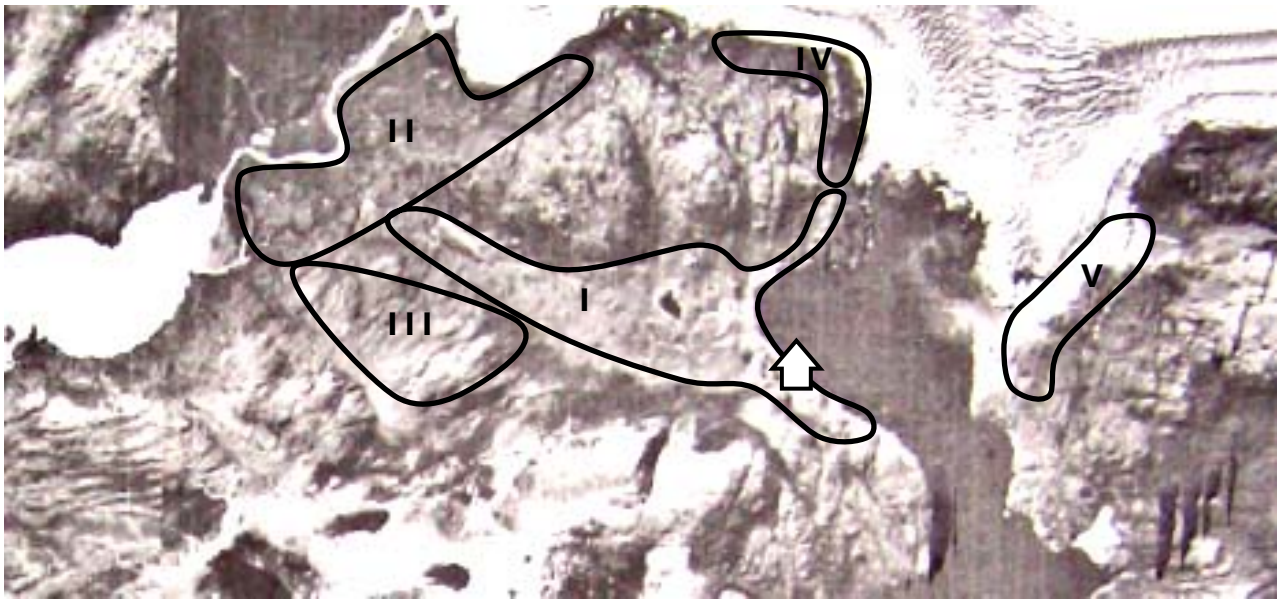

Figure 5: Satellite Photo of Fiordo Témpano. Several valleys are distinguished. Valley I is referred to as Huemul valley, the research station is located at its beach. Valley IV and V show an overlap with the glacier. In the present situation the glacier has retreated further and is not present in the indicated valleys (source: National Army of Chile).

Fiordo Bernardo

Fiordo Bernardo forms the northern border of the Huemul project area. At the end of this fjord lies a valley. A part of the fieldwork of this study took place here. This valley is referred to in this rapport as 'Fiordo Bernardo'. At the terminus of the valley lies a glacier. Retreating, this glacier formed a broad and deep trench allowing seawater into the valley. Mixed with fresh melting water running into the trench a broad and deep river was formed dividing the valley in a north and a south side. Both sides show different characteristics and will be treated separately. The south side has been studied more intensively than the north side so its description will be more extensive. A research station was built at the south side of the river. It's located at the frontal side of the valley, near the sea.

Fauna

In Fiordo Bernardo many of the same species were sighted as in Fiordo Témpano, or their presence was determined. Worth mentioning are tracks found of a puma (*Felis concolor*).

4. Vegetation

4.1 Introduction

The original distribution of the huemul was broader than the original distribution of the cool-temperate rainforests (Diaz, 1993). Its current distribution however, shows a large overlap with the distribution of cool-temperate rain-forests dominated by *Nothofagus*-species, probably because these habitats are the least disturbed (compare Figure 6 with Figure 7).

Nothofagus sp. is an abundant genus in Patagonia and generally the forests are dominated by this genus. South of 50° S three *Nothofagus*-species are present in Chile: *Nothofagus betuloides*, *N. antarctica* and *N. pumilio.* The evergreen *N. betuloides* is adapted to moist and low temperature habitats; the deciduous *N. pumilio* is adapted to drier soils and low temperature. *N. antarctica* occurs in a cold environment, but in a wider range of humidity (Ramírez et al., 1997) and is also deciduous.

The rainforests, present on a narrow strip in Western Patagonia (Figure 6) form a remarkable ecological island of wet forest, because it is isolated by circa 1500-2000 km from other wet closed-canopy forest on the South American continent (Arroyo et al., 1994). The climatic conditions to form these rainforests are prevalent on the western side of the Andes in Patagonia. The Andes intercepts the strong western winds from the ocean whereas the Humboldt Current, an oceanic current coming from Antarctica, provides a stable cooling factor. These two factors make the climate humid and foggy. Because of the strong oceanic influence, the climate stays cool the whole year round.

The area of Fiordo Témpano and surroundings lies on the eastern border of this narrow strip of land. *Campo hielo del Sur*, the ice field of the south, is bordering the area to the east and farther to the east no more rain forests are found. Several endemic species have been found in these forests (Moore, 1983). The area is rich in gradients, often indicative to a large biodiversity. There is an altitudinal gradient, ranging from sea level to the mountaintops. There is a gradient in successional stages; the further located from the glacier, the further it is in its successional stage. And there is a gradient in salinity, correlated with the distance from the sea. Above that, the rough landscape with its small hills and depressions on the relative flat valley bottom assure also gradients from wet to drier habitats.

Given these facts one would expect a high diversity of species, maybe with endemics, in the research area, compared to other sites of the same latitude. These expectations had never been determined however; as there had never taken place any botanical research in the region so far (M. Rosenfeld; pers. comm.).

For the dietary study of this research, basic knowledge of the names of plant species that were present was needed. Given the expectations, an inventory of all plant species present in the area would be an interesting goal to achieve. Although very ambitious, this goal was formulated with the restriction that the focus was first primarily on plant species used by, or expected to be used by the Huemul.

4.2 Methods

Plant samples were collected from December 2003 to April 2004 and a herbarium was made. Species were only collected actively in Fiordo Témpano, because of the lack of time in Fiordo Bernardo. In Fiordo Bernardo, only two species were collected. These species did not occur in Fiordo Témpano and were part of the Huemul diet.

When a species was collected the month of collection was annotated, as well as the habitat, the location, and a short description of the species (height, colours, odour etc.).

In December, five plots of 3x3 meter were made in the periglacial grassland and all species were collected. Furthermore, when was seen that huemul ate from a certain species (not necessarily present in the periglacial grassland) this species was collected. Afterwards, when a species was found that hadn't been collected before, it was added to the herbarium in the manner as described above. Once collected, the samples were dried in old newspapers and they were given a code referring to the codes of their label.

After the research period, the samples were given to CONAF, Punta Arenas for further identification. If there were any duplicates of a species, these were sent to the Utrecht branch of the Dutch National Herbarium. Identification of plant material for this report was done here with the kind help of Prof. dr. P. J. M. Maas.

4.3 Results

Vegetation types

A number of vegetation types were present in Fiordo Témpano. These types show overlap with the distinguished habitats (see chapter 5), but are not the same.

Two types of climax vegetation were found:
- Old growth forest, and
- Moorland

In the valleys of Fiordo Témpano the old growth forests are evergreen rainforests except for one stand on a southern slope where the deciduous *Nothofagus pumilio* was the dominant species.

Moore (1983) distinguished four major evergreen forest societies:
- *Nothofagus betuloides* forest
- *Nothofagus betuloides-Drimys winteri* forest
- *Maytenus magellanica – Drimys winteri* forest
- *Pilgerodendron uviferum* forest

The dominant forest type in Fiordo Témpano is the second type: evergreen Magellan's *coihue* woodland (*N. betuloides*, code 111 in appendix 1) in the common association with *Drimys winteri* (code 116 in appendix 1).

The fourth type, *Pilgerodendron uviferum* (code 158, appendix 1) forest, was also important in the area. It occurred mainly, but not necessarily, on higher altitudes than *Nothofagus betuloides-Drimys winteri* forest. Being very well adapted to humid areas it appeared more in the vicinity of the moorland.

Even higher on the slopes *N. antarctica* was present which is regarded in this study as a shrub species not reaching more than one meter of height.

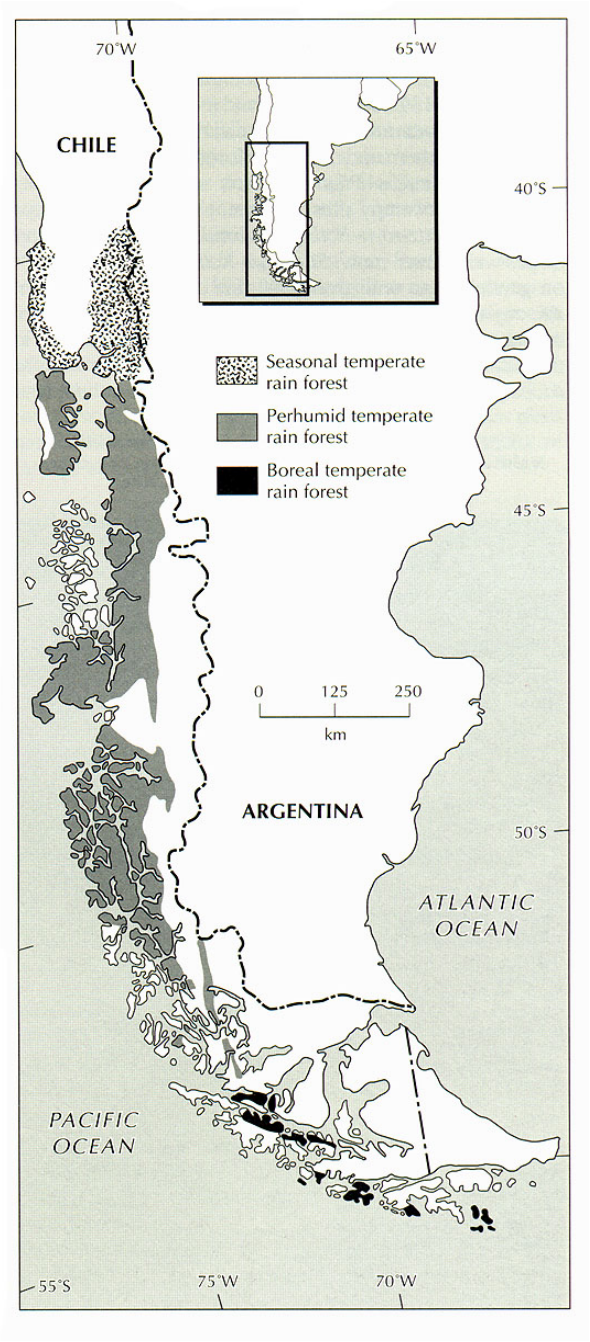

Figure 6: the original distribution of temperate rain forests in southern South-America (source: Kellogg, 1993)

Figure 7: The historical (green) and current (blue) distribution of the huemul (source: Povilitis, 1998)

In general, moorland was situated at higher altitudes than the forest. This type of moorland is being called Magellanic moorland (Frid, 1994). Characteristic for this vegetation type are cushion plants and mosses. Also typical are *Drosera uniflora* and *Lycopodium confertum* (respectively code 118 and 177 in appendix 1).

Next to these two types of climax vegetation, other vegetation types, of earlier stages in succession, are present. The entire valley bottom consists of grassland, here called periglacial grassland because it is in the vicinity of a glacier and formed by glacial retreat. The retreating glacier leaves bare rocks behind and grassland is formed years after primary vegetation (lichens, mosses) colonised these bare rocks. The grassland still has very poor soils. This vegetation type has next to grasses an abundant herb species, *Gunnera magellanica* (code 131, appendix 1), as characteristics. *Gunnera magellanica* has a mutualistic relationship with micorrhiza, a fungus that contributes to the plant's nitrogen uptake (M. Rosenfeld; personal comment).

The last vegetation type determined in Fiordo Témpano was mainly present on hillsides and most likely represents a successional stage between grassland and forest. It is a thick shrub layer. Dominant species is *Pernettya mucronata* (code 107, appendix 1), but also abundant and characteristic are *Berberis buxifolia var. antucoana* and *B. buxifolia var. buxifolia*[1]

Plant species

A short description of all collected species can be found in appendix 1. Worth mentioning here is *Pilgerodendron uviferum* (code 158, appendix 1) that was common in Fiordo Témpano and which is vulnerable according to the 1997 IUCN red list of threatened plants (Walter and Gillett, 1998). Not part of the herbarium, because it was only found in Fiordo Bernardo, but still worth mentioning was *Dacrydium fonkii*, which is also vulnerable according to the same red list.

Also three non-indigenous species were found in the area: *Lunaria annua*, *Ranunculus repens* and *Cerastium fontanum* (respectively code 102, 215 and 213 and 216 in the appendix).

4.4 Discussion

Although the area lies geographically in the (supra)temperate belt, the association *Nothofagus betuloides- Drimys winterii* and the presence of *Fuchsia magellanica* point towards the boreal direction (Amigo and Ramírez, 1998). This suggests that the '*Campo de hielo del sur*' (Icefield of the south) has a significant influence on the local climate and thus on the floral characteristics of the area.

Methods

Only in the periglacial grassland the method of using plots for plant collection was chosen. The usage of plots is more precise and structured, but also more elaborate than randomly collecting plant species. Plots were only used in the grassland because of two reasons. First of all, plant diversity appeared to be far greater in the periglacial grassland than in any other vegetation type in the area. Secondly, huemuls were expected to forage mainly on grasslands as this was the habitat where they were sighted most regularly in other studies in the research area. In order to distinguish plant species quickly in the field while they were foraged upon it was needed to examine these species

[1] Vernacular name is Calafate; the legend is told that when one eats the berry of Calafate, one will return to Patagonia one day.

more carefully. In the other vegetation types it was very easy to distinguish species in the field.

Because of the methods used it cannot be claimed that all species in the area were sampled, but I do claim that the species composition, as found in the herbarium, gives a good, representative, overview of the species that are present in the area as the frequency of new species found became smaller and smaller over time.

Plant species

Due to a lack of scientific knowledge on the flora of this region, both in Chile and in The Netherlands, only 58% (n=51) of the 88 vascular plant species were identified to at least family-level. To genus-level this could only be achieved for 38% (n=33).

Non-indigenous species

Three species were identified that are not indigenous to South-America. These were *Lunaria annua*, *Ranunculus repens* and *Cerastium fontanum*, all three originally from the Eurasian continent. None of these species are common in the area and they were all found relatively close to the sea (the farthest away was one individual plant of *Ranunculus repens* that was found at 100 meters distance from the sea). Of *Lunaria annua*, which is a popular garden plant, only one individual plant was found within meters distance of a corral build for the cows present in the area. Although none of these species were widespread, the observation of these non-native species can be seen as a strong warning. One must not think of a situation as in the National park and World Biosphere Reserve (by UNESCO in 1978) Torres del Paine where in certain areas the scenic view is dominated by dandelion (*Taraxacum officinale*), which is originally from Europe. Masses of tourists go to Torres del Paine every year; Bernardo 'O Higgins National Park is almost completely undisturbed, so a situation as in Torres del Paine can hopefully be avoided. A handful of tourists visit the park by yacht. People are only allowed to go 80 meters inland. There are also larger cruise ships that cross the park, however. The only place where people go on shore during these cruises is in Puerto Edén. Drs. Joep Wensing[2] noted while he was visiting the park and village that a relatively large part of the flora in the village was not of native origin. These plants could be further dispersed into the area by the inhabitants of Puerto Edén.

4.5 Conclusion

A first representative collection of plant species of the research area has been made. At least two species (*Pilgerodendron uviferum* and *Dacrydium fonkii*) are considered vulnerable.

Three non-native species were found in the area. It was the first time that the presence of non-native species was reported, this should be considered as a strong warning.

4.6 Recommendations

Further investigations by botanic specialists are needed to assess whether the high expectations regarding (endemic) plant diversity in the area are justified.

[2] Drs. Joep Wensing works as a biologist for a Dutch zoo and is well grounded in European and South-American flora.

It should be brought into practice that people going inland in the area are controlled of being free of non-native seeds, or organic material that might contain non-native plant material.

5. Habitat descriptions

5.1 Introduction

In the previous chapter the occurring vegetation types were described. These are often associated with habitat types and indeed often show some overlap. But where straightforward descriptions of vegetation types only give information on plant species, described habitat types also give information on other factors as altitude, sheltering possibilities, level of humidity, etcetera.

From a conservationist's point of view habitat types are more important, because they give a more exact description of where the observed species lives. It is important that clear habitat descriptions are made. After this, it can be determined if huemuls are present in these habitats, and if so, how they use the habitats. In this way, it can be easier assessed whether there are opportunities for (new) huemul populations in certain areas.

In this chapter the habitat types present in Fiordo Témpano and Fiordo Bernardo will be described.

5.2 Methods

The first days of the fieldwork on each site were spent to explore the area. During these days habitat types were distinguished and described. For the Huemul Valley in Fiordo Témpano already six types of habitat were described (Frid, 1994). These descriptions were used as a blueprint for the other descriptions and were partly reused. However, Frid's (1994) classification was not thought to be specific enough and two more habitat types were added. Fiordo Bernardo was visited later and was found to have a number of different habitat types. They were described following the same method. Maps were made, first drawn by hand, later digitally. Only for Fiordo Témpano an aerial photograph was available. This photograph was used to make a habitat map. Knowing the scale, it was possible to calculate the surface of each habitat.

5.3 Results

In continuation the habitats are described for Fiordo Témpano and Fiordo Bernardo. First a description of the habitats is given, and then habitat maps of the areas are presented.

Fiordo Témpano

Contrary to Frid (1994), who distinguished six habitat types in Huemul Valley, in this study eight types of habitat are distinguished. Introducing "footslope habitat" as the main transition between the edge of the forest and the grassland on the valley bottom, and dividing Frid's 'Old growth forest' into two forest-types.

1) Periglacial grassland (Frid, 1994) comprises 26% of the area surface and is located on the relatively flat valley bottom, 60-70 meters above sea level. The

vegetation consists mainly of grasses and *Gunnera magellanica.* The soil is moderately well to poorly drained. Possibilities for shelter are scarce, as is the possibility to hide from predators. In Fiordo Témpano, cows are also present is this habitat.

2) Low-elevation bluffs (Frid, 1994) are in general located in the periphery of the flat valley bottom. Mostly surrounded by periglacial grassland on the valley side and footslope habitat on the other side. Characteristic are the steep slopes. Bluffs are very rocky and are overgrown with large patches of mosses. On spots where more sediment is present the vegetation is similar to periglacial grassland. Boundaries of this habitat are primarily given by landscape structure, not by vegetation traits. There is no possibility for shelter in this habitat, but the deer are difficult to be approached upon by predators.
3) Footslope habitat consists of open shrub vegetation located on the footslopes of Huemul valley. It covers 6% of the valley. Dominant shrub species are Chaura (*Pernettya mucronata*) and Hardy fuchsia (*Fuchsia magellanica*; code 201, appendix 1). Grass species are less abundant here than on the valley bottom, *Gunnera magellanica* is the dominant herb species in this habitat. Soils are well drained. Shelter is easily to be found and the deer are not easily to be approached by predators.
4) Forest border habitat (see grassland-forest edge: Frid, 1994) lies between 100 m and 120 m above sea level and is characterised by shrubs, next to *Pernettya mucronata* and *Fuchsia magellanica*, especially *Ribes magellanicum* (code 166, appendix1). Although less abundant, more characteristic for this habitat. Apart from these shrub species, forest border habitat is formed by seedlings of *Nothofagus betuloides*, not reaching over 2 meters in height. Although the forest stretches out all over the length of both slopes, east and west, the forest border habitat type is only restricted to some patches along the slope. It is defined by the presence of seedlings of *Nothofagus betuloides*. Mostly the edge of the forest is very sharp and is directly bordered by footslope habitat. Soils are well drained. The *Nothofagus sp.* seedlings provide shelter against the weather as well as cover against predators.
5) Magellan's c*oihue* woodland; this old growth forest is situated on both slopes, east and west, between 100 m and 400 m above sea level. Dominant species is *Nothofagus betuloides* in association with *Drimys winteri*. The forest floor is packed with fallen logs mostly luxuriant overgrown with mosses. The forest on the eastern slope is denser than the forest on the western slope. Soils are well drained.
6) *Pilgerodendron uviferum*- forest is mostly, but not necessarily, found at higher elevations than Magellan's *coihue* woodland. It is even more adapted to humid conditions. The border between the two woodland types is quite abrupt. Soils are moderately drained. On still higher altitudes the *Pilgerodendron uviferum*-forest gradually gives way to Magellanic moorland.
7) Magellanic moorland (Frid, 1994) extends from 100 m to 1000 m above sea level and comprises half of the research area. The conspicuous red carnivorous herb *Drosera uniflora* (code 118, appendix 1) is indicative for this habitat type as well as the abundance of mosses. Vegetation cover is 30% to 100%. Soils are poorly drained.
8) Beach (Frid, 1994) consists either out of clay or rocks. It is in general only a few meters wide. Beach habitat is found along the coast, where it is influenced by the tides. Exception is a small sandbank at the riverside that was determined as beach habitat.

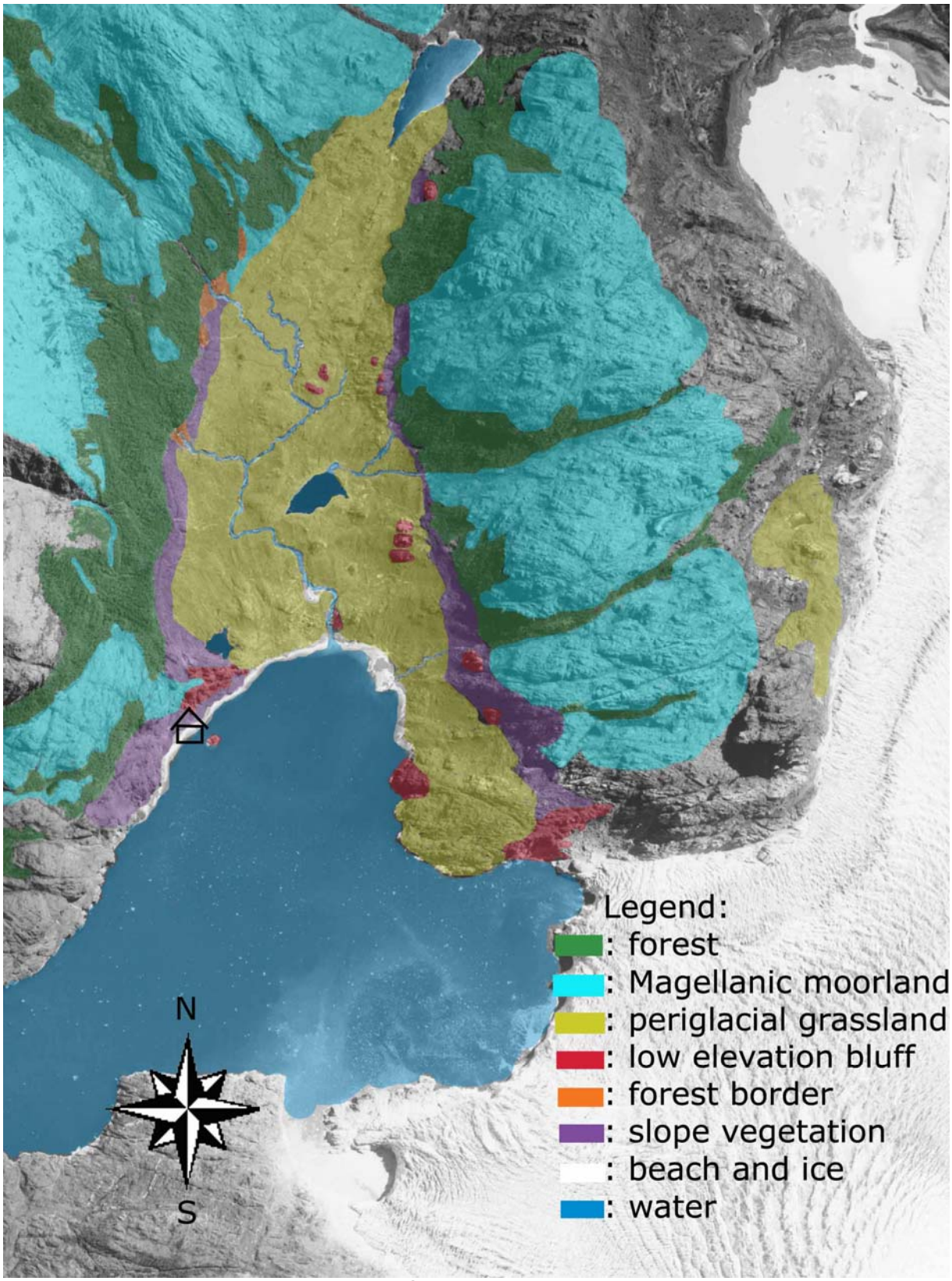

Figure 8: Huemul valley in Fiordo Témpano. The different habitats are indicated. The research station is symbolised by the pictogram of a house.

As can be seen in Figure 8, the main habitats (periglacial grassland, footslope habitat, old growth forest [either *Nothofagus sp.* or *Pilgerodendron sp.*] and Magellanic moorland) are situated quite structurally in strips alongside the valley. When one would cross the valley, one would walk through the former mentioned habitats respectively one after the other. On the eastern slope the forest is the habitat in trenches formed by small rivulets. The research station is located on the western side looking at the beach and is easily reachable from the sea.

Table 4: Surface and percentage of the distinguished habitats in the research area in Fiordo Témpano.

Habitat	**Surface (hectares)**	**Percentage of the area**
Periglacial grassland	272.4	25.6
Low-elevation bluff	13.2	1.2
Footslope habitat	65.0	6.1
Forest border	4.1	0.4
Forest	169.7	15.9
Moorland	532.5	50.0
Beach	8.1	0.8
Total:	**1065.0**	**100**

Fiordo Bernardo

The Valley in Fiordo Bernardo is divided in a southern side and a northern side. Because of the different characteristics, both will be treated separately. Whenever possible, the same habitat descriptions are used as for Fiordo Témpano.

South side

Eight types of habitat were distinguished on the south side of the river in Fiordo Bernardo.

1) Periglacial grassland; as described for Fiordo Témpano, except no cattle is present here.
2) High shrub vegetation; a very dense vegetation of Chaura (*Pernettya mucronata*) and the spiny Calafate (*Berberis buxifolia var. buxifolia*), making it difficult to move freely in this habitat. The height of the shrubs is 1 to 2.5 meters. Mosses are abundant and *Gunnera magellanica* is scarce, as it is only present on narrow tracks running through the habitat. Soils are well drained.
3) Low shrub vegetation; located closer to the glacier than the high shrub vegetation. The most abundant species is Chaura (*Pernettya mucronata*). In this habitat the height of this species is only 20 to 60 cm allowing *Gunnera magellanica* to be more abundant than in the 'high shrub vegetation'. It has an estimated surface cover of 7% in this habitat. Soils are well drained.
4) Beaches and riverbeds; consisting of rocks. The more saline beaches, close to the sea, are dominated by *Asteraceae sp. undet*. (code 227 in Appendix I). On the other beaches and riverbeds a variation of different herb and moss species is found. Vegetation cover is 5-35%
5) Bare rocks; at two places in the valley bare rocks are found. One location is at the terminus of the valley, very close to the glacier. The other location is half way of the valley. There isn't any vegetation present on these spots.

6) Old growth forest; situated on the steep and rocky slope. As in Fiordo Témpano the forest type is Magellan's *Coihue* woodland with as dominant species *Nothofagus betuloides* in the common association with *Drimys winteri*. The forest is hardly accessible.
7) Pioneer vegetation; mainly located very near to the glacier. Consists of rocks, overgrown with mosses. Also some herb species are present, amongst others *Gunnera magellanica*.
8) Footslope vegetation is as described for Fiordo Témpano, only with the exception that there is no Hardy Fuchsia (*Fuchsia magellanica*) present.

North side

On the north side of the river six types of habitat were found:

1) Periglacial grassland; as described for Fiordo Témpano, except no cows are present here.
2) Low shrub vegetation; as described for the south side of the Fiordo Bernardo valley.
3) Open woodland; dominant species is Chaura (*Pernettya mucronata*), reaching 1.5-2 meters of height. Trees (*Nothofagus sp.*) are scattered over this habitat. The two larger areas of 'open woodland' were situated two meters higher than the other parts of the valley. Occasionally narrow, but deep depressions were present (2-2.5 meters), with an average diameter of 4 meters.
4) Pioneer vegetation; as described for the south side of the Fiordo Bernardo valley.
5) Footslope vegetation; as described for Fiordo Témpano, only with the exception that there is no Hardy Fuchsia (*Fuchsia magellanica*) present.
6) Beach; on the frontal side of the valley a gravel beach is situated. On the lateral side lies a sandy beach. On both beaches no vegetation is present.

5.4 Discussion

Fiordo Témpano

For Fiordo Témpano the actual situation was first compared with the described situation according to Frid (1994). It was found that the description of Frid did not give a complete picture of the area. So another division was made. First of all, Frid distinguished 'Old growth forest' as one habitat. Here this is divided into two habitats, following Moore's (1983) division in four major evergreen rain forest types: *Nothofagus betuloides* forest in association with *Drimys winteri*, and *Pilgerodendron uviferum* forest. These habitats have very different characteristics, especially for the huemul, because the vegetation in the *Pilgerodendron uviferum* habitat is not used in their diet. The second additional habitat is 'footslope habitat'. It is the most common transition between the two forest habitats and grassland. Frid (1994) distinguished forest border (Grassland- forest edge, Frid, 1994) as this transition, but because of the unique circumstances of the valley there is hardly an ecotonal zone. The edge of the forest is very abrupt except for on a few spots. The habitat found between the forest and grassland was one that not necessarily was a transition between forest and grassland, but could also well stand on its own. This habitat is defined as footslope habitat, because it occurs on footslopes. In Fiordo Bernardo this term was also plausible.

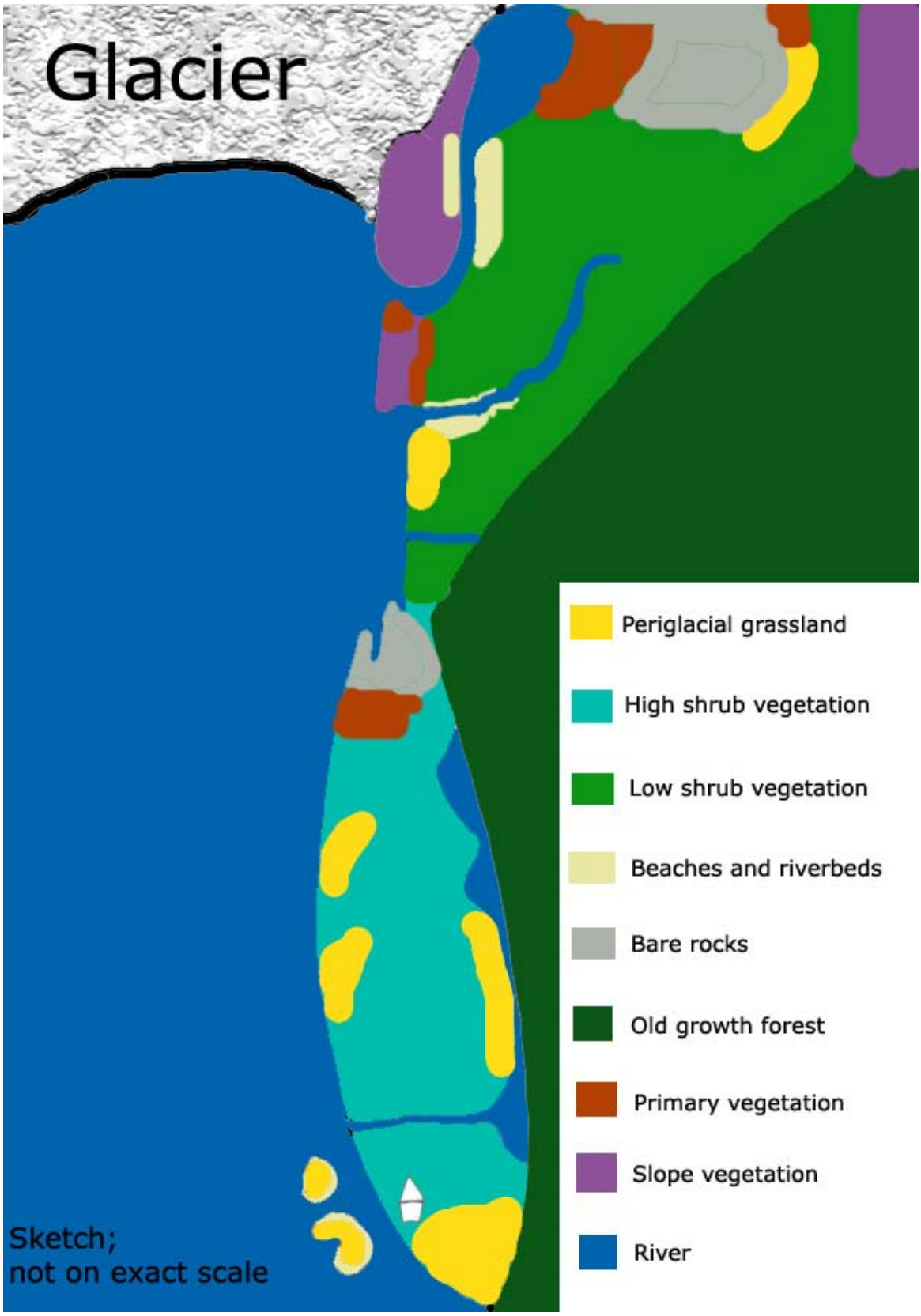

Figure 9: South side of Fiordo Bernardo valley. The eight distinguished land habitats are indicated. The research station (depicted as a house) was situated opposite to two small isles at the entrance of the valley. Old growth forest was located on the very steep slopes and was not present on the valley bottom.

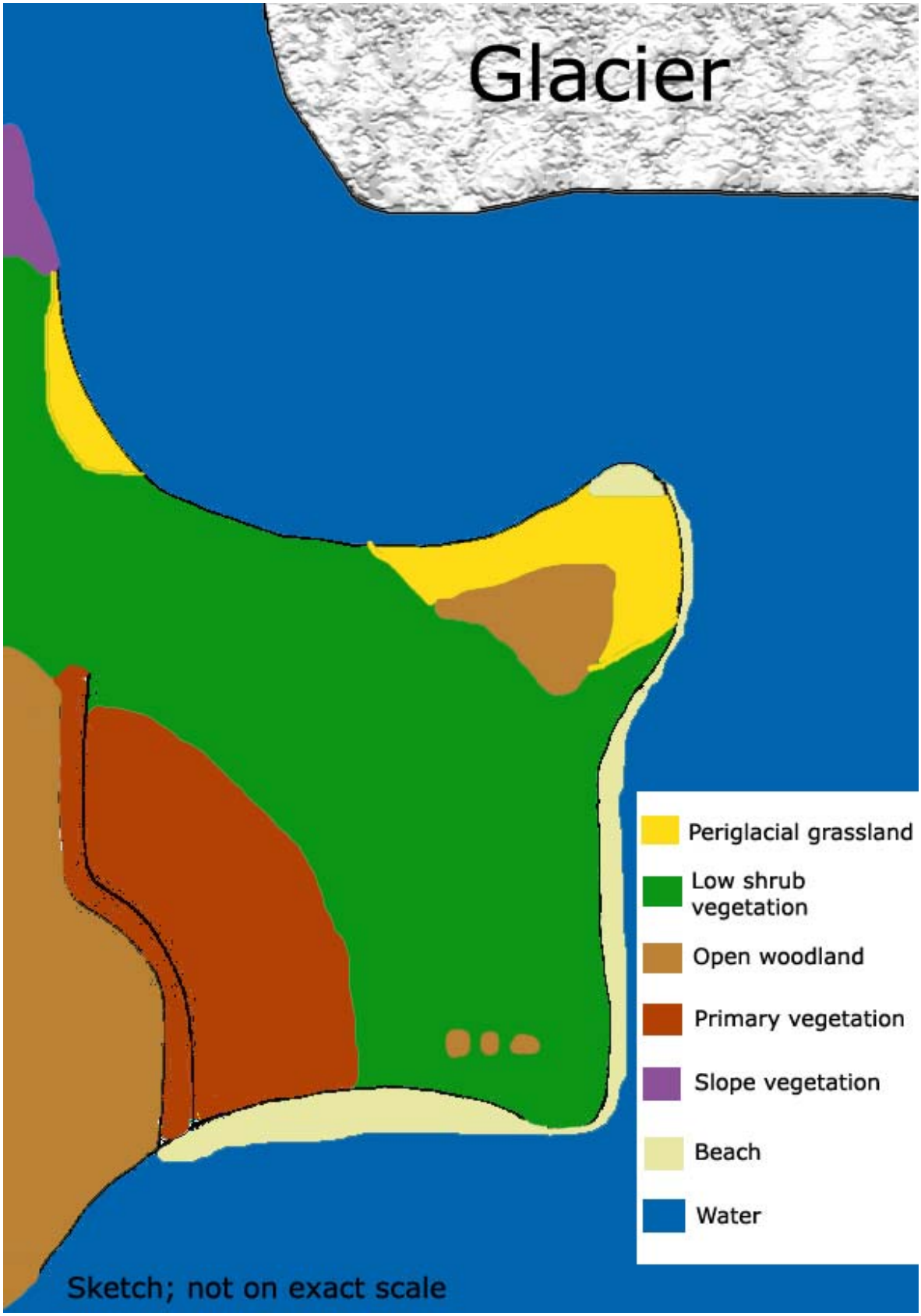

Figure 10: Sketch of the north side of Fiordo Bernardo. The six different land habitats are indicated. The old riverbed is overgrown with pioneer vegetation. The two larger 'open woodland' areas lie circa two meters higher than the rest of the valley.

Fiordo Bernardo

When possible it was chosen to apply the described habitats of Fiordo Témpano to Fiordo Bernardo. These habitats of course differed in some aspects, but had enough similarities to be gathered under the same term. The differences are pointed out in the descriptions. For instance in Fiordo Bernardo no *Fuchsia magellanica* was present; an important difference from a huemul's point of view. The old growth forest in Fiordo Bernardo is of the same type as Magellan's *Coihue* woodland. However there is chosen not to use the same habitat name, because they differed in other than floral characteristics. In Fiordo Bernardo, the forest was situated on a hardly accessible very steep rocky slope. In Fiordo Témpano, the forest was accessible for man and deer.

Succession

The different stages of succession can be easily named in the Fiordo Bernardo Valley. When the glacier retreats it leaves first bare rocks. When these get overgrown with lichens and mosses pioneer vegetation appears, also with some herbal species. Then more herbal species and grass species colonise the habitat and periglacial grassland is the name. After this respectively low shrub vegetation, high shrub vegetation, open woodland and forest appear.

In Fiordo Témpano there is no pioneer vegetation present anymore. The earliest stage in succession here is periglacial grassland, and then there is footslope vegetation, forest border and forest. These appear in this order on slopes.

5.5 Conclusion

A useful and easily usable classification in habitats has been made in this chapter for Fiordo Témpano and Fiordo Bernardo. For Fiordo Témpano the classification that Frid (1994) made was revised. Frid's 'Old growth forest' was divided in Magellan's *coihue* woodland and *Pilgerodendron uviferum*- forest. Also an additional habitat was defined: footslope habitat.

Both valleys differ greatly; when characterising Fiordo Bernardo in one word, this word would be: shrubland. Doing the same for Fiordo Témpano, it would be: grassland. Table 5 gives an overview of which habitats occur in which valley. Next to this, the variation in habitats in Fiordo Bernardo seems to be correlated primarily with the distance from the glacier. In Fiordo Témpano the shifting from one habitat to another appears to be dependent on altitude.

Table 5: All present habitats in the research areas and where they occur.

Habitat	**Fiordo Témpano**	**Fiordo Bernardo South side**	**Fiordo Bernardo North side**
Periglacial grassland	X	X	X
Low elevation bluffs	X		
Footslope habitat	X	X	X
Forest border	X		
Magellan's *Coihue* woodland	X	X	X
Pilgodendron uviferum-forest	X		
Magellanic moorland	X		
Beach (and riverbeds)	X	X	X
High shrub vegetation		X	
Low shrub vegetation		X	X
Bare rocks		X	
Pioneer vegetation		X	X
Open woodland			X

6. Habitat use of the huemul

6.1 Introduction

According to the literature and following the classification of Gajardo (1983) three vegetation types are important as huemul habitat in the south: the deciduous forest of Aisén, periglacial shrub land and Baker's evergreen mixed forest (Aldridge, 1988; CONAF and CODEFF, 2001). They have in common that they are more open than the evergreen forests in the west and are denser then the Patagonian steppe to the east (Aldridge, 1988). Forest fires happen regularly in the deciduous forest of Aisén and in Baker's evergreen mixed forest. Periglacial shrub land has also different stages in succession after deglaciation.

In the southern parts of Chile the huemul occurs mostly within an altitudinal range of 750 and 1000 meters above sea level, but they can be found between sea level and 1300 meters. The precipitation ranges between 700 and 4000 mm annually and the mean annual temperature is between 4° and 6° Celsius. Their habitat are rocky cliffs and small terraces, with slopes till 50°. In some high altitudinal areas they occur on Andean grasslands (above the tree line). In periglacial areas they occur also on moorland and they make use of plains with a shrub vegetation (CONAF and CODEFF, 2001).

The (relict) population in Central Chile forms an exception. They are associated with four other vegetation types (Deciduous frontier forest, Deciduous mountain forest, High Andean deciduous forest of the mountains of Chillán and High-Andean sub-humid steppe). Characteristic are rocky cliffs and slopes with presence of slopes with an angle of over 30°. The altitude varies between 900 and 1900 meters above sea level (CONAF and CODEFF, 2001). But most typically the huemuls are found at elevations between 1450 and 1700 meters above sea level, and at Northern or Western slopes of 30° or 40°. They prefer shrubland (65%) to other vegetation types. In winter they live at lower elevations (1100-1500 m) and in the driest summer months they seek shade, food and water in the tall forests (Povilitis, 1979).

In Argentina the habitat use of the huemul was determined in one area: Lago Escondido (41° S, 71° W) (Vidoz, unpub.). In this area also forest fires occur regularly. Precipitation is between 1200 mm and 2000 mm a year. Preferred habitat was (expressed in different parameters): an altitude of 1400 m above sea level (55%), the northern hillside (92%), Meso-Andean 'Prado'[3] (43%), at mountain slopes (94%): either with or without rocks and cliffs (both 47%), and at slopes with a steepness of 40 to 50 degrees (57%).

At Lago La Plata in Argentina (45° S, 72° W) huemuls occur also. This area is located at 950 m above sea level. The main habitat is dense Lenga forest (*Nothofagus pumilio*). Mean precipitation is 1000 mm, but with great annual differences and great differences per location. Mean winter temperature varies between –4 and –2° Celsius, with a mean precipitation between 300 and 400 mm, mostly as snow (Smith-Flueck and Flueck, 2001).

[3] In this research Meso-Andean 'prado' was defined as: grassland or low shrubs formed after forest-fires at an altitude between 1000 and 1500 meter above sea level.

When comparing these habitats one can see that the periglacial habitat forms the outer range in several parameters. It has the lowest altitude: the only habitat where huemuls occur at sea level. It has the highest precipitation, up to 4000 mm a year, and the species makes use of habitat without steep slopes. Furthermore, in contrast to Fiordo Bernardo and to the habitats mentioned in the literature, does Fiordo Témpano not have periglacial shrublands, the main vegetation type of the valleys is grassland.

In 1990 this periglacial grassland was the main habitat used by huemuls in Fiordo Témpano (Frid, 1994). In 1995, after a heavy winter and the introduction of cattle in the area, grassland was substantially used less (Frid, 2001). Wensing (2005) argued that the most probable and most important reason for this is the presence of cattle in the area. The removal of this cattle is part of the conservation plan. This study can be used as a zero measurement for a comparative study after cattle removal.

In Fiordo Bernardo the largest known huemul (sub)population of the world was discovered. It is important for conservation purposes to get a good insight in it's habitat use. This might be one of the last places where the huemul uses it's optimal habitat (see also the discussion of this chapter).

In this chapter the habitat use of the huemul in Fiordo Témpano and Fiordo Bernardo is presented. Future implications and the use of optimal versus suboptimal habitat are briefly discussed.

6.2 Methods

In Fiordo Témpano in the first weeks all habitats were searched for tracks of huemuls, such as faeces, prints, hairs and signs of feeding behaviour. This gave a first idea of the habitat use of the huemul. During the observations the time spent in the habitats that were described in chapter 5 was annotated. The observations started when the focal deer was adjusted to the observant, then the deer did not seem to be disturbed in their natural behaviour. This usually took less than five minutes. Observations were daily done from the 20th of December till the 11th of April, and from the 30th of April till the 3rd of May.

In Fiordo Bernardo the same procedure was followed, with the exception that no pilot study on huemul tracks was executed due to the lack of time. The observations in Fiordo Bernardo were carried out each day from the 27th of March till the 24th of April.

For the calculation of habitat preferences, Jacobs' (1974) modification of Ivlev's selectivity index was used:

$$S= (r_i - p_i)/(r_i+p_i-2r_ip_i)$$

Where S is the selectivity index, varying from −1 to +1. When the value of the index lies between −1.0 and −0.3 the habitat is avoided, between −0.3 and +0.3 the habitat is encountered with indifference and +0.3 and +1.0 the habitat has preference. r_i is the proportion of time spent in habitat i and p_i is the proportion of habitat i in the area.

6.3 Results

Fiordo Témpano

In Fiordo Témpano four habitat types were used regularly. Most time was spent in footslope habitat (35%). Huemuls used the other three habitats for more or less one fifth of their time. Bluffs and forest borders were both used to the same extend (21%) and

periglacial grassland a fraction less (20%) (Figure 11). These figures do not indicate how favourable a certain habitat is, because this is dependant not only on the habitat use, but also on the probability that an individual without any preferences happens to be in a certain habitat. In other words: it is dependant on the relative surface the habitat covers of the research area. As a measure of favourability or preference, Ivlev's selectivity index was used.

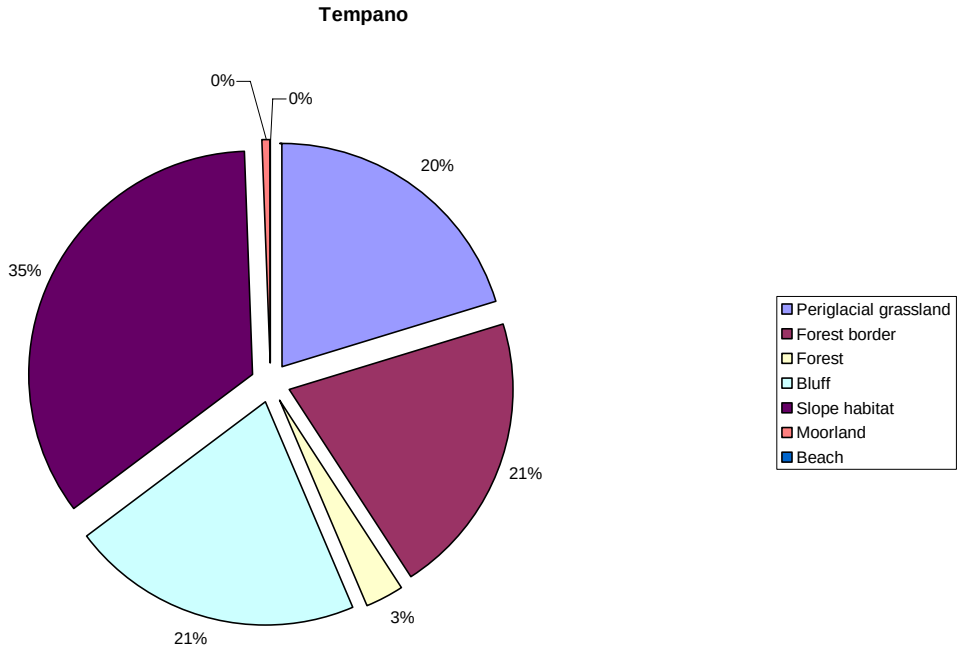

Figure 11: Percentage of time spent per habitat during observations in Fiordo Témpano.

It can be seen then (Figure 12) that periglacial grassland, although used often, does not have a preference, but is regarded with indifference (S=0,15). Forest border (S=0,97), low elevation bluffs (S=0,91) and footslope habitat (S=0,78) have a preference. Moorland (S= -0.99), beach (S= -0,84) and forest (S= -0,74) are avoided.

Fiordo Bernardo

In Fiordo Bernardo there are other habitats present than in Fiordo Témpano. Here huemuls spent their time in four different habitats: pioneer vegetation (8%), periglacial grassland (9%), beaches and riverbeds (27%) and low shrub vegetation (56%) (Figure 13). Exact analysis of preferences could not be performed because no exact data on habitat proportions in Fiordo Bernardo could be computed. But comparing the sketch of the habitats of the south side of Fiordo Bernardo (Figure 9) with the mentioned results of habitat use gives the following estimated preferences according to Jacob's (1974) modification of Ivlev's selectivity index (see also Figure 14):

Estimated S (periglacial grassland): -0,3
Estimated S (low shrub vegetation): -0,3
Estimated S (pioneer vegetation): -0,1
Estimated S (beaches and riverbeds): 0,8

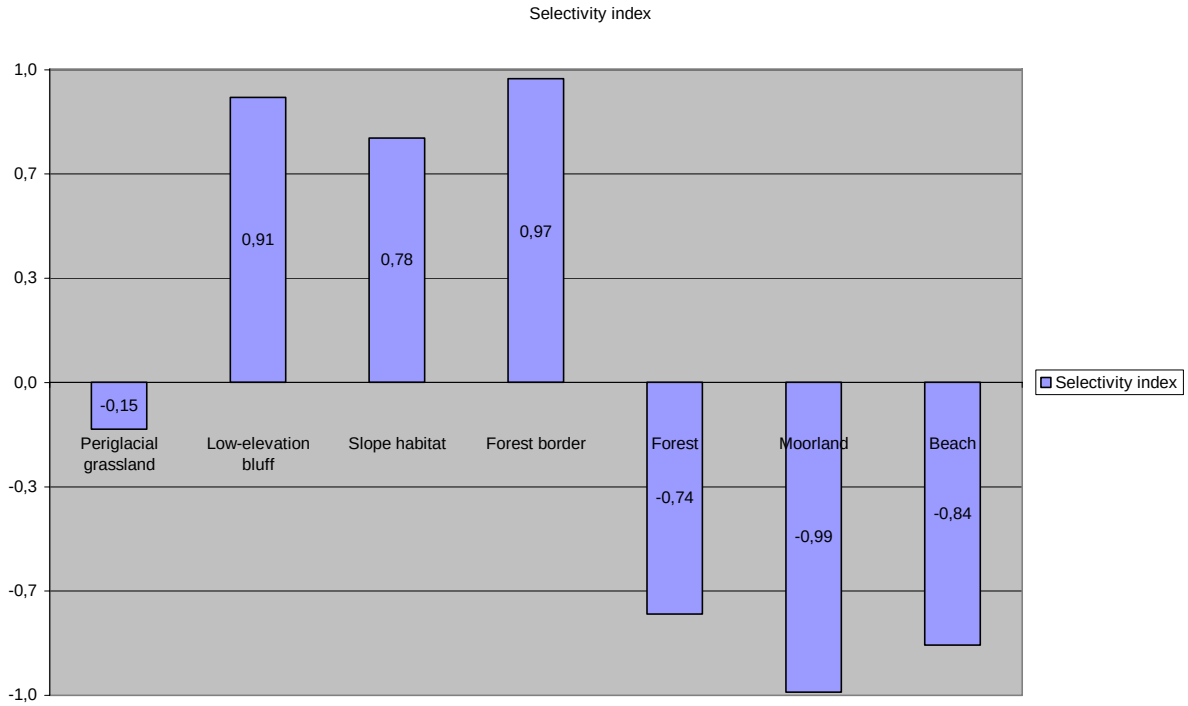

Figure 12: Ivlev's Selectivity index. $S=(r_i - p_i)/(r_i+p_i-2r_ip_i)$, where S is the selectivity index, varying from −1 to +1. Values between −1.0 and −0.3 indicate that the habitat is avoided, between −0.3 and +0.3 that there indifference towards the habitat and between +0.3 and +1.0 that the habitat has preference. r_i is the proportion of time spent in habitat i as shown in Figure 11 and p_i is the proportion of habitat i in the area as shown in Table 4. The huemul shows indifference towards periglacial grassland, preference for Low-elevation bluffs, Footslope habitat and Forest borders and avoidance of Forest, Moorland and Beach in Fiordo Témpano.

This indicates that there is an indifference or maybe even a minor avoidance towards periglacial grassland and low shrub vegetation, there is an indifference towards pioneer vegetation and that there is a preference for beaches and riverbeds.

The estimations for proportions of habitat cover based upon Figure 9 are as follows: periglacial grassland: 15%; low shrub vegetation: 72%, pioneer vegetation: 9%; beaches and riverbeds: 4%.

6.4 Discussion

Methods

Determining habitat use through direct observations has some disadvantages when compared to using radio collared observations. When using direct observations, these observations depend on several factors.

First of all, the observations are time-biased. The deer are only observed during daylight. Habitat use during twilight and night will not be determined using this method with the consequence that maybe not the full pallet of habitats used by the huemul is recorded.

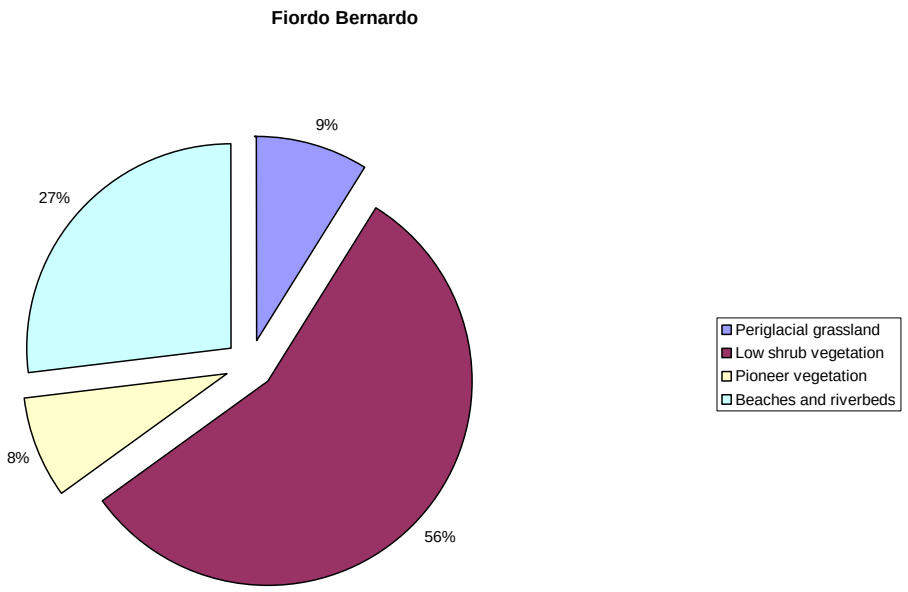

Figure 13: Percentage of time spent per habitat during observations at the south side of Fiordo Bernardo valley.

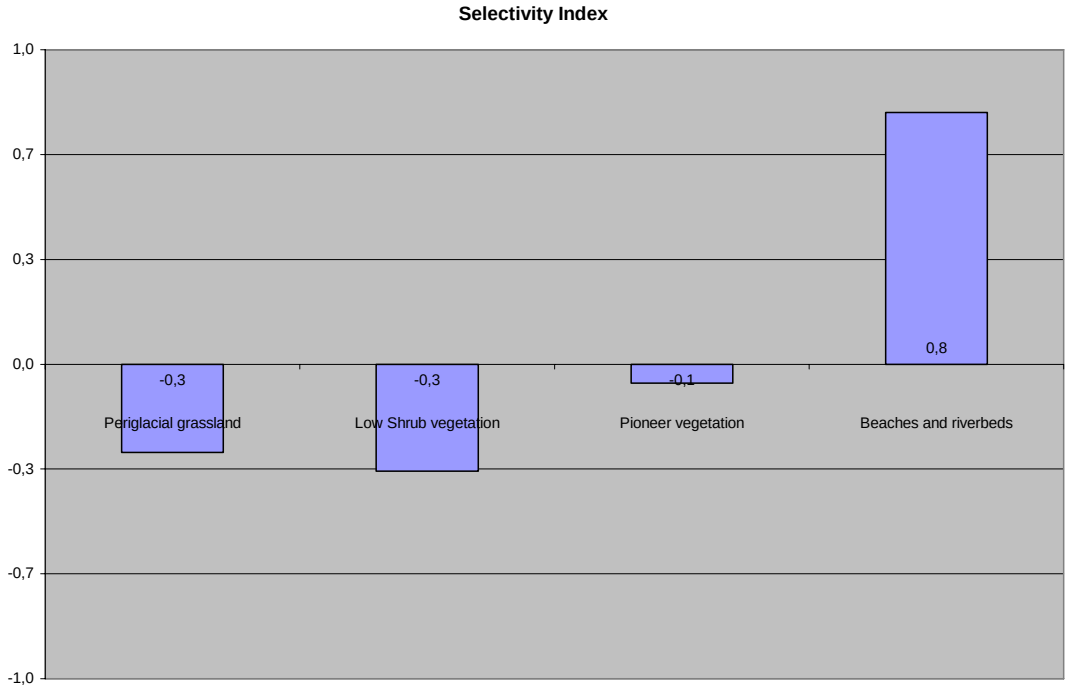

Figure 14: Estimated Ivlev's Selectivity index for four habitats in Fiordo Bernardo. The index is used as a measure of favourability. $S=(r_i - p_i)/(r_i+p_i-2r_ip_i)$, where S is the selectivity index, varying from –1 to +1. Values between –1.0 and –0.3 indicate that the habitat is avoided, between –0.3 and +0.3 that there indifference towards the habitat and between +0.3 and +1.0 that the habitat has preference. r_i is the proportion of time spent in habitat i as shown in Figure 13 and p_i is the proportion of habitat i in the area that was estimated from Figure 9. Beaches and riverbeds was the one preferred habitat. Deer were indifferent to Pioneer vegetation and were indifferent or even avoided Periglacial grassland and Low shrub vegetation.

Secondly, these direct observations are habitat-biased. Huemuls are easier to find in open habitats than in dense habitats. Next to that, huemuls are also easier to follow and observe in easily accessible habitats. Chances of losing an individual deer out of sight are much greater in the thick old growth *Nothofagus*- forest while climbing over obstacles and balancing on trunks than they are on the flat valley bottom in periglacial grassland.

Third, direct observations are behaviour-biased. Typically, finding animals is easier when they are moving. Ruminating or resting individuals are thus more difficult to find. When certain habitats would be associated with ruminating or resting it could be that the use of these habitats is underestimated. However, individuals were always followed for a prolonged period of time. This lowers the impact of the habitat- and behaviour bias of encountering an animal in the field; furthermore Wensing (2005) did not find any significant differences between habitats in behaviour in this research area.

Fourth, habitat use was measured in this study by surveying deer, not by surveying habitats. As a result, some habitats that were hardly accessible and where chances of encountering huemuls were very small, such as Magellanic Moorland or *Pilgerodendron uviferum*-forest, were surveyed to a lesser extend than easily accessible habitat with good chances of finding deer. Here this bias will be called monitor intensity bias. This method is more efficient, but can create a bias in the dataset.

Radio-collared observations were not allowed in the research area. Best efforts were made in gathering data through direct observations. Here below I will discuss what influences these biases could have on the dataset.

Influences of the biases specific for the research areas

Time-bias

In Fiordo Témpano the earliest observations started at 7.45h and the latest ended at 21.15h, but by far the most observations were done between 10.00h and 19.00h. There was no literature found on night behaviour, but several sleeping sites were found halfway the forest on the Western slope and in bluff habitat. In Fiordo Bernardo the observations were done from the end of March till the end of April. Sunset was earlier than in Fiordo Témpano and because of safety reasons, observations could only be done in broad daylight, resulting in a shorter observation period per day. There are no indications that this influenced the data set. Assuming that huemuls use certain habitats at night, this study can only provide statements on the habitat use during daylight.

Habitat-bias

Huemuls are easier to find and follow in open habitats without any obstacles. The habitats ordered from more open habitats to more dense habitats, is as follows:

Beach, Riverbeds, Bare rocks and Pioneer vegetation (++);
Magellanic moorland and Periglacial grassland (+);
Low-elevation bluff, Footslope habitat, Low shrub vegetation (+/-);
High shrub vegetation, Forest Border (-);
Forest (--)

It ranges from completely open habitat, such as beach, to forest habitat with a lot of structures obstructing the view. This means that the first mentioned habitats would be the most positively discriminated and forest habitat would be the most negatively discriminated in the dataset. So reasoning from the intrinsic characteristics of the habitat itself (resulting in a measure of sight) the lower three habitats might have been used

relatively more and the upper six habitats might have been used relatively less by huemuls than the dataset shows.

Behaviour-bias

Wensing (2005) saw trends in differences between behaviour in habitats in the research areas, but there were no significant differences. In Fiordo Témpano, resting behaviour (including ruminating) was mostly seen in grassland-, forest border- and footslope habitat. In Fiordo Bernardo this was only the case in grassland and only for does. So, although there might be a small effect, this is probably too small to play a role of significance.

Monitor-intensity bias

Not all habitats were monitored to the same extend. In the first days after arrival all habitats in Fiordo Témpano were searched for tracks of huemul presence: faeces, prints, hairs and signs of feeding behaviour. Hardly any tracks were found on the beach, Magellanic moorland and in both types of forest. Contrary to the other habitats, moorland and the forest were not easily accessible. When walking from and to the research station there was always a clear view on the beach. Given these facts, moorland and forest were surveyed less than the other habitats. Reasoning from monitor-intensity bias, these two habitats might have been used relatively more by huemuls than the dataset shows.

In Fiordo Bernardo a pilot study to determine where chances of finding Huemuls were greatest was not carried out. Still all habitats were not monitored proportionally to the relative surface. This was mainly due to travelling distance from the research station. Because of this, the habitats 'bare rocks', 'pioneer vegetation', 'footslope vegetation', and 'low shrub vegetation' could have been negatively discriminated in the dataset.

Conclusion on types of bias

Although these four types of bias might have influenced the dataset, the effects were minimized by following deer for a longer period of time. The average observation time per individual deer without pauses was 2 hours and 51 minutes. During these observations the deer changed in behaviour and from habitat and sometimes they crossed the area. These biases have their largest influence on the chance of spotting a deer and so on the first small period of time of the encounter. This period was not used as observation time, because the focal had to adjust to the observant. Also it was not an exception that certain individual deer, found regularly on certain hotspots, were passed by in search of others to reduce the effect of above mentioned biases. Next to this, some biases could level each other out. For example, there was a positive effect on observations in Periglacial grassland because of the habitat-bias, but a negative effect because of the behaviour-bias.

Habitat selection

In Fiordo Témpano huemuls preferred footslope habitat, forest border habitat and low elevation bluffs. These three habitats have in common that they are relatively open compared to the climax vegetation and are situated on footslopes. Forest border and footslope habitat offer vegetation cover and the low elevation bluffs are difficult to reach because of the steep footslopes and the slippery bare rocks, so one could say that these habitats are proper for predator-avoidance. The first two habitats provide plenty of food for the deer. Low-elevation bluffs were not defined by botanical characteristics. Sometimes there was hardly any good food source present, sometimes there was. The

deer avoided forest, moorland and beach. All three are habitats where food is relatively scarce.

In Fiordo Bernardo the Selectivity index could not be computed, but was estimated. This has as a consequence that only major differences can be analysed. Only one result was evident from the results: the deer preferred beaches and riverbeds.

Beaches and riverbeds do not provide cover from predators, although fleeing into water is a known strategy of huemuls that are being chased. When looking at the formerly described biases and looking at the map of the south side of Fiordo Bernardo valley one could hypothesise that the largest part of the observations in beach and riverbed habitat were done on both isles situated at the entrance of the valley. Both isles were indeed a hotspot of finding deer. It might be that these islands were favoured because puma's, natural predator of the huemul, are known to be able to swim, but dislike doing so. For the foxes present in the area (*Pseudalopex culpaeus*) it would also form a barrier of significance. Foxes are known to prey on fawn (Wensing 2005). Puma and foxes would be able to reach one of the islands without swimming only when the tide was at its lowest point. The other island wasn't to be reached without swimming at all. No tracks of either species were found on both islands.

Although the isles were a hotspot of finding deer, the observations in beach and riverbed habitat hardly took place here. Most of these observations took place at a river more to the east. There was plenty of food present here, but there was a lack of cover. The river had mostly a strong current, but was quite shallow. This would not form a barrier of significance, nor for puma's nor for foxes. From this particular location however the deer could also easily reach the large river dividing Fiordo Bernardo valley, as they could from all other beach and riverbed locations.

In Fiordo Témpano, the most important requirements for habitats seem to be food availability, and slopes and cover. For Fiordo Bernardo these seem to be food availability and the possibility for an easy escape into deep water. In general, favourable habitats are open, provide good forage availabilities and sufficient opportunities for anti-predation behaviour.

Optimal and suboptimal habitat

Flueck and Smith-Flueck (2006) warned in their review not to misinterpret the results of research on the current habitat use of the huemul. They claimed that it is improbable that huemuls live today in their optimal habitat, especially at high altitudes, and that they may be displaced into peripheral areas by human activity. In Fiordo Témpano there was livestock present during the research period. Frid (2001) already argued that the shift in habitat use in 1995 was due to anthropogenic influences. Wensing (2005) narrowed it down to the presence of cattle as the most likely cause. Frid (2001) made only use of five days of direct observations to support his findings and, additionally, a faecal pellet study. Faecal pellet studies are easily influenced by other factors than habitat use, i.e. by the decay rate of the faeces (Putman, 1984) in different habitats, or by behaviour (compare Mitchell et al., 1983 and Collins and Urness, 1981 (ex: Hemami et al., 2004)). Flueck and Smith-Flueck (2006) suggest that other methods than faecal counts are best used for Huemul studies. This present study used only direct observations and was more extensive than the five-day study of Frid. It could serve well as a zero measurement for future research after cattle removal.

Given the conditions of the study site at Fiordo Bernardo I do think that these results can be interpreted as the habitat use of the huemul under optimal conditions. The present (sub)population is the largest known in the world and there are hardly any human activities in the fjord. Currently are there only human activities to conserve the huemul.

Comparative study before and after the introduction of cattle in Fiordo Témpano

In the spring of 1990 Frid did a field research in the Huemul Valley in Fiordo Témpano (Frid, 1994). He also used direct observations and measured the time the deer were present in certain habitats. I divided his Old growth forest into two separate habitats and defined an additional habitat (footslope habitat). To make comparison possible these should be categorised into the definitions of Frid. Table 6 shows the habitat proportions in the study area according to Frid (1994) and this study (Van Winden, 2006). Footslope habitat appears to be covered in Frid's research by a combination of Periglacial grassland, Low-elevation bluffs and Forest border and cannot be easily classified within Frid's habitats. Therefore it is not included in the following analysis. Also the outer range of the research area is defined differently resulting in a different Forest-Moorland ratio. A note should be made that there is a time gap of 14 years between both studies: some characteristics of the area might have changed during that interval.

Taking into account the differences in measured habitat proportions, both studies can be best compared by Ivlev's Selectivity Index. This index was calculated for the data of Frid (1994) and the results are presented in Figure 15. A preference can be seen for Periglacial grassland, Low elevation bluffs and Forest border. Forest, Moorland and Beach are avoided. If compared with Figure 12 it can be seen that indeed a shift has taken place. Periglacial grassland was a preferred habitat in 1990, but is not anymore in 2004.

Future research should verify whether this shift indeed was caused by cattle. If so, the preference for habitat with opportunities for anti-predation behaviour and other habitat conditions might be influenced by anthropogenic activities.

Table 6: Habitat proportions and proportions of time spent in habitats for Fiordo Témpano as used by Frid (1994) and this study (Van Winden, 2006). Only the data for adults and yearlings was used.

Habitat	**Frid, 1994 (total 98 ha)**		**Van Winden, 2006 (total 106 ha)**	
	Habitat proportion of the area	**Proportion of habitat use**	**Habitat proportion of the area**	**Proportion of habitat use**
Periglacial grassland	27.5	66	25.6	20
Low-elevation bluff	4.5	28	1.2	21
Footslope habitat			6.1	35
Forest border/ Grassland Forest edge	0.9	5	0.4	21
Old growth Forest	20.7	0	15.9	3
Moorland	46.2	1	50.0	0
Beach	0.2	0	0.8	0
Total:	**100**	**100**	**100**	**100**

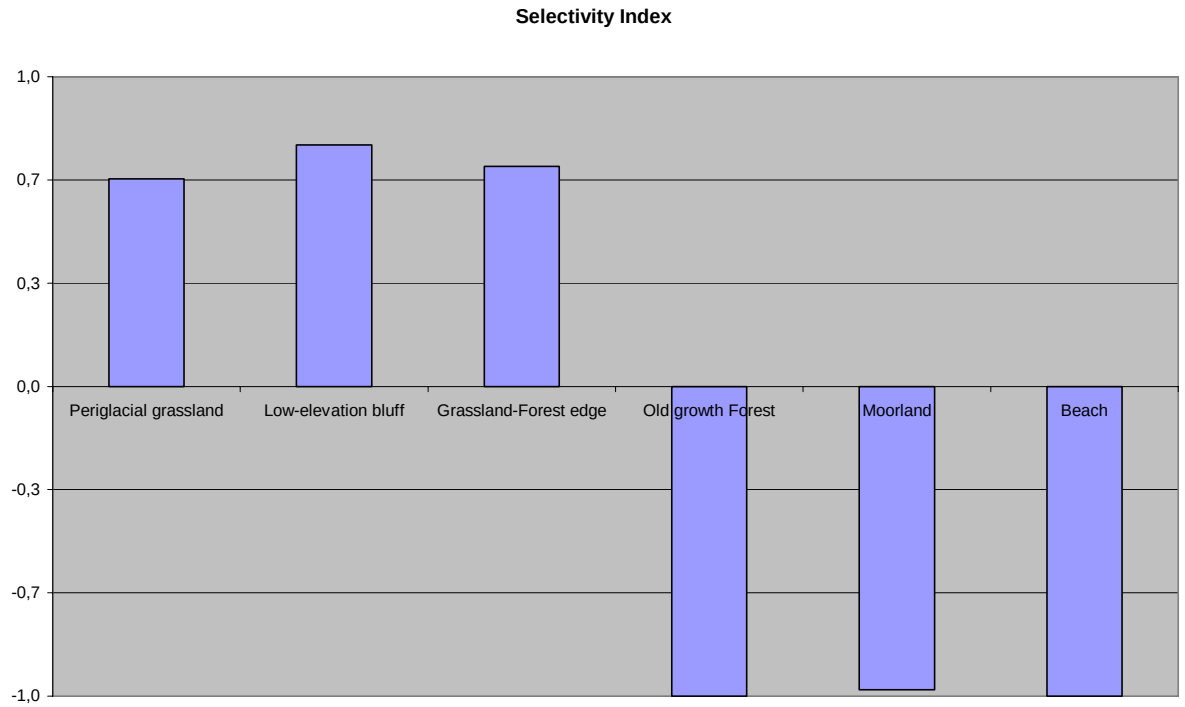

Figure 15: Ivlev's Selectivity Index, computed from data of Frid (1994). The index is a measure of favourability. $S=(r_i - p_i)/(r_i+p_i-2r_ip_i)$, where S is the selectivity index, varying from −1 to +1. Values between −1.0 and −0.3 indicate that the habitat is avoided, between −0.3 and +0.3 that there indifference towards the habitat and between +0.3 and +1.0 that the habitat has preference. r_i is the proportion of time spent in habitat i, and p_i is the proportion of habitat i in the area as shown in Table 6.

Future prospects of the area

It was found that huemuls prefer relatively open habitats, compared to the climax vegetation. These habitats in Patagonia are naturally either created by forest fires or by glacial retreat. Because of global warming the rates of glacial retreat are increasing, resulting in a rapid enlargement of the huemul's habitat. Therefore chances for preserving this species from extinction are greatest in periglacial sites where habitat is not destructed, but formed by man. For this reason, Bernardo 'O Higgins National park offers good opportunities for long term conservation measures for this species.

Current surveys to find suitable habitat for huemuls should not only focus on today's, but also on tomorrow's chances by already mapping areas where suitable habitat is expected in the coming 20 years, because, driven by succession, the huemul's habitat is expected to shift continuously.

Distinctiveness of populations

While the future prospects of the huemul are best in periglacial sites, only three (sub)populations have been studied at such sites. All are close to each other: at Fiordo Témpano (ca. 48° 40–43' S, 73° 59' –74° 30' W) (Frid, 1991, 1994, 1997, 1999, 2001; Wensing, 2005), Fiordo Bernardo (ca. 48° 34-37' S, 73° 53-55' W) (Wensing, 2005) and Estero Bernardo (ca. 48° 34–37' S, 73° 36-32' W) (Frid, 1999, 2001) research was performed. I want to argue that these huemul populations should be treated in a distinct way from populations using other habitats. Not only habitats differ between these

populations, but also diet and conservation chances and risks. It is likely that there are also differences in population biology.

6.5 Conclusion

One of the research questions was:

> To what extent are the habitats that occur in both fjords used by huemuls?

It was hypothesised that huemuls are not indifferent to their environment, but show preferences for certain habitats.

In Fiordo Témpano the most time was spent in footslope habitat, low-elevation bluffs, forest border and periglacial grassland. Correcting for the relative surface, a measure for preference, Ivlev's Selectivity Index, was computed. This shows that a large proportion of time was spent in the periglacial grassland, but that huemuls show no preference for that habitat. A preference was shown for footslope habitat, low-elevation bluffs and forest border.

In Fiordo Bernardo most time was spent in low shrub vegetation and on beaches and riverbeds. An estimated selectivity index shows that this last mentioned habitat has a strong preference.

Another research question was:

> Is there a difference in habitat use between both fjords?

The hypothesis was that there are local differences in habitat use, depending on the available local conditions.

In both fjords other habitats are used more intensively and also is there a preference for others types of habitat. The availability of types of habitat is very different in the two fjords.

The last question on habitat use was:

> Is there one or are there more conditions that habitats must have to be used frequently by huemuls in both fjords?

It was hypothesised that general preconditions can be given for important huemul habitat in this area.

Three important preconditions could be pointed out for important huemul habitat in this area. Huemuls prefer open habitat with, as a first precondition sufficient food availability. Another factor that the most important habitats of both fjords had in common is the opportunity to perform predator avoiding behaviour, such as hiding and fleeing. It can be disputed whether this is their natural preference, in particular because former research found (open) periglacial grassland as an important favourable habitat for Fiordo Témpano. Here there are no opportunities to hide or flee from predators. After introduction of cattle the habitat preference shifted to habitats with more cover.

6.6 Recommendations

To get a better insight in all year round day and night habitat use of the huemul the usage of radio collared animals is recommended. A lot of data can then be easily gathered and processed with a Geographical Information System (GIS). When using

radio collars, also the home ranges should be assessed. This is important to predict genetic exchange between (sub)populations, but it can also be used as a measure for habitat quality (Harestad and Bunnell, 1979), as was done by Widmer et al (2004). Smaller home ranges indicate a better habitat and vice versa. At this moment home ranges are assessed at Tamango reserve (Manzur et al, 1997; Saucedo and Gill, 2004), Nevados de Chillán (Povilitis, 1979) and La Baguala and Candonga (Saucedo and Gill, 2004) and values are found between 300 and 400 ha. Monitoring these home ranges for years will indicate ameliorations and deteriorations of the habitat.

Also habitat use should be measured after cattle removal to verify whether the cattle indeed caused a shift in habitat use and it is not, for instance, a time-effect.

7. Diet study

7.1 Introduction on diet selection by deer

The members of the deer family (Cervidae) are ruminants. They benefit from a mutualistic interaction with bacteria and other micro-organisms in their foregut to convert plant cellulose to energy (Hanley, 1997). It is important to understand the process of diet selection, because it determines the quantity and quality of food intake. This is responsible for a number of other factors: the nutritional status of individual animals and their physiological condition, their time and activity budgets, growth rates, potential reproductive rates and potential survival rates (Hanley, 1997). It also determines which plants are consumed, where, when and to what extent. Therefore diet selection can also have a great influence on plant communities and their ecosystems (Hanley, 1997).

A first step to be made to unravel the process of diet selection is a division in broad forage categories: grasses, herbs and browse. Three conceptual statements were given by Hanley (1982): (1) "Large animals are more time limited in their dietary choices than are small animals but require less energy per unit body mass than do small animals; (2) Large rumino-reticulums[4] are an adaptation to exploiting high-cellulose diets (i.e., grasses), while small rumino-reticulums are an adaptation to exploiting high-lignin diets (i.e., browses); and (3) large mouths can harvest and process more material per unit time than can small mouths, but small mouths can be more selective in biting than can large mouths." Through these statements it is clear that physical anatomy can give much information on diet preferences.

Hofmann (1985) made a classification of 19 species of deer and three species of domesticated ruminants (goat, sheep and cattle). This classification was importantly based on the anatomy of the digestive tract, but he also used data on feeding behaviour. It is a classification between (1) concentrate selectors, (2) grass-roughage eaters and (3) intermediates, although it should be seen as a continuum. Concentrate selectors in general select high-energy and low-fibre food. A good non-deer example is the Giraffe (*Giraffa camelopardalis*). The extreme grass-roughage eaters are non-selective grazers such as the African buffalo (*Syncerus caffer*) (Hofmann, 1985).

When talking about diet selection, the concentrate selector is the feeding type we must focus on, as the extreme grass-roughage eaters are non-selective. The stereotype concentrate selector is characterised by a number of anatomical and behavioural traits.

In general, concentrate selector species, such as Pudu (*Pudu sp.*), Muntjak (*Muntiacus sp.*) and Mazama (*Mazama sp.*) are smaller than their intermediate or grass-roughage counterparts. In 1970, Bell already made the generalisation that where forage quantity is limiting, small body size is favoured, whereas limitations in forage quality rather than quantity favour large body size. Exception to this rule seems to be the moose (*Alces alces*), which is the northern size-equivalent of the African giraffe. Both are, despite their sizes, within the concentrate selectors group (Hofmann, 1985).

[4] The rumen is the first stomach of a ruminant. The reticulum is its second stomach. Rumino-reticulum is a term used when both stomachs are considered together as one parameter.

One would expect the most extreme concentrate selectors to live in mountainous regions. Here the maximisation of selective feeding is most likely to occur, because there is wide variability in exposure, slope, and altitude that creates a diversity of microclimatic influences (Klein, 1985). This diversity of microclimate is important because of the spreading in time of the early phenological stages of plant growth. The plant parts in the early growth stages are rich in nutrients (Klein, 1965) and have generally low levels of secondary chemicals (Rhoades and Cates, 1976), that can inhibit digestion, or are toxic to rumen micro-organisms or the animal itself (Klein, 1985).

The stereotype concentrate selector uses ecotone bush habitat, so it can seek cover in its main food source. For part of the year it is territorial. Its diet can be divided into three types of food: (1) consumption food, (2) storage food and (3) maintenance food (Hofmann, 1985).

Consumption food is of high quality and fulfils the high energy demands during spring and summer (territorial fights in bucks, final stages of foetal growth in does, etc.) (Weiner, 1977). Storage food is directed towards fat deposits. It consists of energy- and nutrient rich fruits and seeds in autumn (Mautz, 1978). In winter and into early spring there is a lack of easily digestible food. The energy that is required is gained from maintenance food and from the fat deposits, largely built up during autumn (Hofmann, 1985).

7.2 Introduction on the food habits of the huemul

The Huemul is a browsing species (Eisenberg, 2000). The species is known to eat several tree-, shrub- and herb species (Colomes Gonzales, 1978; Frid, 1994). When categorised in the above mentioned classification it would be expected in the concentrate selectors group, but not as an extreme example in this regard. It is not large, but neither very small, which would point to the intermediate group. The proportional size of the rumino-reticulum could not be found in the literature, so no predictions could be given using that parameter. When compared to grass-roughage eaters it has a small mouth. It also lives in mountainous regions and at least in Fiordo Témpano it uses ecotone bush habitat. These arguments point towards the concentrate-selectors group. But of course only a diet study can provide more meaningful information.

Previous diet studies have mainly focused on a microhistological analysis of the faeces (Colomes Gonzales, 1978; Povilitis, 1978; Sierralta, 2003), although Frid (1994) forms an exception. In this study the diet composition is examined through direct observations.

7.3 Methods

The food habits of the huemul were observed in Fiordo Témpano and the North side of Fiordo Bernardo. In both fjords the time that was spent foraging on a certain species was recorded. At the beginning and end of each observation the time of day and habitat was recorded. Also, if there was a preference for specific plant parts, for example fruits or flowers, this was indicated. Average observation distance in Fiordo Témpano was 4 m. In Fiordo Bernardo the average observation distance was 6 m. Within these distances the individuals did not seem to be disturbed in their natural behaviour. The observations were recorded when the focal deer had become accustomed to the observant. This usually took less than five minutes. Observations in Fiordo Témpano were done daily from the 20th of December till the 11th of April, and from the 30th of April till the 3rd of May. In Fiordo Bernardo the observation period was from the 27th of March till the 24th of April.

7.4 Results

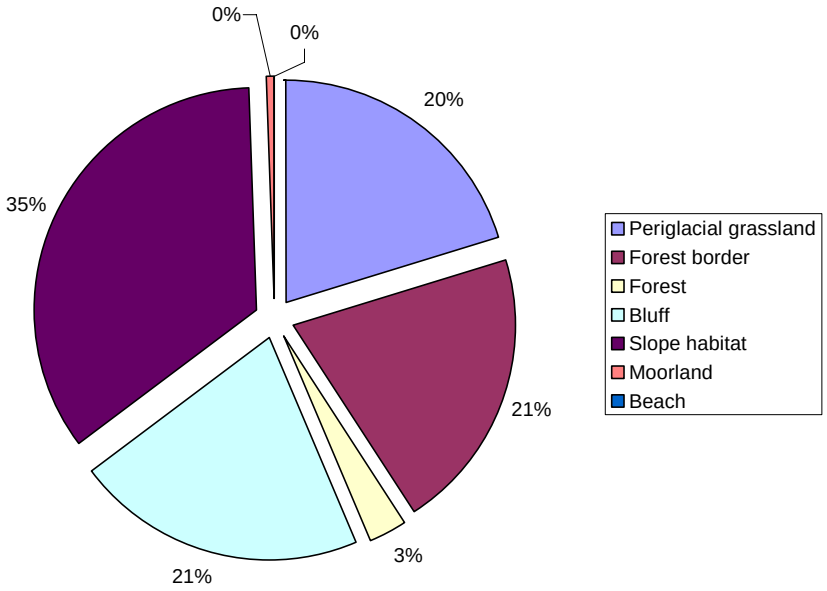

Figure 16: Percentage of foraging time spent per habitat in Fiordo Témpano. Most time was spent in Footslope habitat followed by Forest Border, Low elevation Bluffs and periglacial grassland.

Fiordo Témpano

Huemuls spent their foraging time in Fiordo Témpano mostly in Footslope habitat (35%), Forest border (21%), Low elevation bluffs (21%) and Periglacial grassland (20%) (Figure 16). Their diet in Fiordo Témpano exists mainly of two species: *Fuchsia magellanica* (71%) and *Gunnera magellanica* (25%). The remaining foraging time is divided between 10 species, mainly shrubs such as *Ribes magellanicum*, *Escallonia sp.*, *Nothofagus antarctica* and *Berberis buxifolia*.

The feeding habits of bucks and does regarded separately show that does spent more time foraging on *Fuchsia magellanica*. For bucks the amount of time spent on feeding on both *Fuchsia sp.* or *Gunnera sp.* differs little (Figure 17 and Figure 18).

Food habits in time

During the observation period the proportion of *Gunnera magellanica* as a food source decreased. *Fuchsia magellanica* substituted *Gunnera magellanica* as a food source. The proportions of *Nothofagus betuloides* and other shrub species than *Fuchsia* and other herb species than *Gunnera* are relatively constant during time. The category 'other shrub species' consisted of *Ribes magellanicum* (0,8%-3,2%), *Escallonia sp.* (0%-1,1%), *Nothofagus antarctica* (0%- 0,7%) and *Berberis buxifolia* (0%- 0,4%). The category 'other herb or grass species' consisted of *Acaena magellanica* (0%- 1,0%), *Cerastium fontanum* (0%- 0,5%) and Coirón (*Poacacae sp.*) (0%- 0,3%).

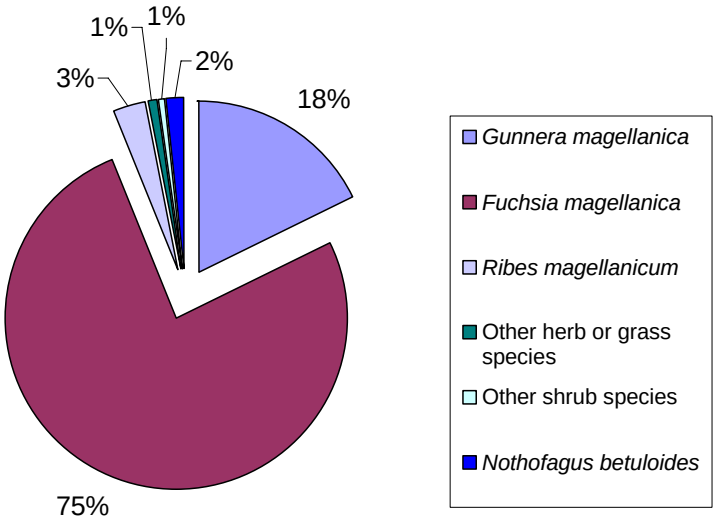

Figure 17: Diet composition of adult does in Fiordo Témpano. It shows a strong preference for *Fuchsia magellanica*. 93 percent of the foraging time was spent on either *Fuchsia magellanica* or *Gunnera magellanica*. Total feeding time: 26,7 hours. N=5.

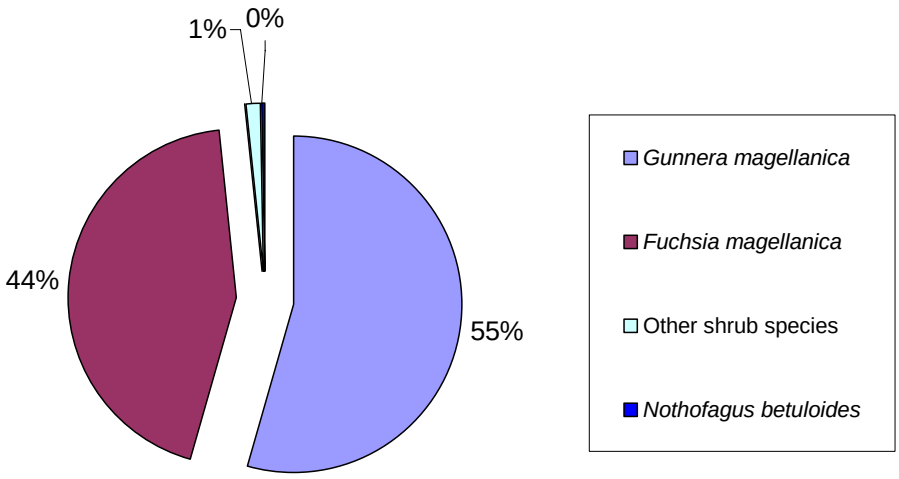

Figure 18: Diet composition of adult bucks in Fiordo Témpano. 99 percent of the diet consists of either *Gunnera magellanica* or *Fuchsia magellanica*. Total feeding time: 8,3 hours. N=3

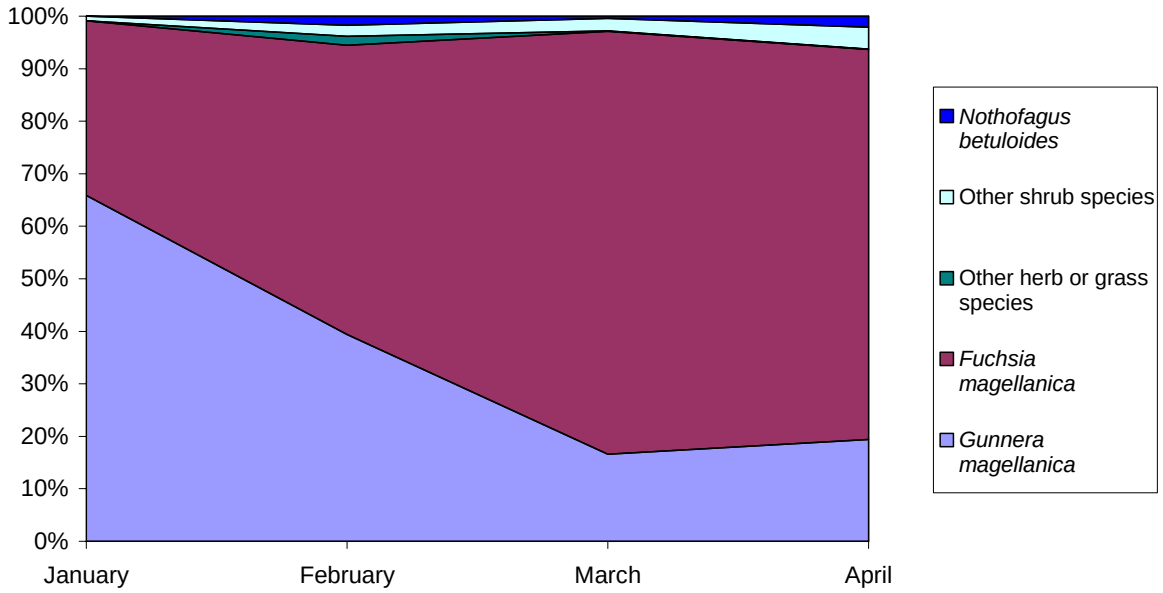

Figure 19: Diet composition in time in Fiordo Témpano. *Gunnera magellanica* is substituted as main food source by *Fuchsia magellanica*. Furthermore there is a small increase in foraging on other shrub species, mainly *Ribes magellanicum*, during the year.

Fiordo Bernardo

The main food source of Fiordo Témpano, *Fuchsia magellanica*, is not present in Fiordo Bernardo. The main food source here is *Gunnera magellanica* (82%). An additional important food source is *Senecio sp.* and on beaches *Asteraceae sp. undet.* (respectively code 169 and 227 in appendix I) (Figure 21). The largest proportion of the foraging time was spent in Low shrub vegetation (59%) (Figure 20).

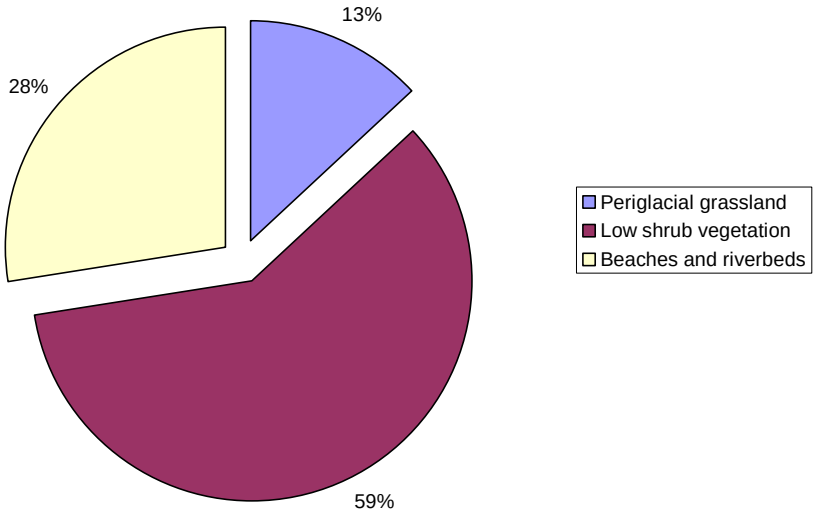

Figure 20: Percentage of foraging time spent per habitat in Fiordo Bernardo. 59% of the time was spent in Low shrub vegetation, 28% on beaches and riverbeds and 13% on periglacial grassland

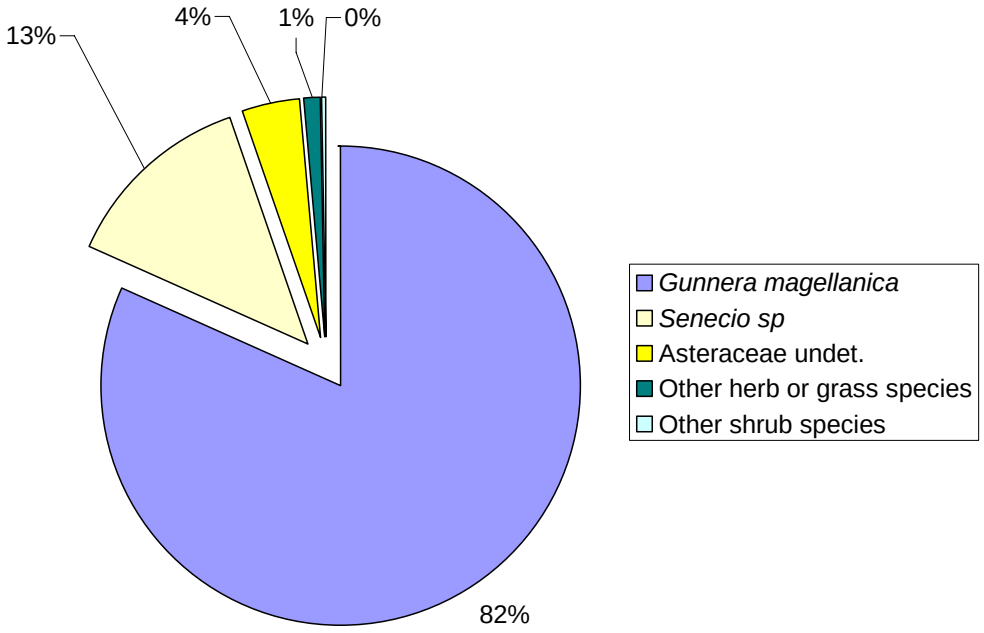

Figure 21: Diet composition of the Huemul in Fiordo Bernardo in March-April. It shows a strong preference for *Gunnera magellanica*. Total observation time: 8,4 hours, N= 20

Fruits, flowers and salt licking

Apart from eating green plant parts some other observations worth mentioning were done.

Usually the deer foraging upon plants did not only eat the leaves and twigs, but also flowers and fruits without any signs of favouring or disfavouring them, except for two species. Although not quantitatively measured in this research, huemuls seemed to favour the red fruits of *Gunnera magellanica* when available and foraging on that species.

In Fiordo Témpano the deer ate little of *Senecio sp.* and when eating from it they avoided eating the flowers. In Fiordo Bernardo this species formed a substantial part of their diet and they did swallow the flowers without exception.

One doe was observed licking rocks that were washed over with sea water. The doe spent thirteen minutes doing so.

7.5 Discussion

Methods

Microhistological analysis of the faeces has some advantages and disadvantages compared to the method of direct observations. First of all, data can be collected without intensive observations of the species; these observations could influence the (food) habits of the species. Furthermore the topography or vegetation density does not limit the data collection. And because of the possibility of long-term storage of the faeces, the number of samples to be analysed is unlimited (Sierralta, 2003). But using the microhistological method two assumptions are made: the epidermis of the species' cells has the same characteristics before and after digestion. And the proportion of different species' epidermia does not change during digestion. It is not certain that these assumptions are correct (Sierralta, 2003). Furthermore it can be difficult to identify several species (Sierralta, 2003). Also comparison of food habits between different habitats is not possible.

One should interpret the results of this research on the basis of direct observations, not as proportions of biomass intake from different plant species, but proportions in terms of feeding effort on a species. Although biomass is an important parameter, feeding effort might give a better idea of which plants are most important in the diet of the huemul. Some plants may be richer in nutrients than others. After all, not the quantity, but the efficiency of the forage as a food source is most important for survival and reproduction.

Plant species used as food source in time

It was only possible for Fiordo Témpano to compose a graph as in Figure 19. The research period in Fiordo Bernardo was too short. In 1994 Frid published a paper where he presented results of the average diet of huemuls in 1990 for the months October till December. The area used in Frid's research was also Huemul Valley in Fiordo Témpano and he also measured the time spent on certain plant species. So it was possible to combine his data with the data of this investigation. In this way one gets a more complete picture of what the diet of the huemul looks like during the year in the research area (Figure 22). We can see a consistent trend. The proportion of *Fuchsia magellanica* diminishes even more and *Gunnera magellanica* is even more important in early spring. The amount of *Nothofagus betuloides* is a small proportion larger than in January, but fluctuates quite constantly between 0% and 3% during the seven months the graph shows. The proportion of other shrub species than *Fuchsia magellanica* is larger in the months October till December than in the other months. In Frid's study this category consisted mainly of *Nothofagus antarctica* (2,5%), *Escallonia serrata* (1,8%) and *Ribes*

magellanicum (1,5%). In this present study this was mainly *Ribes magellanicum* (0,8%-3,2%), *Escallonia sp.* (0%-1,1%), *Nothofagus antarctica* (0%- 0,7%) and *Berberis buxifolia* (0%- 0,4%).

Based upon data gathered in National Reserve Tamango (47°S, 72°W) and in the Rio Claro sector of the National Reserve Rio Simpson (45°S, 72°W), Aldridge (1988) described an order in which the most important plants species of the diet are consumed during the year. In October the huemul starts intensively feeding on *Ribes sp.* and it is still eaten to a large account until December. When available, *Fuchsia magellanica* is the most consumed species from November on. Next to these shrub species are, amongst others, consumed: dandelion (*Taraxacum officinale*), *Anemona multifada*, *Nothofagus pumilio*, *Senecio sp.*, *Pernettya mucronata*, *Gaultheria sp.* and *Plantago lanceolata*. During these months neither quantity, nor quality of the food forms a problem. Between May and September, quantity still is not a problem, because there are enough species with perennial leaves such as *Embrothrium coccineum*, *Pernettya mucronata*, *Chusquea sp.*, *Escallonia rubra*, *Senecio sp.* and *Notofagus dombeyi*. But the nutritional value of these species in winter is much lower than of the species consumed during spring and summer.

When comparing this with the combined results of Frid (1994) and this present study, both carried out in Fiordo Témpano, the first thing that attracts attention is the small proportion of *Ribes magellanicum* in the diet in Fiordo Témpano. Although present in the area it only is a very small proportion of the diet. The second striking difference is that according to Aldridge *Fuchsia magellanica* is the most important species from November onwards. In Fiordo Témpano this is only the case from February onwards. Several reasons for these differences can be proposed. First of all the areas where Aldridge's data is from are situated more to the north than Fiordo Témpano is. This probably results in high nutritional values in plant tissue earlier in the year. This can explain part of the later peak in the usage of *Fuchsia magellanica* as main food source in Fiordo Témpano, but it is hard to believe that this explains a difference of three whole months. Another explanation is *Gunnera magellanica*, which is not present in the research area of Aldridge or at least not used as a food source. *Gunnera magellanica* might be a more efficient food source than *Fuchsia magellanica* from December until February. From February on, the nutritional value of Gunnera might decrease and it is replaced as major food source by *Fuchsia sp*. This could also explain why *Ribes magellanicum* is not as important in Fiordo Témpano as it is in the National Reserve Tamango and Rio Simpson. Feeding on *Gunnera magellanica* might simply be more efficient. A first step to assess this is carrying out measurements of nutritional value of different species in time. But not only nutritional value is a factor that determines how efficient it is to use a species as a food source, also search time and handling time are two important factors. The nutritional value of *Gunnera magellanica* is unknown, but it is easy to make statements about search and handling time especially when compared to *Ribes magellanicum* in the area. In general *Gunnera magellanica* was very common in the area and very easy to find. Search time would be reduced to a minimum by eating *Gunnera* as a bulk food. *Gunnera magellanica* is a herb which is not very woody. Its rhizome can be woody, but this part of the plant is almost not eaten. In contrary *Ribes magellanicum* was not very common and its leaves are farther apart from each other. Therefore search time is larger than for *Gunnera magellanica.* So is handling time, because it is a more woody plant species.

In her doctoral thesis Smith-Flueck (2003) found little difference in the diet in three seasons. She remarks that that is uncommon for South American deer species. In this current research also no large differences in time were found in species composition, but a shift in importance of plant species as part of the diet was found.

Ranking order of plant species

A preliminary ranking order of plant species can be given for the two research sites together:

1. *Gunnera magellanica*
2. *Fuchsia magellanica*
3. *Asteraceae spp.*
4. *Ribes magellanicum*
5. *Nothofagus spp.*

Gunnera magellanica is seen as the most important plant species of the diet because in both sites this species was a major part of the diet. *Fuchsia magellanica* was also important, but it was only available in Fiordo Témpano. *Asteraceae* species were a substantial part of the diet in Fiordo Bernardo and *Ribes magellanicum* and *Nothofagus* species were in small amounts but constantly present in the diet in Fiordo Témpano. Other species were only consumed occasionally.

Winter diet

During the year there was an increase in foraging on other shrub species than *Fuchsia magellanica*, mainly *Ribes magellanicum*. In April there was also foraged upon *Nothofagus antarctica*. It is most likely that the evergreen *Nothofagus betuloides* will take up a larger part of the diet composition in autumn and winter, being already a small but permanent part of the diet in summer. Next to these species other species that were yet not used as a food source are expected to be part of the winter diet in the area. *Pernettya mucronata* is very common in the area and a known food source. Less common but available are *Embrothrium coccineum* and *Escallonia sp.*

Fruits, flowers and salt licking

The avoidance of the flowers of *Senecio sp.* by huemuls in Fiordo Témpano can be explained by the possibly low palatability of the flowers. This low palatability could be caused by toxins or chemicals that reduce the digestibility of the plant part. It is known for other *Senecio spp* such as Ragwort (*Senecio jacobaea*) that they are toxic, sometimes the flowers are twice as toxic as the rest of the plant parts. However, it is remarkable that huemuls in Fiordo Bernardo do eat the flowers of *Senecio sp*. There are two possible explanations: (1) the palatability of the flowers depends on the time of year. As the observations in Fiordo Bernardo were performed later in the year this could have influenced the data that were gathered. (2) The flowers are used in Fiordo Bernardo despite their low palatability, because it is the most efficient way of attaining the important nutrients and minerals that they contain. In Fiordo Témpano there may not be such a need for these nutrients and minerals, because other plant species such as *Fuchsia magellanica* are an easier source.

Mineral lick is not uncommon in deer species, probably it is a way of replenishing a deficiency in Sodium (Na) (Kennedy et. al., 1995; Bechthold, 1996; Atwood and Weeks, 2002, 2003), however for huemuls it has never been described in literature before.

Concentrate selector, grass-roughage eater or intermediate?

The huemul could best be classified in the concentrate selector group, but is definitely not an extreme example in this regard. It uses its small mouth to select high nutrient and low fibre plant parts, but only few plant species are of major importance to its diet. One or two species are the bulk part of the diet and this is supplemented by the intake of other high quality species. The bulk species are a result of the trade-off between

nutrients, search-time, handling-time and digestibility. In winter, nutrient rich plant parts are scarce and the diet will probably be more varied in species composition.

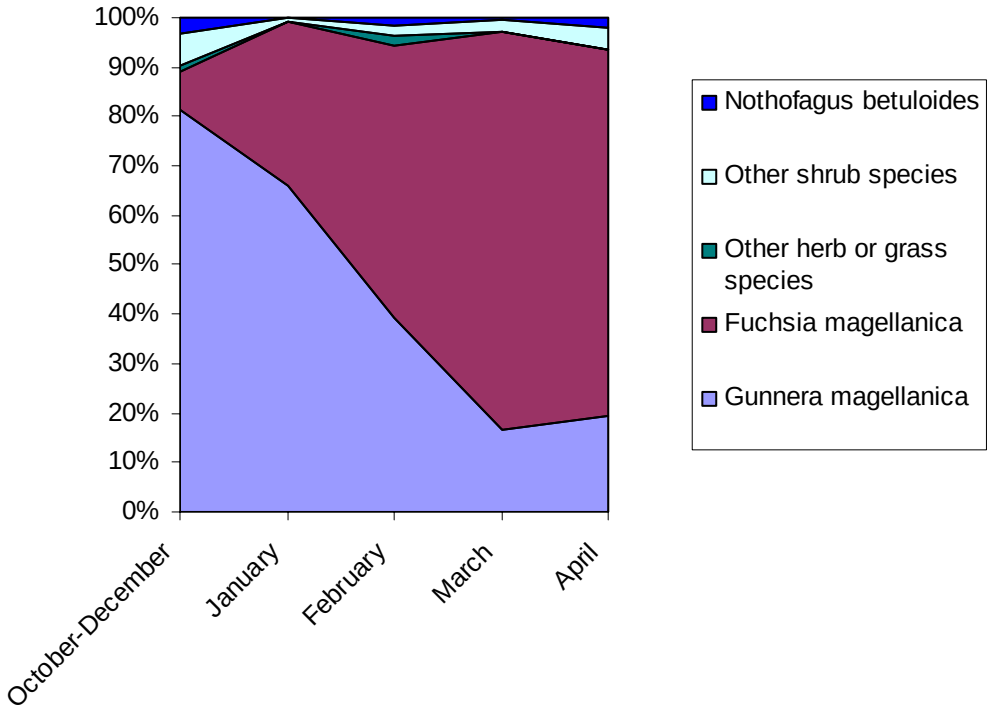

Figure 22: Average proportion of time spent on feeding on five categories of food. Data of Frid (1994) are included in the Figure. Frid also used direct observations and measured the time spent foraging upon plant species. The observations of his research were carried out from October till December 1990 in Fiordo Témpano.

7.6 Conclusions

A major question in this research was:

Which plant species do huemuls consume in both fjords and what is the relative contribution to their diet?

Gunnera magellanica and, when available, *Fuchsia magellanica* are the most important species in the diet of the huemul in the research area. Species composition of the diet does not differ much during the year, but there is a shift in importance of plant species in the diet. The huemul can be classified within the concentrate selectors group, but is not an extreme example in this regard.

Another research question was:

Is there a difference in food habits between both fjords?

The hypothesis was that there are local differences in food habits, depending on the available local conditions.

The research has shown that there are differences in diet between both fjords. One reason is that certain plant species are not available at certain sites, but also if present on both fjords the use of certain plant species can differ, such as with *Senecio sp.*.

The last research question on food habits was:

Which plant species are common diet species for the huemul in both fjords?

In both fjords was *Gunnera magellanica* a major part of the diet.

7.7 Recommendations

An all year round study on the huemul diet would be an important complement to our knowledge. Especially data on the winter diet is missing, while this is the time of year that there are the most stringent conditions. Diet in winter might be the most important diet to study for conservation purposes.

The effort should be made to do a comparative study on the microhistological method of diet studies and diet studies by direct observations. When it is found that both types of study are of equal quality, both methods can be used in a complementary way. Microhistological analysis then is more efficient to get insight into the overall diet and direct observations can give answers to questions about where and when certain plants are consumed.

To formulate statements on feeding efficiency, one should measure the energy content and nutrient values of the species in the diet over time and one should measure search time and handling time for the different species.

8. Synthesis

8.1 Introduction

In this chapter the conclusions and results will be discussed in a wider context. The findings of the separate chapters will be combined and often linked to conservation issues or -measurements regarding the huemul.

8.2 Research questions

The research area was the surroundings of two fjords located in the very much undisturbed National park Bernardo 'O Higgins: Fiordo Témpano and Fiordo Bernardo. Here, the largest known (sub)population of huemuls in the world was found (see also Wensing, 2005). Botanically the area lies on the eastern border of the *Nothofagus* dominated evergreen temperate rainforests. A first representative collection of plant species of the area was made. Only part of the collection could be determined and at least two species (*Pilgerodendron uviferum* and *Dacrydium fonkii*) are considered vulnerable according to the 1997 IUCN red list of threatened plants (Walter and Gillett, 1998). Also three non-indigenous species were found in the area: *Lunaria annua*, *Ranunculus repens* and *Cerastium fontanum*, all from European origin. The presence of these species should be considered as a warning. Further research on the vegetation is needed and measures should be taken to avoid colonisation of the area by non-native species.

The habitats in the research area were also described. Frid's (1994) classification for Fiordo Témpano was partly revised. Both areas differ considerably; when characterising Fiordo Bernardo in one word, this word would be: shrubland. Doing the same for Fiordo Témpano, it would be: grassland. Table 5 (page 37) gives an overview of which habitats occur in which valley.

Huemuls were found to prefer open habitats with enough food sources present and sufficient possibilities to exhibit anti-predation behaviour. The latter might be only a precondition when the huemul is influenced by possible threats. A shift in habitat preference, from the open periglacial grassland on the valley bottom to habitats with more cover on slopes, was found after the introduction of cattle in Fiordo Témpano.

Huemuls can be classified within the concentrate selectors group, but are not an extreme example in this regard. In both fjords they use *Gunnera magellanica* as a bulk food source. In Fiordo Témpano, *Fuchsia magellanica* was also a very important part of the diet. In Fiordo Bernardo, where no *Fuchsia magellanica* is present this role was partly taken over by Asteraceae sp. Species composition of the diet during the year does not alter, but there is a shift in importance of the different species.

Let us reconsider the main research question that was answered in this research:

What habitat- and dietary preferences do huemul have within Fiordo Témpano and Fiordo Bernardo?

My hypothesis that huemuls are not indifferent to their environment, but have clear habitat and dietary preferences was confirmed in this research. We can learn from the answer, combined with the knowledge of population dynamics (see Wensing, 2005), what area's contain promising habitat for (future) huemul populations.

We have seen that the preferred habitat is an open habitat with cover or fast routes into deeper water, but that habitat preferences might also be related with human activities in an area.

We have seen that certain plant species, for instance *Gunnera magellanica* and *Fuchsia magellanica*, are an important food source in the area. This also provides insight in what areas are likely to be able to support huemul populations.

8.3 Consequences for population dynamics

Results of this current research could explain some findings of Wensing (2005) whose research partly concentrated on population dynamics. Possible explanations of the differences in group size and buck-doe ratio of carcasses in the two areas are given.

Note on predation

Huemuls have two natural predators: the fox (*Pseudalopex culpeus)* and the puma (*Puma concolor*). The presence of both was determined in both fjords. Densities of pumas however are not considered to be high. In all carcasses found, there was no sign of predation by a puma, which ought to leave marks behind (Vila, personal comment). It has always been hypothesised that foxes may prey on fawn of the huemul, however this had never been witnessed before. During this study it was witnessed for the first time (see also Wensing, 2005). Also a piece of huemul skin (10x15 cm) was found, surrounded by lot of fresh footprints of several foxes. After this finding an adult doe was never seen again. She might have been weakened for some reason and attacked by foxes (see also Wensing, 2005). In my opinion foxes might form a problem if they occur in high densities. Therefore fox populations should be monitored and foxes should not be fed by park guards as currently happens sometimes. High population densities of foxes might create a too high predation pressure for the huemul.

Group sizes in relation to predator avoidance strategies, food habits, population densities and habitat characteristics

In Chapter 6 it was hypothesised that both populations in Fiordo Témpano and Fiordo Bernardo have different predator avoiding strategies. In Fiordo Témpano cover would be the most important and in Fiordo Bernardo fleeing into nearby water would be the most important. This might be one of the reasons that huemuls live in larger groups in Fiordo Bernardo. When hiding is the main strategy it has disadvantages to live in larger groups, because the chance of being noticed by a predator is increased. When fleeing is the main strategy the chances of survival increase with group size because of safety by numbers.

Klein (1985) states that gregariousness among ungulates is related to predation avoidance (Geist, 1971; Treisman, 1975), but that this safety goes at expense of feeding efficiency. The quality of the food intake is less because there is a strong competition in the group for the most nutrient rich plant parts. This drawback of gregariousness is probably most evident in early spring when new plant growth starts and forage of high quality is limited.

This could explain the larger group sizes in Fiordo Bernardo in two ways. First, the observations in Fiordo Bernardo were done in the beginning of fall. The strategy of

solitary foraging is most profitable in early spring. It might be that group size increases towards winter. Second, Fiordo Témpano has a more varied landscape with more (altitudinal) gradients. Because of this, the timing of initial plant growth is expected to vary more widely than in Fiordo Bernardo where the landscape does not show a large variation in gradients. Competition for nutrient rich plant parts is expected to be higher when the appearance of newly grown parts is spread out over a larger period of time. The rate of competition is lower when initial plant growth starts all at once and there is an abundance of nutrient rich plant parts for a short period of time.

Also is it found by Gerard et al (1995) that for roe deer (*Capreolus capreolus*) group size is correlated with openness of the habitat and with population densities. Indeed, the used habitats were more open in Fiordo Bernardo and population densities were much higher (1,32 and 8,64 individuals/km^2) (Wensing, 2005).

Mortality under nutritional stress

Wensing (2005) found a large discrepancy in the gender of the carcasses that were found in both fjords. In Fiordo Témpano five remains of deer were found: four of adult does, and one fawn. In Fiordo Bernardo eight carcasses were found: seven adult bucks and one adult doe. It was evident that this last one was killed by men. This large difference might indicate that the population level of Fiordo Bernardo is at its carrying capacity. Klein (1985) states that under nutritional stress (which is the case when a population level has reached the carrying capacity) a higher mortality rate among males is to be expected, because under these conditions they are not able to recover the body reserves that they have lost during the rutting period. Winter then takes a heavier toll of bucks through malnutrition and starvation. It is also worth noting that when a population is at its carrying capacity larger group sizes and more interactions are expected and the rutting period will have a higher energy cost than in areas with lower population densities.

8.4 Consequences for conservation strategies and conservation measurements

The aim of this research was to create a foundation for constructive conservation measurements. Further research for new populations should now be focussed on areas where the above mentioned habitats and food sources are prevalent. Areas with these conditions should be safeguarded as possible future huemul habitat.

Fiordo Bernardo at its carrying capacity?

Further (long term) research on population dynamics is necessary, especially at Fiordo Bernardo. The high population density and the extreme buck-doe ratio in the carcasses (7 bucks to 1 doe that was killed by man) might indicate that the population is at its carrying capacity. When this is verified (by research on population dynamics and migratory patterns) the population of Fiordo Bernardo might be used as a genetic pool by transporting bucks from it to other, genetically poor, areas. This should be done with great care and the population of Fiordo Bernardo should be monitored intensively when this measurement is taken. Fiordo Bernardo may also function as a natural source of individuals to other areas, for example Fiordo Témpano.

Long term habitat analysis

The habitats appropriate for huemuls in Bernardo 'O Higgins National Park are associated with periglacial sites. This means that, in time, huemuls will always be on the move as their habitat will follow the glacial retreat. Long term conservation measures should consider this as the time scale of this process can be expressed in decades. This research

has shown that huemuls favour open habitat with some cover or with an easy access to open water. This means that in decades time the habitat of Fiordo Témpano will improve as more shrubs will appear at the valley bottom. In the valley of Fiordo Bernardo the huemuls will be pushed back more to the east. In time, the possibilities of the large, yet open, valley connecting Fiordo Témpano and Fiordo Bernardo are promising. At this moment it is not known to what extent huemuls make use of that valley, therefore in the future an effort should be made to monitor this valley.

Mineral licks

Mineral licking was observed at a natural site in Fiordo Témpano. Most commonly this is used to replenish a deficiency in Sodium (Na). A shortage of Sodium in the diet might decrease the rate of pregnancy, lactation and the formation of antlers (Atwood and Weeks, 2002 and 2003). Coastal populations have a natural resource to optimize their mineral balance because the sea water is rich in Sodium. For inland populations, where no mineral lick sites are available, a conservation measurement could be the distribution of some licking stones in the area. These points could then well be monitored by cameras as a system to register population dynamics. Deer are expected to visit the licks regularly once they have found the sites. This measurement is best used in protected areas, because the lick sites could also be a vulnerable spot as poachers can also make use of it.

8.5 Recommendations for future research

For future research, it is recommended to:

- Do further botanical analysis on the collected plants to get a full overview of the species that occur in the area.
- Radio-collar and monitor a number of huemuls to describe year round habitat use and home range.
- Measure the habitat use after cattle removal.
- Make a further inventory of other (promising) huemul populations in Bernardo O'Higgins National Park.
- Monitor the population dynamics of the huemul populations.
- Perform genetic analyses on different (sub)populations inside and outside the national park to determine genetic variance.
- Monitor fox populations to keep an eye on predation pressure in the areas.
- Study the huemul diet all year round. Especially winter is important, because of the stringent conditions.
- Perform parallel diet studies, using the microhistological method and direct observations. The results should be compared and can be evaluated. Clear standards to which method should be used for which research questions should be developed.
- Measure nutrient and energy content and secondary plant compound levels over time in the most important species in the diet: *Gunnera magellanica*, *Fuchsia magellanica*, *Senecio sp.*, *Asteraceae* undet. and *Ribes magellanicum* to get more insight into the diet quality.
- Measure also search and handling time and average bite volume of these species to perform further analyses.

8.6 Conclusion

This report contributes to the knowledge of habitat use and diet preferences of the huemul in periglacial sites and can be used as a guide to find suitable habitat for reintroductions. Also can it be used to assess on which sites chances of finding huemuls

are largest and it thus gives more direction to the efforts of conserving this wonderful species.

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Appendix I

Plants of Fiordo Témpano

Collected by Jasper van Winden in
Fiordo Témpano, Chile.
December 2003 - April 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

ASTERACEAE.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 20 m

Shrub, 1,20 m tall, flowers white; at 50 m distance from glacier

J. van Winden Nr.: 101
January 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

ROSACEAE
Acaena
magellanica (Lam.) Vahl.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano. On periglacial grassland and on slopes.

48º 69' S, 73º 99' E Alt: 75 m

Herb, 0.15 m; inflorescense with sticky purple hairs; common.

Vernacular name: Cadillo

J. van Winden Nr.: 103
January 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

BRASSICACEAE
Lunaria
annua

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland, near beach

48º 69' S, 73º 99' E Alt.: 10 m

Shrub, 0.5 m tall, flowers violet; near corral for cows

J. van Winden Nr.: 102
January 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

herb, 0.05 m tall, flowers yellow, darker at base

J. van Winden Nr.: 104
January 2004

Figure 1: Clockwise, plant code 102, 103 and 104 (photographs by Jasper van Winden)

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

CANIPANACEAE
Pratia
longiflora Hooker f.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano;
.

48º 69' S, 73º 99' E Alt: 100 m

Herb, 0.03 m tall, petals white from above, underside purple

J. van Winden Nr.: 105
January 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

ERICACEAE
Pernettya
mucronata (L.f.) Gaudich ex. G. Don

Det. : J. van Winden & P.J.M. Maas 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano

48º 69' S, 73º 99' E Alt.: 125 m

Shrub, 2 m tall, flowers white; common.

Vernacular name: Chaura

J. van Winden Nr.: 107
January 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

LILIACEAE
Philesia
magellanica J. F. Gmelin.

Det. : J. van Winden & P.J.M. Maas 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano. In evergreen *Nothofagus*-forest.

48º 69' S, 73º 99' E Alt.: 150 m

Climbing shrub, flowers pink; common.

Vernacular name: Coicopihue

J. van Winden Nr.: 106
January 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

ASTERACEAE

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

Herb, 0.10-0.20 m tall, flowers yellow, inflorescence white;

J. van Winden Nr.: 108
January 2004

Figure 2: clockwise, plant code 105, 107, 114 and 118 (photographs by Jasper van Winden)

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest border

48º 69' S, 73º 99' E Alt.: 80 m

Shrub, 1.5 m tall, flowers white, heart conspicuously dark purple/black. Alternate stamens

J. van Winden Nr.: 109
January 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

FAGACEAE
Nothofagus
betuloides (Mirbel) Oersted.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; .

48º 69' S, 73º 99' E Alt: 150 m

Tree, 15 m tall,
.

Vernacular name: Coigue

J. van Winden Nr.: 111
January 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland,

48º 69' S, 73º 99' E Alt.: 50 m

Herb, 0.05 m tall, flowers white;

J. van Winden Nr.: 110
January 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

PROTEACEAE
Lomatia
ferruginea R. Br.

Det. : J. van Winden & P.J.M. Maas 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano. Coastal forest border

48º 69' S, 73º 99' E Alt: 200 m

Shrub, 2 m tall, flowers red.

J. van Winden Nr.: 114
January 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest border

48º 69' S, 73º 99' E Alt.: 100 m

shrub, 1 m tall

J. van Winden Nr.: 115
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; slope; forest border

48º 69' S, 73º 99' E Alt.: 100 m

shrub, 2,5 m tall; blue berries

J. van Winden Nr.: 117
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

WINTERACEAE
Drymis
winteri Forster & Forster

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano. In the forest.

48º 69' S, 73º 99' E Alt: 150 m

Tree, 3 m tall, white flowers, aromatic leaves and branches; common.

Vernacular name: Canelo

J. van Winden Nr.: 116
January 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

DROCERACEAE
Drosera
uniflora Willd.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; moorland

48º 69' S, 73º 99' E Alt.: 400 m

Carnivorious herb 0.04 m tall, common.

J. van Winden Nr.: 118
February 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

GLEICHENIACEAE
Gleichenia
Quadripartita (Poiret) T. Moore

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; *Nothofagus*-forest

48º 69' S, 73º 99' E Alt.: 100 m

fern, 0,20 m tall

J. van Winden Nr.: 120
February 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

SCROPHULARIACEAE
Calceolaria
Tenella Poepp. and Endl.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

herb, 0,07 m tall; flowers yellow

J. van Winden Nr.: 122
February 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest

48º 69' S, 73º 99' E Alt.: 100 m

shrub, 3,0 m tall

J. van Winden Nr.: 121
February 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

moss

J. van Winden Nr.: 124
January 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

moss

J. van Winden Nr.: 125
January 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

POACACEAE

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

Grass, 0,07 m tall;

J. van Winden Nr.: 129
February 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

POACACEAE

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

Grass, 0,20 m tall;

J. van Winden Nr.: 127
February 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

URTICACEAE
Pilea
magellanica Lam.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt: 75 m

Herb.

J. van Winden Nr.: 130
February 2004

Figure 3: clockwise, plant code 131, 133, 134 (photographs by Jasper van Winden).

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

GUNNERACEAE
Gunnera
magellanica Lam.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt: 75 m

Herb, 0,05 m- 0,15 m tall, flowers white, fruit red; common.

Vernacular name: Fruta del diablo

J. van Winden Nr.: 131
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

ASTERACEAE

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

herb, 0,06 m tall; flowers purple

J. van Winden Nr.: 133
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

POACACEAE

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

grass, 0,06 m

J. van Winden Nr.: 132
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

Herb, 0,05 m tall; flowers white/pink

J. van Winden Nr.: 134
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

moss, 0,02 m;

J. van Winden Nr.: 135
January 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest

48º 69' S, 73º 99' E Alt.: 150 m

Herb, 0,25 m; berry

J. van Winden Nr.: 139
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest-moorland ecotone

48º 69' S, 73º 99' E Alt.: 450 m

Shrub, 3,0 m tall;

J. van Winden Nr.: 136
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 130 m

herb, 0,10 m tall;

J. van Winden Nr.: 140
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

HYMENOPHYLACEAE
Hymenophyllum
.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest.

48º 69' S, 73º 99' E Alt: 130 m

0,15 m tall,

J. van Winden Nr.: 141
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

POACACEAE
Festuca?
gracillima?

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

grass, 0,80 m tall;

Vernacular name : Coirón

J. van Winden Nr.: 144
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

DESFONTAINEACAE
Desfontainea
spinosa Ruiz.& Pav.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano, forest

48º 69' S, 73º 99' E Alt.: 150 m

Shrub, 2.5 m tall, flowers orange with yellow; common.

Vernacular name: Taique

J. van Winden Nr.: 142
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

POTAMOGETONACEAE
Potamogeton
lingatus Hagström.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; fresh water, with and without current

48º 69' S, 73º 99' E Alt: 60 m

Aquatic plant

J. van Winden Nr.: 145
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest

48º 69' S, 73º 99' E Alt.: 120 m

Fern, 1,5 m tall;

J. van Winden Nr.: 146
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

POACACEAE

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest border

48º 69' S, 73º 99' E Alt.: 130 m

grass, 0,15 m tall;

J. van Winden Nr.: 148
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

SAXIFRAGACEAE
Ribes

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; cypress forest

48º 69' S, 73º 99' E Alt.: 150 m

Shrub, 1,50 tall;

J. van Winden Nr.: 147
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

ASTERACEAE

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; cypress forest border

48º 69' S, 73º 99' E Alt.: 100 m

Herb, 0,10 m tall; flowers white

J. van Winden Nr.: 149
February 2004

Figure 4: clockwise, plant code 142, 146, 149, 150 (photographs by Jasper van Winden).

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

CARYOPHYLLACEAE
Stellaria
debilis D'Urv.

Det. : J. van Winden and P.J.M. Maas 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano

48º 69' S, 73º 99' E Alt: 130 m

Herb, 0.02 m. tall, flowers white; common.

J. van Winden Nr.: 150
Februarry 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest border

48º 69' S, 73º 99' E Alt.: 100 m

Herb, 0,03 m;

J. van Winden Nr.: 152
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest border

48º 69' S, 73º 99' E Alt.: 100 m

herb, 0,04 m tall;

J. van Winden Nr.: 151
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

ERICACEAE
Pernettya
pumila (L. F.) Hooker.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano;

48º 69' S, 73º 99' E Alt: 125 m

Herb, 0.02 m tall, berry pink or red

J. van Winden Nr.: 153
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

ASTERACEAE

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; cypress forest

48º 69' S, 73º 99' E Alt.: 150 m

Herb, 0,10 m tall;

J. van Winden Nr.: 155
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

POLYGONACEAE

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; cypress forest border

48º 69' S, 73º 99' E Alt.: 80 m

Shrub, 0,40 m;

J. van Winden Nr.: 157
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

POACACEAE

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest border

48º 69' S, 73º 99' E Alt.: 120 m

Grass, 0,12 m tall; flat, seeds pointed downwards

J. van Winden Nr.: 156
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

CUPRESSACEAE
Pilgodendron
uviferum (D. Don.) Florin.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano

48º 69' S, 73º 99' E Alt.: 150 m

Tree, 7 m tall.

J. van Winden Nr.: 158
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

POLYGONACEAE

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; cypress forest border

48º 69' S, 73º 99' E Alt.: 80 m

Shrub, 0,40 m;

J. van Winden Nr.: 160
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; cypress forest border

48º 69' S, 73º 99' E Alt.: 80 m

Herb;

J. van Winden Nr.: 164
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; cypress forest border

48º 69' S, 73º 99' E Alt.: 110 m

Herb, 0,03 m tall;

J. van Winden Nr.: 161
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

SAXIFRAGACEAE
Ribes
magellanicum Poiret

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest borders and on slopes.

48º 69' S, 73º 99' E Alt: 125 m

Shrub, 1.5 m tall, lemonish aroma; common.

Vernacular name: Zarzaparilla

J. van Winden Nr.: 166
February 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

LILACEAE?

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest border

48º 69' S, 73º 99' E Alt.: 100 m

Herb, 0,07 m tall; flowers white

Comment : flowers smell like marzipan

J. van Winden Nr.: 167
February 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

ASTERACEAE
Senecio

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

herb, 0,25 m tall; flowers yellow

J. van Winden Nr.: 169
February 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

PROTEACEAE
Embothrium
coccineum Forster & Forster f.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano

48º 69' S, 73º 99' E Alt: 250 m

Shrub, 1 m tall, flowers bright red;

Vernacular name: notro, ciruelillo

J. van Winden Nr.: 168
February 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest border

48º 69' S, 73º 99' E Alt.: 300 m

Herb, 0,15 m tall; inflorescence white, flowers yellow

J. van Winden Nr.: 170
February 2004

Figure 5: clockwise, plant code 166, 169, 176 and 201 (photographs by Jasper van Winden).

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland at seaside

48º 69' S, 73º 99' E Alt.: 50 m

Shrub, 0,25 m tall; flowers in bud, purple

J. van Winden Nr.: 171
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest border

48º 69' S, 73º 99' E Alt.: 100 m

shrub, 0,40 m;

J. van Winden Nr.: 173
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

LYCOPODIACEAE
Lycopodium
magellanicum (P. Beauv.) Schwartz.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano;

48º 69' S, 73º 99' E Alt: 380 m

.

J. van Winden Nr.: 172
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

fern, 0,05 m tall;

J. van Winden Nr.: 174
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; bluff at sea side

48º 69' S, 73º 99' E Alt.: 20 m

Fern, 0,60 m tall

J. van Winden Nr.: 175
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

LYCOPODIACEAE
Lycopodium
Confertum Willd.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; moorland

48º 69' S, 73º 99' E Alt: 400 m

Vernacular name: Siempre viva

J. van Winden Nr.: 177
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

ONAGRACEAE
Epilobium
ciliatum Rafin.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano

48º 69' S, 73º 99' E Alt.: 65 m

herb, 0.1 m tall,

J. van Winden Nr.: 176
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; moorland

48º 69' S, 73º 99' E Alt.: 300 m

herb, 0,10 m tall; inflorescence white

J. van Winden Nr.: 178
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

ASTERACEAE

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; moorland

48º 69' S, 73º 99' E Alt.: 300 m

herb, 0,07 m; inflorescence white

J. van Winden Nr.: 179
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; moorland

48º 69' S, 73º 99' E Alt.: 200 m

Moss,

J. van Winden Nr.: 181
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; moorland

48º 69' S, 73º 99' E Alt.: 300 m

herb, 0,15 m tall; inflorescence yellow

J. van Winden Nr.: 180
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; moorland

48º 69' S, 73º 99' E Alt.: 300 m

shrub, 0,30 m tall

J. van Winden Nr.: 183
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; moorland

48º 69' S, 73º 99' E Alt.: 300 m

herb, 0,03 m tall;

J. van Winden Nr.: 184
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; moorland

48º 69' S, 73º 99' E Alt.: 300 m

shrub, 0,70 m tall;

J. van Winden Nr.: 188
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; moorland

48º 69' S, 73º 99' E Alt.: 300 m

herb, 0,02 m;

J. van Winden Nr.: 185
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; moorland

48º 69' S, 73º 99' E Alt.: 200 m

Moss,

J. van Winden Nr.: 191
February 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; moorland

48º 69' S, 73º 99' E Alt.: 300 m

herb, 0,02 m tall

J. van Winden Nr.: 193
March 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; moorland

48º 69' S, 73º 99' E Alt.: 200 m

Moss;

J. van Winden Nr.: 195
February 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; Moorland

48º 69' S, 73º 99' E Alt.: 200 m

Moss,

J. van Winden Nr.: 194
February 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; moorland

48º 69' S, 73º 99' E Alt.: 300 m

herb, 0,01 m tall;

J. van Winden Nr.: 196
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; moorland

48º 69' S, 73º 99' E Alt.: 300 m

herb, 0,01 m;

J. van Winden Nr.: 197
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; moorland

48º 69' S, 73º 99' E Alt.: 200 m

Moss,

J. van Winden Nr.: 199
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; moorland

48º 69' S, 73º 99' E Alt.: 300 m

herb, 0,02 m tall; red fruit

J. van Winden Nr.: 198
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

ONAGRACEAE
Fuchsia
magellanica Lam.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest borders and on slopes.

48º 69' S, 73º 99' E Alt: 115 m

Shrub, 2,2 m tall, flowers red-pink with purple; common.

Vernacular name: Chilco

J. van Winden Nr.: 201
March 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; bluff

48º 69' S, 73º 99' E Alt.: 80 m

Shrub, 0,10 m tall

J. van Winden Nr.: 202
March 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

ASTERACEAE

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest-moorland border

48º 69' S, 73º 99' E Alt.: 300 m

herb, 0,20 m tall; inflorescence yellow

J. van Winden Nr.: 204
March 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; bluff

48º 69' S, 73º 99' E Alt.: 80 m

moss; 0,03 m

J. van Winden Nr.: 203
February 2004

FLORA OF CHILE
Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest border

48º 69' S, 73º 99' E Alt.: 100 m

shrub, 2,0 m; inflorescence white

J. van Winden Nr.: 205
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest

48º 69' S, 73º 99' E Alt.: 130 m

herb, 0,80 m tall;

J. van Winden Nr.: 206
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest

48º 69' S, 73º 99' E Alt.: 180 m

Climber, flower orange

J. van Winden Nr.: 208
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest

48º 69' S, 73º 99' E Alt.: 150 m

shrub, 2,0 m tall

J. van Winden Nr.: 207
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; forest

48º 69' S, 73º 99' E Alt.: 150 m

Moss,

J. van Winden Nr.: 209
March 2004

Figure 6: clockwise, plant code 203, 211, 213 and 214 (photographs by Jasper van Winden).

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

grass, 1,0 m;

J. van Winden Nr.: 210
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

CARYOPHILLACEAE
Cerastium
fontanum L.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano. Near coast.

48º 69' S, 73º 99' E Alt: 30 m

Shrub, 0.3 m tall, flowers white.

J. van Winden Nr.: 213
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

POLYGONACEAE

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland at sea side

48º 69' S, 73º 99' E Alt.: 10 m

shrub, 1,20 m tall; flowers yellow with a conspicuous red centre

J. van Winden Nr.: 211
February 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

APIACEAE
Apium
australe Thouars.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; beach

48º 69' S, 73º 99' E Alt.: 0 m

Shrub, 0.5 m tall, flowers white; leaves taste like fennel

Vernacular name: Apia de la playa

J. van Winden Nr.: 214
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

RANUNCULACEAE
Ranunculus
Repens

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

Herb, 0,25 m tall; inflorescence yellow, flowers yellow

J. van Winden Nr.: 215
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; bluff

48º 69' S, 73º 99' E Alt.: 80 m

moss;

J. van Winden Nr.: 217
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

CARYOPHILLACEAE
Cerastium
fontanum L.

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano.

48º 69' S, 73º 99' E Alt: 50 m

Shrub, 0.3 m tall, flowers white.

J. van Winden Nr.: 216
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

POACACAE

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

Grass; 0,40 m;

J. van Winden Nr.: 218
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

POACACAE

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

Grass; 0,40 m;

J. van Winden Nr.: 219
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

J. van Winden Nr.: 222
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

herb; 0,03 m; flowers yelowish

J. van Winden Nr.: 221
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

Herb; 0,15 m; flowers white

J. van Winden Nr.: 224
March 2004

Figure 7: clockwise, plant code 215, 227 and 228 (photographs by Jasper van Winden).

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

POACACAE

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Témpano; periglacial grassland

48º 69' S, 73º 99' E Alt.: 50 m

Grass; 0,40 m;

J. van Winden Nr.: 225
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Bernardo; gravel

Alt.: 5 m

J. van Winden Nr.: 228
March 2004

FLORA OF CHILE

Nationaal Herbarium Nederland - Utrecht branch (U)

ASTERACEAE

Det. : J. van Winden 2004

Chile, Magellanes, National park Bernardo O' Higgins, Fiordo Bernardo; Beach

Alt.: 0 m

Herb, 0,25 m; Flowers white

J. van Winden Nr.: 227
March 2004

Appendix II

Habitat descriptions with photographs

Figure 1: Periglacial grassland (Photograph by Jasper van Winden).

Periglacial grassland (Frid, 1994; Figure 1)) consists mainly of grasses and *Gunnera magellanica.* The soil is moderately well to poorly drained. Possibilities for shelter are scarce, as is the possibility to hide from predators. In Fiordo Témpano, cattle is present in this habitat.

Low-elevation bluffs (Frid, 1994; Figure 2) are in general located in the periphery of the flat valley bottom of Huemul valley. The bluffs are mostly surrounded by periglacial grassland on the valley side and slope habitat on the other side. Characteristic are the steep slopes. Bluffs are very rocky and are overgrown with large patches of mosses. On spots where more sediment is present the vegetation is similar to periglacial grassland. Boundaries of this habitat are primarily given by landscape structure, not by vegetation traits. There is no possibility for shelter in this habitat, but the deer are difficult to be approached upon by predators.

Figure 2: Low Elevation Bluff (Photograph by Daan Wensing).

Footslope habitat (Figure 3) consists of open shrub vegetation located on footslopes. Dominant shrub species are Chaura (*Pernettya mucronata*) and in Fiordo Témpano Hardy fuchsia (*Fuchsia magellanica*). Grass species are less abundant; *Gunnera magellanica* is the dominant herb species in this habitat. Soils are well drained. Shelter is easily to be found and the deer are not easily to be approached by predators.

Figure 3: Footslope habitat (Photograph by Daan Wensing).

Forest border habitat in Huemul valley (see grassland-forest edge: Frid, 1994; Figure 4) lies between 100 m and 120 m above sea level and is characterised by shrubs, next to *Pernettya mucronata* and *Fuchsia magellanica*, especially *Ribes magellanicum*. Although less abundant, more characteristic for this habitat. Apart from these shrub species, forest border habitat is formed by seedlings of *Nothofagus betuloides*, not reaching over 2 meters in height. Although the forest stretches out all over the length of both slopes, east and west, the forest border habitat type is only restricted to some patches along the slope. It is defined by the presence of seedlings of *Nothofagus betuloides*. Mostly the edge of the forest is very sharp and is directly bordered by slope habitat. Soils are well drained. The *Nothofagus sp.* seedlings provide shelter against the weather as well as cover against predators.

Figure 4: Forest border habitat (photograph by Daan Wensing).

Magellan's *coihue* woodland (Figure 5); this old growth forest is situated between 100 m and 400 m above sea level. Dominant species is *Nothofagus betuloides* in association with *Drimys winteri*. The forest floor is packed with fallen logs mostly luxuriant overgrown with mosses. The forest on the eastern slope is denser than the forest on the western slope. Soils are well drained.

***Pilgerodendron uviferum*- forest** is mostly, but not necessarily, found at higher elevations than Magellan's *coihue* woodland. It is even more adapted to humid conditions. The border between the two woodland types is quite abrupt. Soils are moderately drained. On still higher altitudes the *Pilgerodendron uviferum*-forest gradually gives way to Magellanic moorland.

Figure 5: Magellan's *Coihue* woodand (photograph by Daan Wensing).

Figure 6: Magellanic moorland with trees in the background (photograph by Jasper van Winden).

Magellanic moorland (Frid, 1994; Figure 6) extends from 100 m to 1000 m above sea level and comprises half of the research area. The conspicuous red carnivorous herb *Drosera uniflora* is indicative for this habitat type as well as the abundance of mosses. Vegetation cover is 30% to 100%. Soils are poorly drained.

Beach (Frid, 1994; Figure 7) consists either out of clay or rocks. It is in general only a few meters wide. Beach habitat is found along the coast, where it is influenced by the tides. Exception is a small sandbank at the riverside of Huemul valley that was determined as beach habitat.

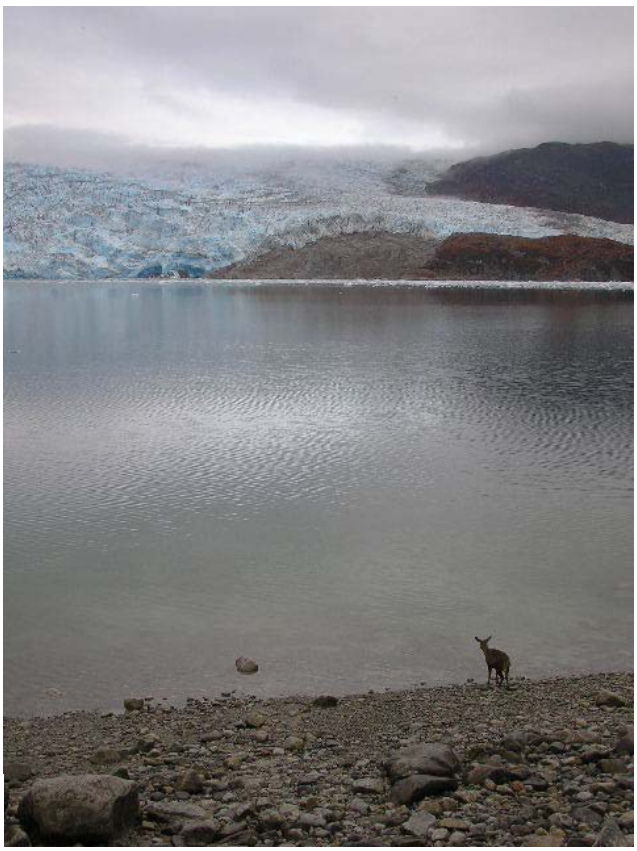

Figure 7: Beach (photograph by Daan Wensing).

High shrub vegetation (Figure 8); a very dense vegetation of Chaura (*Pernettya mucronata*) and the spiny Calafate (*Berberis buxifolia var. buxifolia*), making it difficult to move freely in this habitat. The height of the shrubs is 1 to 2.5 meters. Mosses are abundant and *Gunnera magellanica* is scarce, as it is only present on narrow tracks running through the habitat. Soils are well drained.

Figure 8: A path cleared in High shrub vegetation (photograph by Daan Wensing).

Figure 9: Low shrub vegetation (photograph by Daan Wensing).

Low shrub vegetation (Figure 9); located closer to the glacier In Fiordo Bernardo than the high shrub vegetation. The most abundant species is Chaura (*Pernettya mucronata*). In this habitat the height of this species is only 20 to 60 cm allowing *Gunnera magellanica* to be more abundant than in the 'high shrub vegetation'. It has an estimated surface cover of 7% in this habitat. Soils are well drained.

Bare rocks (Figure 10); at two places in the valley bare rocks are found. One location is at the terminus of the valley, very close to the glacier. The other location is half way of the valley. There is no vegetation present on these spots.

Figure 10: Bare rocks (photograph by Daan Wensing).

Pioneer vegetation (Figure 11); mainly located very near to the glacier. Consists of rocks, overgrown with mosses. Also some herb species are present, amongst others *Gunnera magellanica*.

Figure 11: Pioneer vegetation (photograph by Daan Wensing).

Open woodland (Figure 12); dominant species is Chaura (*Pernettya mucronata*), reaching 1.5-2 meters of height. Trees (*Nothofagus sp.*) are scattered over this habitat. The two larger areas of 'open woodland' were situated two meters higher than the other parts of the valley. Occasionally narrow, but deep depressions were present (2-2.5 meters), with an average diameter of 4 meters.

Figure 12: In the background: open woodland (photograph Daan Wensing).