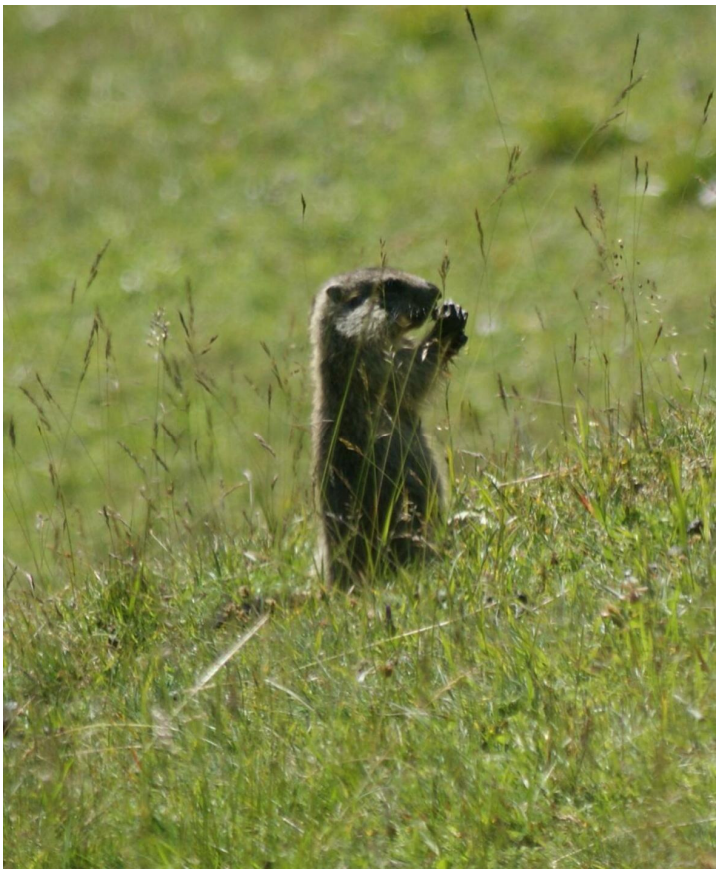
Population Size and Life-History Traits of the Alpine Marmot (Marmota marmota) at Selected Sites in the Swiss National Park



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1. Introduction

The alpine marmot (*Marmota marmota*) is a widespread animal in the alpine ridge. Even though it can often be observed while hiking, it was not until the 1980's that marmots were studied in more detail. Since then a lot of biologists and ecologists have tried to identify the alpine marmots' life history traits, but some are still not fully recorded and understood (Lenti Boero 2003a; Müller 1986, P.3). One reason for this is the huge amount of time marmots spend underground. This lifestyle makes it very difficult to visually observe specific behaviour patterns or simply fully record the size of a family. Even data such as population size, which seems to be simple at first glance, can therefore already deliver a lot of novel information. Through a census, not only information about the population size is recorded, but also knowledge about the distribution across an area, habitat choice and the reproductive potential may be gained (Lenti Boero 2003a). Together with another detailed set of data, for example the distribution of burrows in the marmots' territory, a holistic picture of marmots in a specific area can be created. This study will enhance to some degree, the holistic view of the alpine marmot in the Swiss National Park (SNP).

The SNP has to fulfil three goals: conservation, scientific research, and information (NN 2009). This implies that the inhabiting flora and fauna should not be disturbed or altered, the park supports research by scientists and also conducts its own research, and park visitors are informed and educated. The goal of most of these research studies is to record and analyze changes over time in a natural ecosystem that is no longer directly influenced by man. These results are important for scientists since they create a better understanding of natural processes. Currently a study aimed to answer part of these questions is being implemented by the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL). This study, trophic cascades, looks at the coherence of the vegetation on subalpine grasslands and the grazing regime of different herbivore groups. Within the context of this three year study, the population size of all the different herbivores will give an overview of the potential grazing pressure on the six selected subalpine grasslands. As part of the study trophic cascades a survey of the alpine marmot population is necessary, since marmots are important components of the herbivore communities on these grasslands.

The overall aim of this study is to grasp the size of each marmot population at the six different trophic cascades study sites. Moreover information about the age and burrow distribution within a territory and the marmots daytime activity will give a holistic impression of the marmots living in the SNP. Along with the survey four other study topics will be investigated.

1.1 Study Topics

The following research questions will be studied in this thesis:

I. What are the current marmot population sizes at all six grassland sites?

A population can be defined as a group of individuals of one species inhabiting a certain area (Molles 1999, P.164). In the SNP the boundary of one marmot population is usually given by the environment, for example a forest. This implies that each different study site is home to a small marmot population. If the area is large enough this population can theoretically consist of more than one marmot family.

II. How large is the proportion of juveniles in each marmot population?

The size of alpine marmots differs greatly between adults and juveniles. This difference makes it easy to visually estimate the age distribution within a population. The number of young also gives an idea of the populations' vitality and their long-term survival chances (Molles 1999, P.194). Consequently the number of juveniles will also allow estimates about the population size in the future.

III. What are the spatial patterns of burrows and marmot holes in the marmot territory on the grassland site Alp Stabelchod?

Marmots spend a significant time of their lives in burrows. Their distribution gives information about the areas marmots use for living and the size of their territory. This detailed map of the marmots' burrows will help locate the existing distribution range. Furthermore a great amount of data in various biological fields already exists for Stabelchod. The detailed inventory will help extend this set of information.

IV. What are the daytime activity patterns of marmots?

Marmots generally spend a lot of time either resting or grazing. Over the course of a day their activeness varies though. By understanding their daily behaviour, their observation can be optimized. Furthermore this will contribute to the holistic view of the life of marmots.

V. What predictions can be made about the influence of marmots on the trophic cascades study?

The trophic cascades study is set up to exclude four groups of different sized herbivores from specific areas with fences of different mesh sizes. To be able to make predictions about the influence of marmots on the relevant vegetation, the certainty that marmots are actually in the vicinity of the study setting is necessary. To test if this is the case, the marmot territory needs to be determined. Only if the relevant areas lie within the marmots' territory, an influence of marmots on the vegetation is possible.

2. Biology of the Alpine Marmot

The alpine marmot (*Marmota marmota*) belongs to the order *Rodentia* within the family *Sciuridae* (Frey-Roos 2009). While it is the second largest rodent in Switzerland, the largest being the beaver (*Castor fiber*), its closest relative is the Squirrel (*Sciurus vulgaris*) (Dorndorf 1999). The marmot is typically 40 – 50 cm long with a short tail of 10 – 15 cm (Arnold 1999a). Its body shows the adaptation to a life in burrows under harsh conditions, with small ears and strong front leg and breast muscles. During the long winter months, the marmot falls into hibernation and loses a lot of its body weight. In the spring, after 6 -7 months of hibernation, male marmots weigh about 3 kg (Frey-Roos 2009). Females can be slightly lighter. Generally the size does not differ between male and females though, neither do their fur color (Arnold 1999a). This makes it impossible to differentiate between sexes from a distance. Juveniles are significantly smaller than adults though and their fur is gray and darker. Alpine marmots are born after a pregnancy of about 33 days and only weigh 30 g (Müller 1986, P.34). The first 40 days of their lives are spent in the burrow. When they first emerge, usually in July, they are already able to eat plants and to immediately begin gaining weight for hibernation.

14 different marmot species exist worldwide on the northern hemisphere. They are typical inhabitants of elevated steppes, such as the alpine ridge (Arnold 1999a). The altitudinal range alpine marmots inhabit in the European Alps can vary slightly, but they generally can be found in an area ranging from 800 m a.s.l. to 3000 m a.s.l. (Müller 1986, S.9). Often they inhabit a 200 m belt above the tree line. With human influence the tree line was shifted to lower altitudes. This created suitable marmot habitats: open and almost completely treeless grass pastures (Arnold 1999a). A marmot territory usually has a size of 2.5 ha, but can measure up to 6 ha if the food supply is insufficient (Müller 1986). High temperatures limit the marmots' distribution in lower areas. Since these rodents have restricted physiological abilities to cool their own body temperature, they are very sensitive to high temperatures and suffer from heat stress (Pattie 1967). Due to this reason, the alpine marmot is most active on warm, sunny days during the morning and late afternoon hours. When temperatures stay below 25° C the marmots usually are active during the whole day, while during rainy or foggy days their activities are very limited and the animals rarely leave their burrows (Türk & Arnold 1988). Night activity on the other hand has never been registered (Müller-Using 1972, P.50).

Marmots spend almost 90% of their lives underground in burrows (Frey-Roos 2009). These burrows are preferably dug in areas where ground material is loose, so that long tunnels and deep chambers can be established. The types of burrows vary as well. A winter burrow, where the marmots hibernate, is very deep and is made of a network of tunnels and chambers (Arnold 1999a). Summer burrows on the other hand are not as deep and often in the near vicinity of the winter burrow. The classification of winter and summer burrows can sometimes be misleading, since winter burrows can also be inhabitated during the summer period (Müller-Using 1972, P.42). A better classification suggested by Feldhamer et al. (2003) is the distinction between a home burrow or den and a hibernation burrow. The third kind of burrow is the flight or escape burrow. These are short and shallow tunnels which allow the marmots to quickly disappear underground when predators appear (Müller 1986, P.20). For both adults and juveniles, the main predator is the golden eagle. Otherwise adult marmots do not have many enemies, especially since other large predators such as wolves and lynx have been greatly diminished by humans. For juveniles though other large birds of prey, such as the eagle owl, sparrow hawk and goshawk, and foxes can be a serious threat (Müller 1986, P.43). Hence marmots usually stay within a 10 – 15 m radius of the nearest burrow (Arnold 1999a), the mortality by predation is only minimal in comparison to the mortality in winter though. Arnold (1990) measured a mortality rate of 6 % of adult marmots due to predation and 9 % due to the winter. For juveniles the mortality rate by predation is a lot higher, with 14 % but even more significant, 24 %, for winter mortality. If the kittens survive the dangerous juvenile state, their life expectancy is about 12 years. The oldest marmot ever found in the wild reached the age of 13 (Frey Roos 1998).

Marmots are social animals that share a burrow and territory within a group. This group is made up of a dominant mating pair (who are also the head of the group), subordinate males and females (of 2 - 4 years), yearlings and juveniles (Perrin et al. 1993). Depending on environmental factors, such as food availability, these groups range in size from 2 - 20 individuals (Müller 1986). Generally all members of these groups are related and probably are offspring of the same dominant pair (Naef-Daenzer 1984). Not all age groups are represented in these families though, due to a high infant mortality in the first few months (Müller 1986). When subordinate marmots become sexually mature they can either subject themselves, migrate or drive the dominant animal away. Marmots usually do not reach sexual maturity before their third summer (Ratti 1970). In some cases subordinate animals have been found to stay with the family for as a long as six years before they migrate (Frey Roos 1998). Migration usually takes place in the spring, during April and May (Arnold 1990). If the dominant animal is driven away by one of its own offspring, inbreeding can occur and cause a family to collapse after a few years (Filli 2009).

An alpine marmots' life if dominated by a long time of hibernation during the winter followed by a short period of feeding during the summer. Hibernation lasts until April or even the beginning of May (Schmotzer 2007). In these months, the snow is often not completely melted and the animals have to dig through a layer of snow to reach the surface. With many parts of the vegetation still being covered the marmot is still not able to start regaining energy and weight. During this time the dominant pair mates. The short vegetation period is vital. The required fat reserves for the winter period have to be acquired. Hence during the summer months the animals are very active and spend the day feeding or resting. This activity slowly diminishes in the late summer, usually in September. In October the whole marmot family disappears in their winter burrow and falls into hibernation again (Türk & Arnold 1988). Large families have an advantage now, because the animals huddle together and create more warmth (Arnold 1993). A study by Signorell and Jenny (2003) examined the variability in weight of different age groups during the seasons. They discovered that kittens and one year old marmots gain 183 % and 114 % of their body weight respectively over the summer period. Adults on the other hand only gain 30 % of their body weight from April to September. Moreover adults also lose more weight during hibernation. They can lose up to 25 % more of their body weight than juveniles and one year old animals do. This occurs because the adult animals seem to warm the younger ones. Large marmot families can create more warmth in their winter burrow, which is why it is beneficial to live in larger families (Arnold 1999b).

3. Material and Methods

3.1 Study Site

The whole study is set up in the Swiss National Park (SNP), located in the east of canton Graubünden at the Italian border. The Park was founded on the 1. August 1914 and is a strictly protected area. The international union for conservation of nature and natural resources (IUCN) classified the park under their conservation area categories, as a category 1a, a strict nature reserve (Heidelberg 2008). Furthermore in 1979 the UNESCO claimed the Park as a biosphere-reserve. Consequently these statuses imply very high conservation sanctions. Within the SNP the flora and fauna is fully protected, which means it is forbidden to alter it in any way (e.g. hunting or harvesting). Moreover nothing inside the SNP is allowed to be removed (this also includes dead wood and stones). The idea behind this total protection is not only the conservation of its species but also of natural processes involved in this ecosystem.

The SNP covers an area of 170.3 km^2, which is only 0.4 % area of the whole of Switzerland (SNP 2002). Furthermore it is the only national park in Switzerland. Its altitude ranges from 1400 to 3173 m a.s.l. at Piz Pisoc. Structurally more than half of this area is rock and debris (51 %) and made of approximately 80 % dolomite and limestone. Forest areas make up 28 % of the SNP and the other 21 % are alpine grass mats (SNP 2002).

Figure 1: Map of the SNP
Source: http://www.nationalpark.ch/deutsch/B_1_3.php#

Research is a central part of the SNP's philosophy. The first long-term observational vegetation plots were established in 1917 and first annual data documentation initialized. Since then numerous studies, either by the park administration itself or other institutions have been conducted in the Park. One institution is the WSL, which has been actively studying in this area for decades. The study trophic cascades is a new study (initiation: April 2009) aimed at grasping the influence of different vertebrate and invertebrate herbivores on vegetation and soil processes in subalpine grassland ecosystems. The study sites are located on six different grasslands in Val dal Fuorn, Val dal Botsch, Val da Stabelchod (Fig. 2) and Val Minger. All of these sites are on dolomite parent rock. 20 fences, each 7 m x 9 m, were erected at the six different grasslands. Inside the main fence, three more fences

were built, each with a different mesh size. Their locations are at Alp Stabelchod (1985m a.s.l.), Stabelchod Dadaint (2050m a.s.l.), Margonet (2186m a.s.l.), Alp Val dal Botsch (2060m a.s.l.), Alp Minger (2000m a.s.l.) and Alp Grimmels (2055m a.s.l.). At least two fences were erected at each location, one in a nutrient-rich short grass and the other in a nutrient-poor tall-grass field. At Alp Stabelchod, Alp Grimmels and Alp Minger four fences, two in each vegetation type were established. The survey of the marmot population will contribute to the trophic cascades study. Hence these six mentioned locations are the relevant study areas.

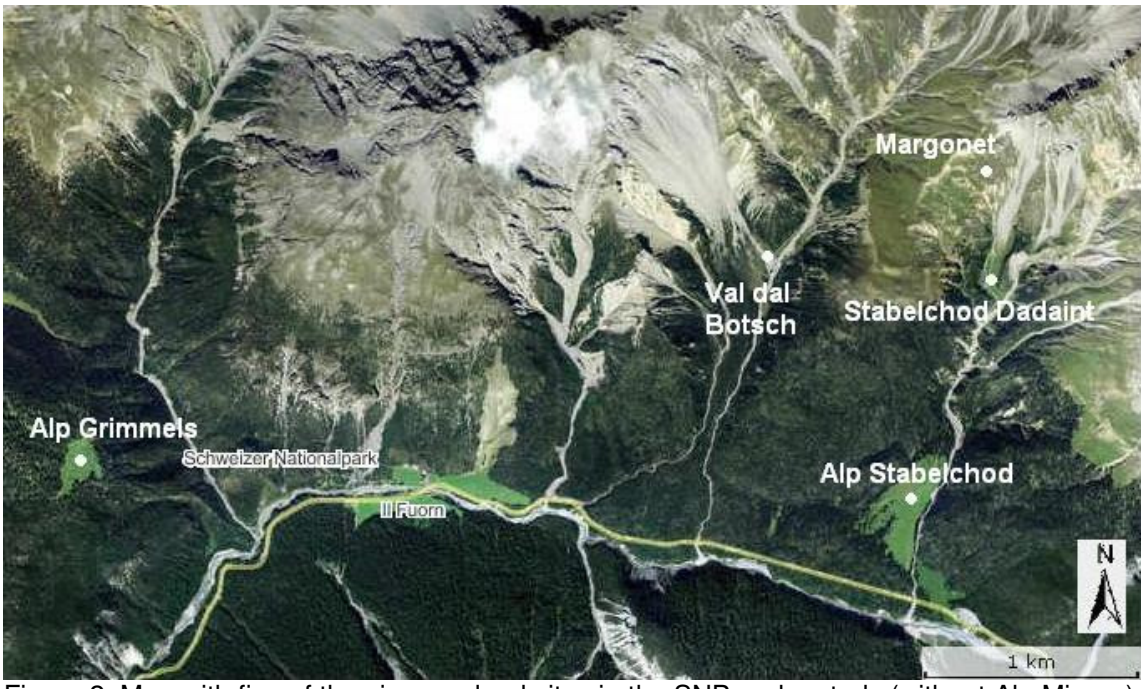

Figure 2: Map with five of the six grassland sites in the SNP under study (without Alp Minger)
Source: www.map.search.ch (amended)

3.2 Observations

The observations took place over a two week period starting on July 21 and another two week period starting on August 18. In total 17 days were spent in the field observing. The success of the field observations greatly depended on the weather conditions, since marmots tend to stay in their burrows when it is too hot, raining or very foggy (Türk & Arnold 1988). The two weeks in July and August were mostly very warm and sunny. On a minority of days the temperatures were a bit lower, morning fog and later during the day rain showers appeared. These days were not suitable for observations and data obtained on these days showed that only a few of the marmots actually left the burrow.

As other authors recorded, marmots are most active in the morning hours and again later in the afternoon (Müller-Using 1973; Müller 1986). Observations undertaken by Allainé et al. (1994) for a study on habitat preference were undertaken during the morning hours until 13:00 and continued at 16:00 until sunset in the afternoon. This information was considered for the observations in the SNP. Morning observations generally took place between 7 am and 11 am. Usually the morning observations were most promising until the first groups of tourists appeared or the temperature got too high for the animals. The evening observations started at 4 pm and lasted until 7 or 8 pm.

During observations the marmots should not be disturbed so that the animals are not restricted in their normal activities and are able to walk to their preferred feeding or resting sites. To fulfil this condition, the spot for observing had to be chosen carefully and the

observations were done with 10 x 70 binoculars. The ideal observation site is located on a small elevation to give an overview of the whole area. Furthermore in other studies a minimum distance of 200 m from the marmots and their burrows was suggested, so that the animals are not disturbed (Schmotzer 2007; Barash 1973). Unfortunately at most locations it was not possible to implement this distance. Consequently a spot had to be chosen, which was as far away from the home burrow and the marmot territory as possible. Ideally it also should not be within the vicinity of the outer escape burrow. This way the area can be overlooked at all times without causing too much disturbance by ones own movements. Not all six study sites are equally ideal and easily overlooked though, which makes finding a suitable, raised position that overlooks the whole area difficult. This was especially a problem at Alp Stabelchod. Grimmels, Val dal Botch and Margonet were most overlookable, while at Val Minger and Stabelchod Dadaint the areas are only partly in clear view.

3.3 Survey

To collect the data for the survey, a lot of time was spent in the field simply observing and counting. Since on some days only a few marmots of a family will emerge from the burrows, it is important to spend more than one day at each location. Therefore each pasture was observed at least once in each of the two observation periods. At locations where the view was partly blocked or places where the marmots were inactive during the day of observation, more than two observations were necessary.

To avoid recounting the same animal, two different methods were used. For every alp an aerial photograph was used to map the exact location of each marmot. Early in the morning most marmots usually rest in front of their burrows before they start to graze. During this time it is easy to closely identify some individual characteristic appearances. These can be lighter or darker fur, body size (juveniles and one year old marmots are smaller than adults) and other fur traits such as dark flanks or white spots on top of the nose. After identifying these traits, the later travelling of the individuals can be mapped on the aerial photograph. This method proved very effective on locations where there are only a few marmots present, such as Alp Stabelchod, Stabelchod Dadaint and Alp Val dal Botsch. The second method was more useful at locations where many animals were present, which travelled more in their territory. The morning locations in front of the burrows were again recorded on the aerial photograph. Then the number of marmots was recorded in regular periods of time. At the same time the mapping on the aerial photograph helped identify animals which disappeared in burrows. This method was useful at Margonet, Alp Minger and Alp Grimmels.

3.4 Detailed Mapping of Alp Stabelchod

For the detailed recording of the burrow locations on Alp Stabelchod, a previously established grid of the whole Alp was used (Fig. 3). This grid was established a few years ago to precisely map and record different biological information, e.g. spatial patterns of different plant species, *Formica esxecta* mounds, deer grazing areas and biomass consumption by deer and amount of phosphorus in topsoil. The grid consists of 268 cells (20 m x 20 m) and is marked on the Alp with short wooden posts. These posts help determine ones own location while mapping in the field.

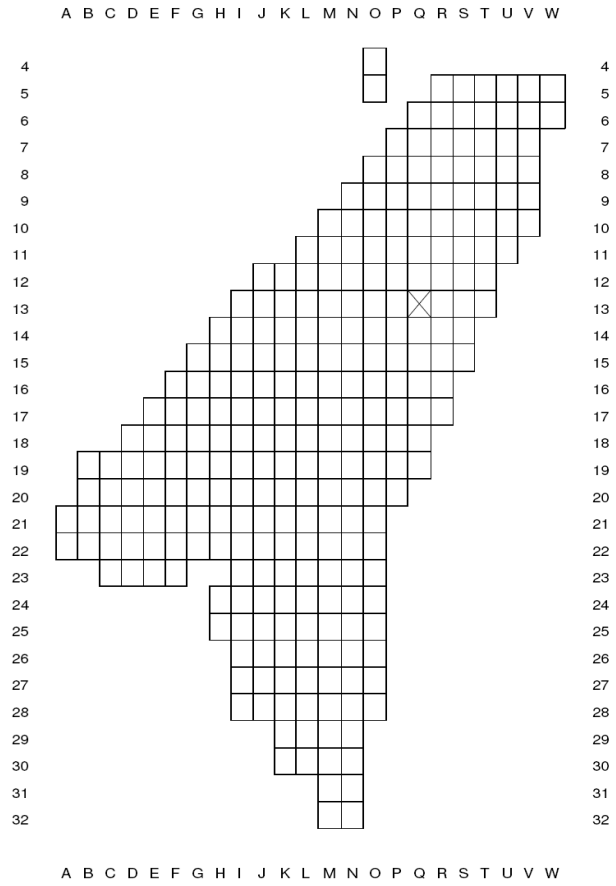

Figure 3: The experimental grid on grassland Alp Stabelchod (X = cottage).

Within each of these grid cells the number and type of marmot holes were recorded. Since several authors use different labels for the different burrow types (Feldhamer et al. 2003; Arnold 1999a; Müller-Using 1972), I confined myself to two types of burrow holes i) holes that lead either to complex home burrows and ii) escape burrows. Home burrows can further be differentiated between winter and summer burrows (Arnold 1999a). This distinction could, however, not be made at this time of the year, since all the observations were conducted during the summer. Hence the exact location of the winter burrow could not be detected.

Holes leading to home burrows differ in appearance from escape burrows. Since home burrows are much larger, more underground material is brought to the surface, which is found in front of these exit holes. Consequently the exit holes of these burrows are usually characterized by small throw mounds. Due to the frequent usage of these burrows and the alteration in soil composition at the surface, the surrounding vegetation is greatly altered (Müller-Using 1972, P.43). Moreover some plants growing in the proximity build an important part of the marmots' diet. These plants are heavily grazed and allow other plants to flourish, which now experience less competition. Finally at very highly frequented burrows, the vegetation can be missing completely due to trampling. An escape burrow on the other hand is generally not very deep and not regularly visited. Hence these holes are not characterized by a lot of digging material and the surrounding vegetation is mostly intact.

3.5 Recording of Daily Activity at Alp Grimmels

Alp Grimmels is home to a large number of marmots, including juveniles. Hence it makes the most sense to record the marmots' daily activities at this site. The daily observation periods started at 7:00 o'clock in the morning and lasted until 19:00 o'clock. During the whole day the number of adult and juvenile marmots was recorded, as well as their activity type. These activities were classified into four different categories: sitting, travelling, grazing and other. They were chosen, so that they could be easily identified also at a short glance while in the field. The sitting category was quite broad and included resting in front of the burrow, sunbathing and looking out for possible predators. Travelling animals are found running from one location to another, for example between burrows or to get to a specific grazing spot. Grazing marmots spend most of the time eating plants or small insects. While grazing the marmots are also continuously moving and walking across the alp, but at a much slower pace than when traveling. The last category other includes any other kind of activities the marmots tend to during a day. These include playing and grooming one another, digging, looking out while standing on their hind legs, whistling and bringing nesting material back to the burrow. Furthermore the number of tourists was also recorded.

Every ten minutes an observation screening was done and the different activity categories recorded. A certain spot was chosen from where most of Alp Grimmels could be overlooked. Then while following a counter clockwise rotation, all the data was recorded. This gave a snapshot image of the current activity. Throughout the whole day this procedure remained constant.

3.6 The Trophic Cascades Study

In order to identify if marmots could play an important role in the trophic cascades study, the grazing areas have to be identified. Potentially every location within the marmots' territory can be used for grazing, if the preferred plants grow there. Consequently the territory of a marmot family has to be identified. The location of burrows was used to determine this territory. Since marmots generally do not travel further than 10 - 15 m from the nearest burrow entrance (Arnold 1999a), the location of the last burrow holes indicate the boundary of the territory.

4. Results

4.1 Survey

The survey showed a great variability in the number of marmots found at the six study sites. While marmots lived in a large family at alp Grimmels and Alp Minger other areas such as Val dal Bitsch, were only sparsely inhabited. The largest marmot family lives at Alp Grimmels, with 12 adults and 5 juveniles. At Val dal Botsch or Stabelchod Dadaint, however, only 2 and 3 marmots and no juveniles reside, respectively (Table 1). Juveniles where only observed at those three of the six locations where the numbers of adults was highest (Table 1).

Table 1. Survey results at each study site

Location	Number of Adults	Number of Juveniles
Alp Stabelchod	5	0
Stabelchod Dadaint	3	0
Margonet	6	3
Alp Val dal Botsch	2	0
Alp Grimmels	12	5
Alp Minger	10	1

The SNP also conducts surveys at different grasslands each year. The data for Alp Stabelchod, which dates back to 1964, can be viewed in Appendix 1. These data show the fluctuation in population size over decades. While in some years the population reached sizes of 14 adults and 4 young (in 1971) or 12 adults and 7 young (in 1967), the population size crashed in other years, such as 1976 and 1980, when no marmots were sighted at all.

4.2 Detailed Mapping of Alp Stabelchod

The mapping of marmot holes on Alp Stabelchod indicates that almost half of the grassland is part of the marmots' territory. The size of the territory is approximately 4 ha. The approximation is based on the assumption that every hole is part of the marmots' territory and still in use. Since marmots do not spend the whole summer in the same burrow, but tend to travel within their territory (Arnold 1999a), this assumption is valid. Furthermore during observations the marmots were also sighted at many different locations within the territory. Travelling to other grazing areas, also to those further away from the main burrow, was not an uncommon behaviour. Moreover burrow holes, which are located at the outskirts of the territory, showed signs of marmots recently utilizing them.

Figure 4 below shows the distribution of marmot holes on Alp Stabelchod. Every square has a size of 400 m^2 and the square with the X indicates the location of the cottage. The cottage square is shaded in light green, because one escape burrow was also located here. The numbers of marmot holes in figure 4 represents the total number of home and escape holes. A total of 348 holes were counted across the whole alp. 81 of these holes were identified as leading to home burrows. The exact location of these two burrow types can be seen in the Appendix 2.

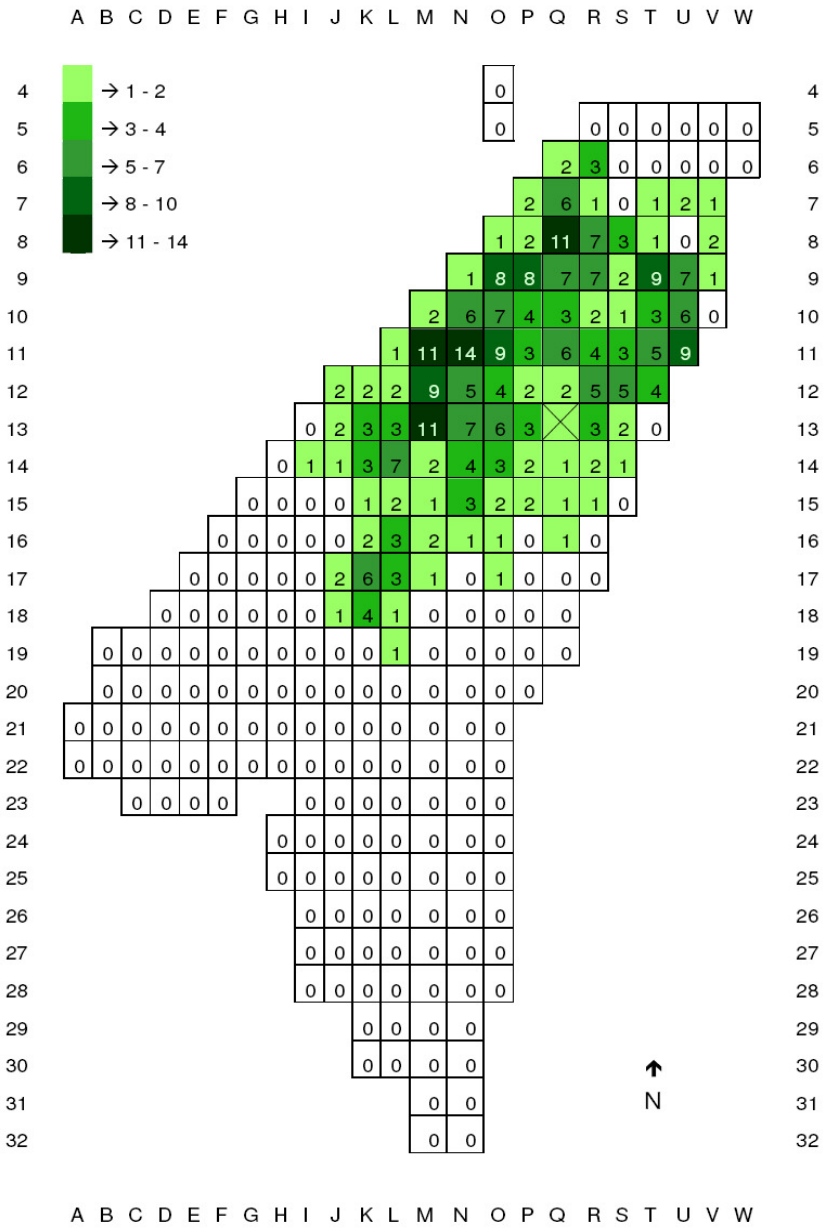

Figure 4: Spatial patterns of burrow holes on grassland Alp Stabelchod

In the northern part of Alp Stabelchod the territory border was marked by the first trees of the surrounding forest. In the south the territory is not enclosed by any visible environmental border. The main burrow, where the marmots were seen every day of observation, is located in square N 11. This location holds the most burrow holes. It is especially fitting to serve as the location for the main burrow, since the burrow is situated under a fallen tree. The marmots were often seen laying on top of the tree trunk sunbathing or being on the lookout. Furthermore the location is slightly elevated, so that the tree trunk is slightly higher than the surrounding area. During the observations, marmot activity was only monitored above row 15.

4.3 Recording of Daily Activity at Alp Grimmels

The largest marmot population from all the six locations was found at Alp Grimmels. 12 adult and 5 juvenile marmots live here. Marmots were present throughout the whole observation period from 7:00 to 19:00 o'clock. Especially the juvenile marmots spent basically the whole day outside the den with grazing or playing. For the raw data of the observations see Appendix 3.

The temporal daily activity patterns of marmots, i.e. the time spent outside the burrow by adults and juveniles can be seen in Figure 5 (For raw data see Appendix 3).

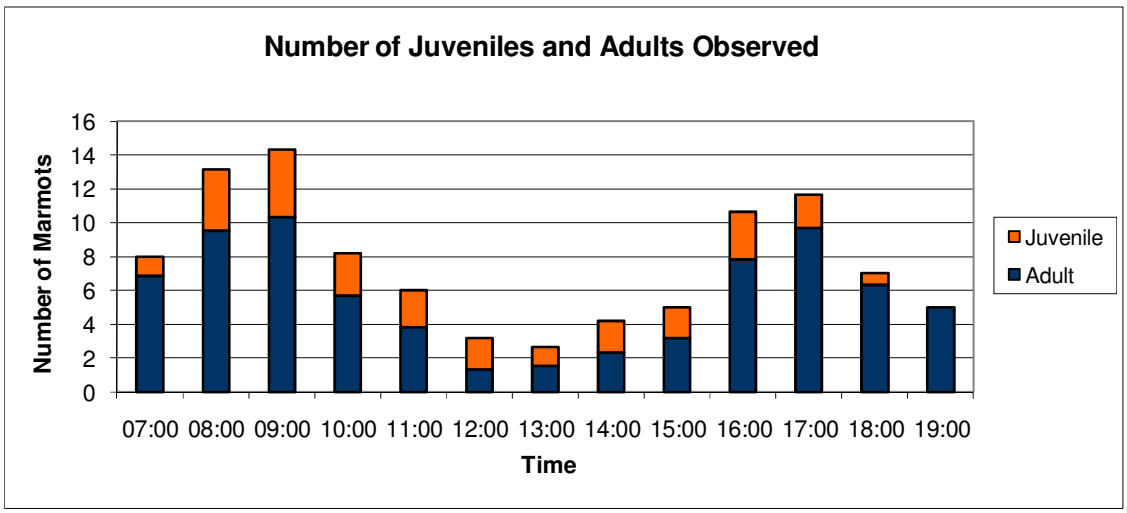

Figure 5: Temporal daily activity patterns of adults and juvenile marmots at Alp Grimmels.

Marmots are most active outside their den in the morning hours and again in the late afternoon (Figure 5). Proportionally the young marmots can be seen more frequently outside the burrow than the adults. From five juveniles an average of three could be seen in every ten minute 'snapshot'. Most of this time is spent outside for grazing. The adult marmots also spend a lot of their time resting in the sun or being on the lookout. The three main activities, which the marmots tend to during the day, are represented in figure 6.

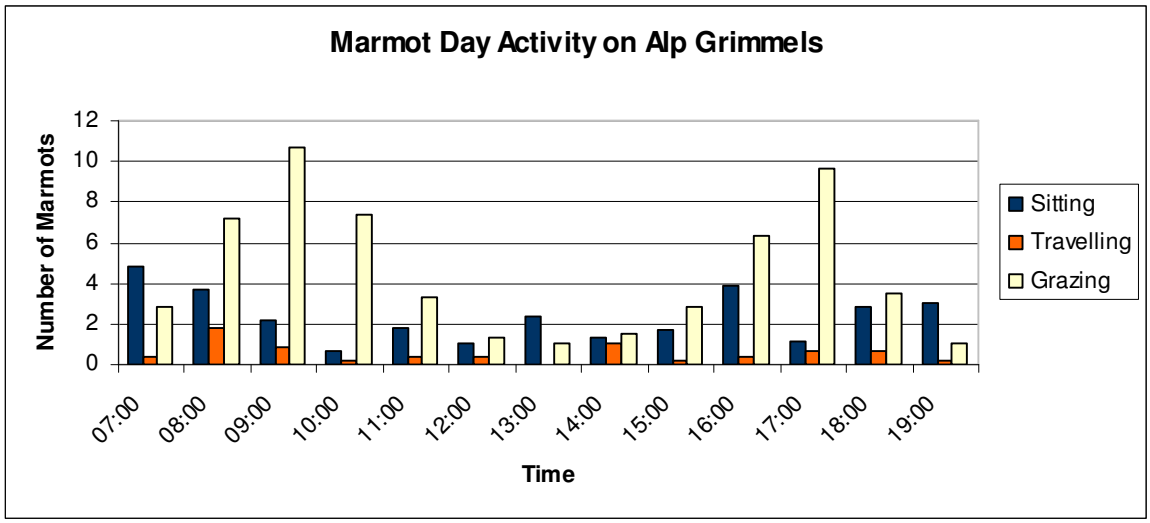

Figure 6: Type of activities undertaken by the marmots throughout the whole day

Grazing and sitting are the two main activities recorded. While the early morning hours, 7:00 and 8:00 o'clock, are still spent by a lot of marmots with sitting and resting, the

rest of the day is mainly used for grazing. The fourth category for activity, classified as other, is not represented in this figure, due to the limited amount of recorded data. Even though the marmots were seen playing, socializing, digging or bringing nesting material back to the burrow, this activity often did not take place at the moment of the 'snapshot' observation. An alarming whistle, indicating danger to the rest of the family, was heard four times during the day. Twice the whistling was caused by tourists. After the alarm was called, most marmots ran into a burrow or stayed at the burrow hole to lookout for the cause of the alarm. The four whistles were heard at 9:44, 11:50, 14:27 and 16:03. The sun disappeared behind the surrounding trees between 17:30 and 17:40. Even though it was still light afterwards, fewer marmots could be seen outside the burrows, their grazing activity was lower and a higher proportion of adults sat in front of the burrows.

Besides the number of marmots, the number of tourists visiting Grimmels was also recorded. The daytime occurrence of marmots and tourists is depicted in Figure 7.

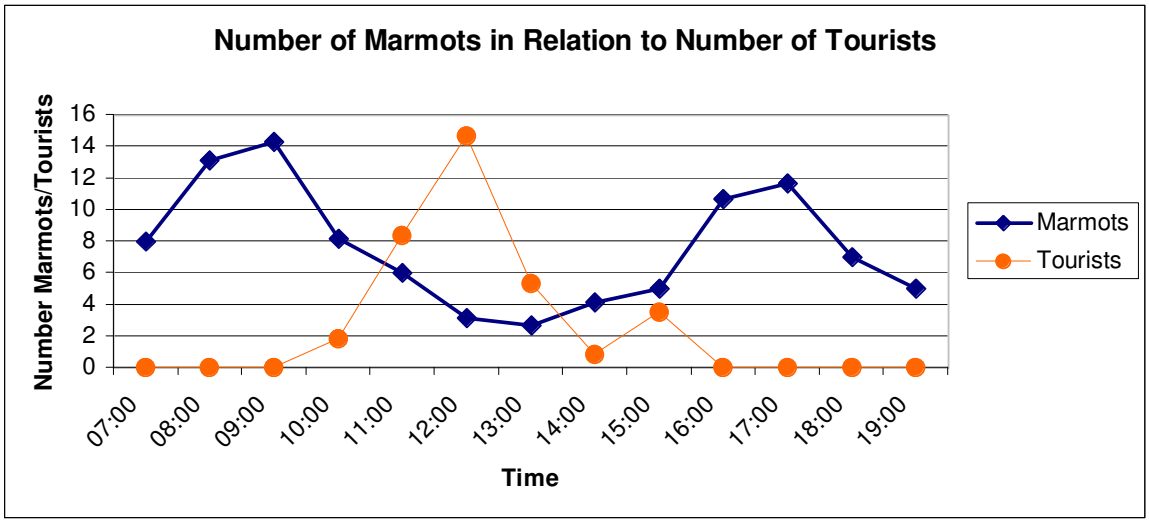

Figure 7: Daily number of tourists and marmots at Alp Grimmels

The first tourists appeared at 10:20 and the last were seen at 15:30. Most of them stayed at the picnic area for a while to watch the marmots, eat their lunch or relax in the sun. This area is located in the center of Grimmels and was used for grazing by the marmots before the first tourists appeared. While humans occupied the picnic area, the marmots were seen at the border of their territory, close to the forests edge.

4.4 The Trophic Cascades Study

Generally the marmots do not seem to be afraid to enter the fence enclosure, since one marmot was seen to enter fence 9, during observations. Theoretically this cognition implies that marmots will enter any fence, as long as it is located within the territory. The territory of each marmot population at the six study sites was determined by situating the location of burrows. The marmot territory and the location of the fences can be viewed in Appendix 4. From the 18 fences, 16 lie directly within the marmots' territory. These fences are all fences at Alp Stabelchod (numbers 1 – 4), fence 6 at Stabelchod Dadaint, both fences at Margonet (numbers 7 and 8) and Val dal Botsch (numbers 9 and 10), at Grimmels fences 11 – 13 and all fences at Alp Minger (numbers 15 – 18). The other two fences, number 5 and 14, are not directly located within the marmot territory. The possibility of a marmot entering the vicinity of these fences can not be excluded, but the probability of this occurring is marginal.

5. Discussion and Conclusion

5.1 Survey

The census shows that the population size can vary greatly from one grassland site to another. Furthermore the annual survey data from Alp Stabelchod reinforces this fluctuating trend. Alpine marmot populations tend to fluctuate naturally every year, while the size of their territory stays constant (Allainé et al. 1994). Different factors influence this phenomenon, such as limitation in the food supply during the summer and then a high rate of winter mortality (Müller 1986, P.41). Moreover these population dynamics could partly be a result of the reduced frequency of reproduction. The recorded age distribution supports this assumption, since offspring were only present at three of the six study sites. One reason for marmot families not reproducing could be the snow intense winter (as experienced in 2009) and the late snow melt (Van Vuren & Armitage 1991). Marmots awake from hibernation when the snow has not completely melted. They can only start taking up food though, when the vegetation appears from under the snow. South facing alps as well as locations with high levels of solar radiation, such as Margonet and Alp Grimmels, experience an earlier snowmelt and hence make food available sooner. This can put the marmots living here at an advantage, since mothers have access to food earlier and the offspring will be larger and emerge sooner (Allainé 2004).

The six study sites differ in various environmental aspects. These include the size of the habitat and hence the food supply, number of hours the sun reaches the grassland and the resulting mean, maximum and minimum temperatures. The first sunrays reach Alp Grimmels at least 1.5 hours earlier than Val dal Botsch and Stabelchod Dadaint. Consequently the temperature in the two latter sites is significantly lower (Werhahn 2009), especially in the morning hours, and the vegetation is covered longer with morning dew. Furthermore these two sites are both smaller grasslands and therefore have fewer food resources. Consequently the connotatively smaller populations at these sites, in comparison to Alp Grimmels, are not surprising.

Marmots show several preferences in their environment, when choosing a habitat. This habitat preferencing further explains the population size variations at the six study sites. Allainé et al. (1994) measured different environmental factors, which could influence the marmots' habitat choice. Their results show that an intermediate slope, a higher exposure to solar radiation such as on south facing slopes and in valleys, a low level of human disturbance as well as a moderate plant cover were preferred. Furthermore the reproductive success of the dominant mating pair depended on available food resources and the possible home range area. These factors also vary at the different study sites, which also explain the differences in population size.

5.2 Detailed Mapping of Alp Stabelchod

On Alp Stabelchod five adults and no juveniles were recorded during the summer of 2009. Their territory expands over an area of roughly 4 ha, which is higher than the average size of 2 - 2.5 ha, calculated by various authors (Arnold 1999a; Lenti Boreo 2003b; Müller 1986; Perrin et al. 1993). A need for a larger territory usually only occurs if the quality of the habitat is bad, which means the food resources are limited. Furthermore the feeding grounds are also always smaller than the whole territory. This suggests that when the family size increases, the animals move to other parts of the territory to prevent one area from being overgrazed. Moreover the marmots probably do not use the same burrows each year, but alternate within their territory. Lenti Boreo (2003b) confirmed this behaviour. She counted an average of 18 burrows in each of her study sites, but recorded that only four of the same burrows were used across a seven year study period. Similar results were

recorded by Feldhamer et al. (2003), where adults used an average of 6 - 8 burrow systems per year, even though they had 78 burrows to choose from.

A total of 81 burrow holes were counted on Alp Stabelchod. Since one burrow can have more than one entrance, the actual number of home burrows is much less than the number of holes. On the days of observation only seven home burrows were identified as being in use, but a marmots territory always holds more home burrows, than are actually in use (Lenti Boreo 2003b). For Alp Stabelchod the used burrows are all located in the north and north-eastern part of the territory. No activity was recorded in the southern burrows. These burrows did not look abandoned though, which suggests the marmots either used this area before my observations or in the previous year. As the data from previous years show, the population size of the marmots has greatly fluctuated across the years. The southern burrows could also have been inhabited more during these past years.

Theoretically the marmot territory could still be extended into the southern parts of Alp Stabelchod. The border of the territory here is not marked by a natural barrier, such as the forests edge (as is the case in the north) or a river (the east). The border in the south is probably the result of a missing necessity to further expand. It is also unlikely that the territory will expand into this region in the next years, since marmots rarely dig completely new burrows (Feldhamer et al. 2003, P.197). Furthermore it is also possible, that the southern parts of Alp Stabelchod are avoided due to the high densities of the narrow-headed ants (Formica exsecta) inhabiting this area (Schütz et al. 2008).

5.3 Recording of Daily Activity at Alp Grimmels

The marmots at Alp Grimmels can be observed outside their burrows throughout the day, even though not all members of the family spent equal amounts of time outside. Individual marmots spend between 5 to 10 hours during the summer period outside the burrows (Müller 1986, P.18). The outside activity is not evenly distributed over the whole day. Wüthrich (1982) measured marmot activity outside the den and characterized it, as the number of marmots seen every half hour. He discovered that roughly most marmots can be found outside their burrows at 7:00 am. During midday, the activity is greatly reduced and in the late afternoon hours, they reappear. Similar observations were made at Alp Grimmels. Marmots were visible continuously across the whole day, but the greatest activity took place in the morning and again in the afternoon. The two main activities marmots tend to outside the burrow are either grazing or resting (Müller 1986). Since marmots need to gain weight over the summer months, so they can survive the long winter in hibernation, they need to take up as much food as possible during the vegetation period. This explains why especially the juvenile marmots were found outside the den throughout the whole day.

It also seems as though the juveniles do not feel as disturbed by visitors as the adults do. Before the first visitors appeared, the marmots used the whole alp for grazing, including the vicinity of the picnic area. With the presence of tourists, only juveniles were seen close to this area. The highest number of visitors was registered at midday and early in the afternoon. This time also represents the period, when the least number of marmots are found outside. Furthermore the movement of tourists also caused individual animals to sound the alarming whistle. Consequently most marmots ran to the burrows and disappeared. On the other hand, when the visitors rested at the picnic area themselves, most marmots did not seem to be greatly disturbed. Hence the presence of tourists is probably not the only reason for a reduced number of marmots outside the den during midday. Another important factor, which explains this absence, is the strong solar radiation and the warm temperatures (Türk & Arnold 1988).

5.4 The Trophic Cascades Study

The trophic cascades study will only deliver relevant results, if the marmots enter the vicinity of the fences. During the data recording for the marmot survey, a marmot was seen entering fence 9. Unfortunately the marmot only passed through and did not graze inside the enclosure. This still clearly shows that the marmots have accepted the fences as part of their territory and are not afraid to enter.

At most locations the requirement for marmots to enter the fencing is given, as the fences are located inside the marmot territories. Only fences 5 and 14 do not lie directly within marmot territories. At Stabelchod Dadaint, where fence number 5 is located, only three marmots were recorded. The probability of a marmot grazing inside this fence is pretty low. Fence 14 is located at Alp Grimmels, where the marmot population is very high and activity outside the burrows is present throughout the whole day. Even though the fence is located outside the possible marmot territory, the probability of a marmot entering fence 14 to graze is probably higher than at Stabelchod Dadaint. To guarantee this happening, the position of these fences should have been chosen differently though.

5.5 Summary

In total, 47 marmots were counted at all six study sites. Nine of these animals were juveniles, but not every marmot population had offspring this summer. The long winter period could be one of the reasons for this fact. The size of the territory seemed only to be a secondary restraint for the size of the marmot population. Alp Stabelchod covers an area of 11.16 ha of which only 4 ha are actual marmot territory. Theoretically the grassland would be large enough to shelter three separate marmot populations. At the moment only five animals were seen at this location though. On the other hand, Alp Grimmels is much smaller but 17 marmots were seen, including five juveniles. Several circumstances, which already have been stated, can be the reason for this. It shows though, that the size of the territory does not directly influence the number of marmots within the population. Unfortunately this also implies that the best technique to create a marmot survey is to visually count them, rather than rely on secondary information, such as number of burrows or habitat size.

Marmot activity can be generalized on the other hand. Since marmots spend most of the day grazing and resting or wary sitting, the obseervations made on Alp Grimmels can be projected across all the other areas as well. Especially in conformance with the observations made at the other sites for the census data, the daily activity and time spent outside the burrows, this can be confirmed. Astonishingly at some sites, such as Val dal Botsch and Stabelchod Dadaint, the marmots did not leave their burrows for very long time periods. At these two places, the tourist trail is not very far from the burrows. With the appearance of the first tourists, the marmots often tended to disappear in their burrows. For the trophic cascades study, this observation would imply the likelyhood of the marmots entering fences 5 and 10 is nominal.

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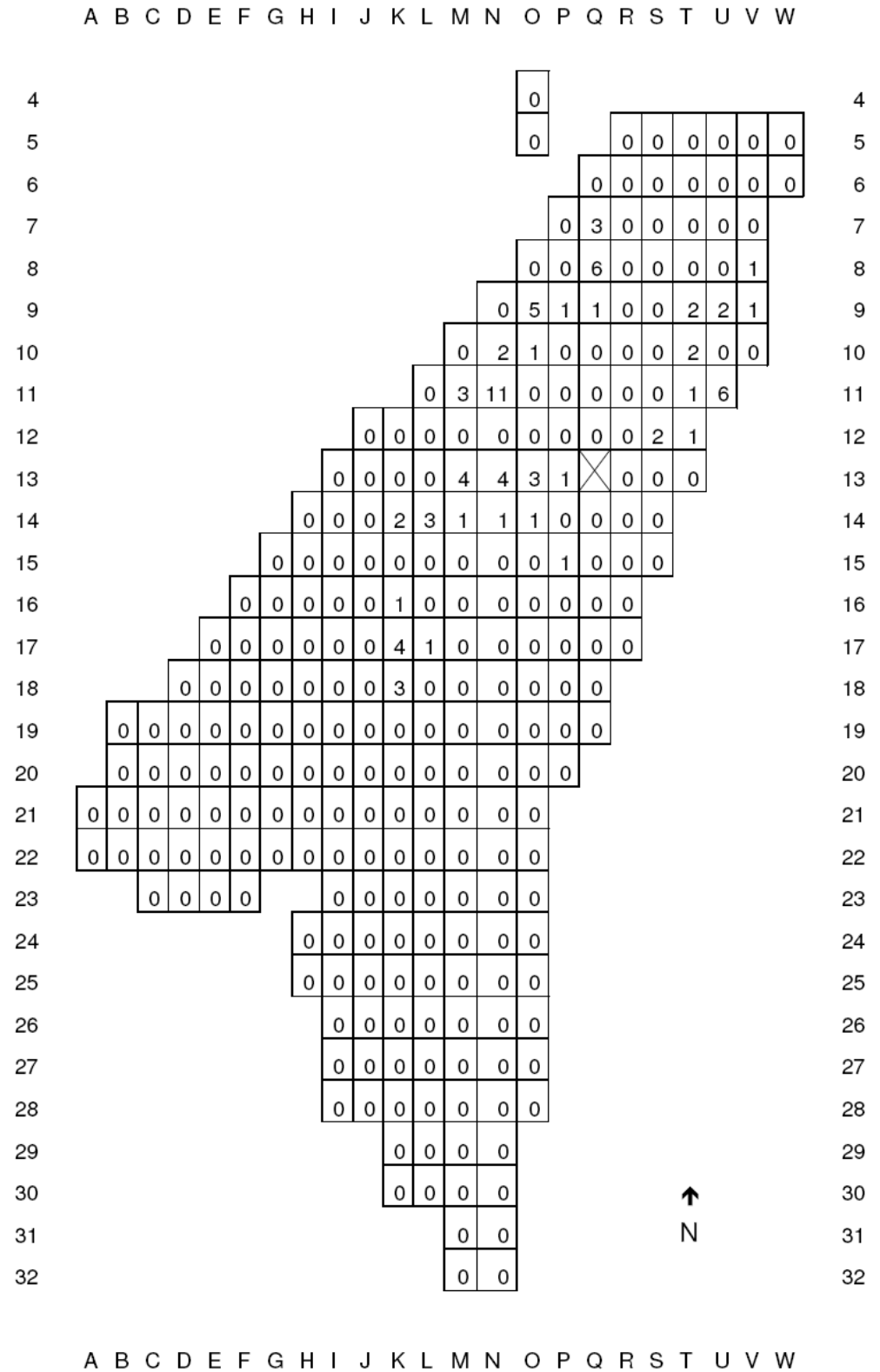
Appendix

Appendix 1: Survey data collected on Alp Stabelchod, 1964-2007

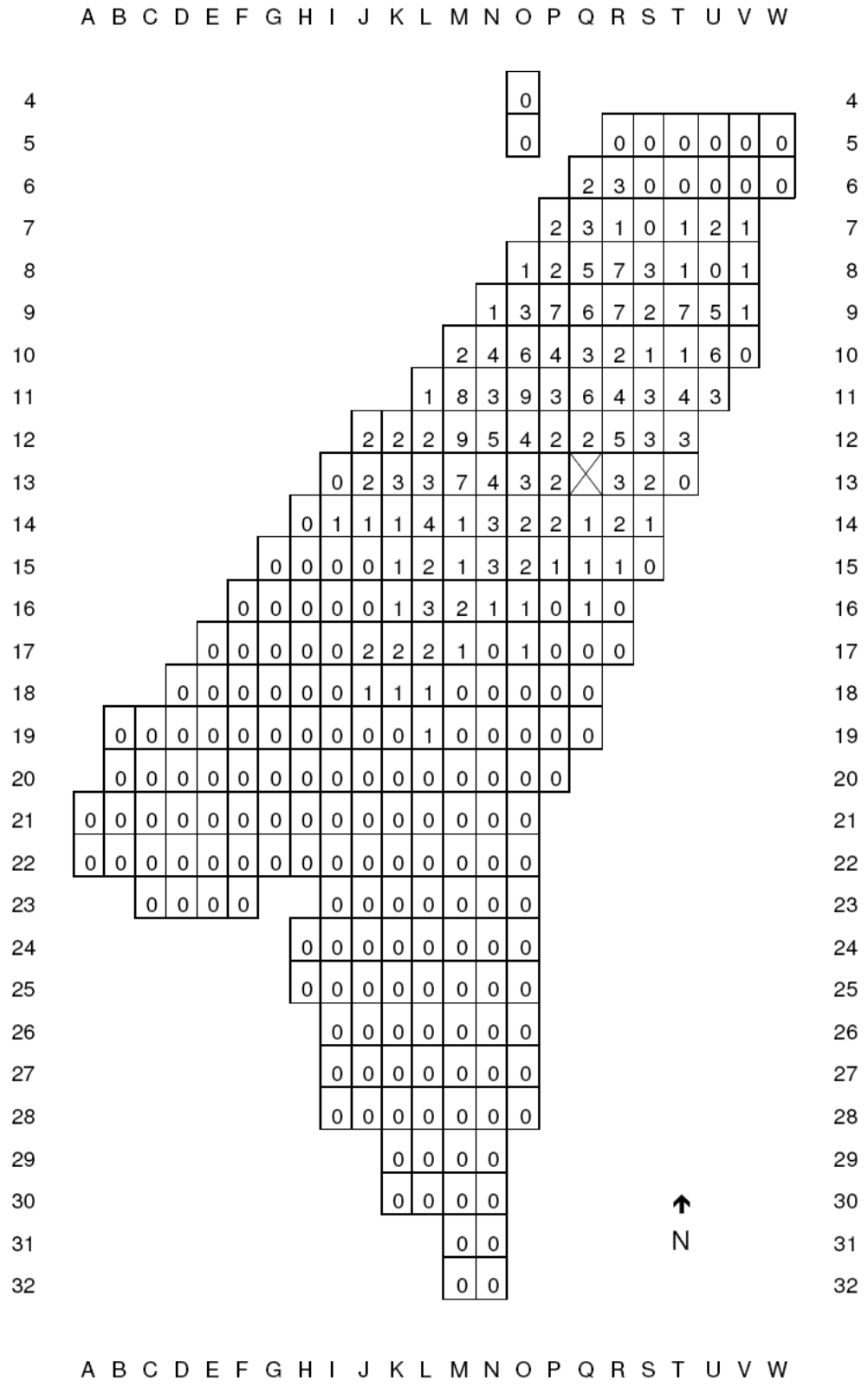
Jahr	Adult	Juvenile	Total
1964	12	4	16
1965	11	3	14
1966	10	4	14
1967	12	7	19
1968	14	4	18
1969	12	3	15
1970	12	4	16
1971	14	4	18
1972	9	0	9
1973	8	5	13
1974	8	2	10
1975	10	0	10
1976	0	0	0
1977	0	0	0
1978	4	6	10
1979	8	2	10
1980	0	0	0
1981	7	2	9
1982	8	1	9
1983	9	3	12
1984	10	2	12
1985	10	4	14
1986	10	4	14
1987	10	6	16
1988	12	5	17
1989	12	4	16
1990	0	3	3
1991	0	3	3
1992	5	0	5
1993	3	0	3
1994	4	0	4
1995	4	3	7
1996	4	0	4
1997	3	3	6
1998	5	0	5
1999	6	0	6
2000	5	2	7
2001	5	0	5
2002	7	2	9
2003	7	2	9
2004	9	4	13
2005	11	2	13
2006	9	7	16
2007	7	3	10

Appendix 2: Grid of Alp Stabelchod indicating the location of burrows

Home Burrows, 81 in total:



Escape Burrows, 267 in total:

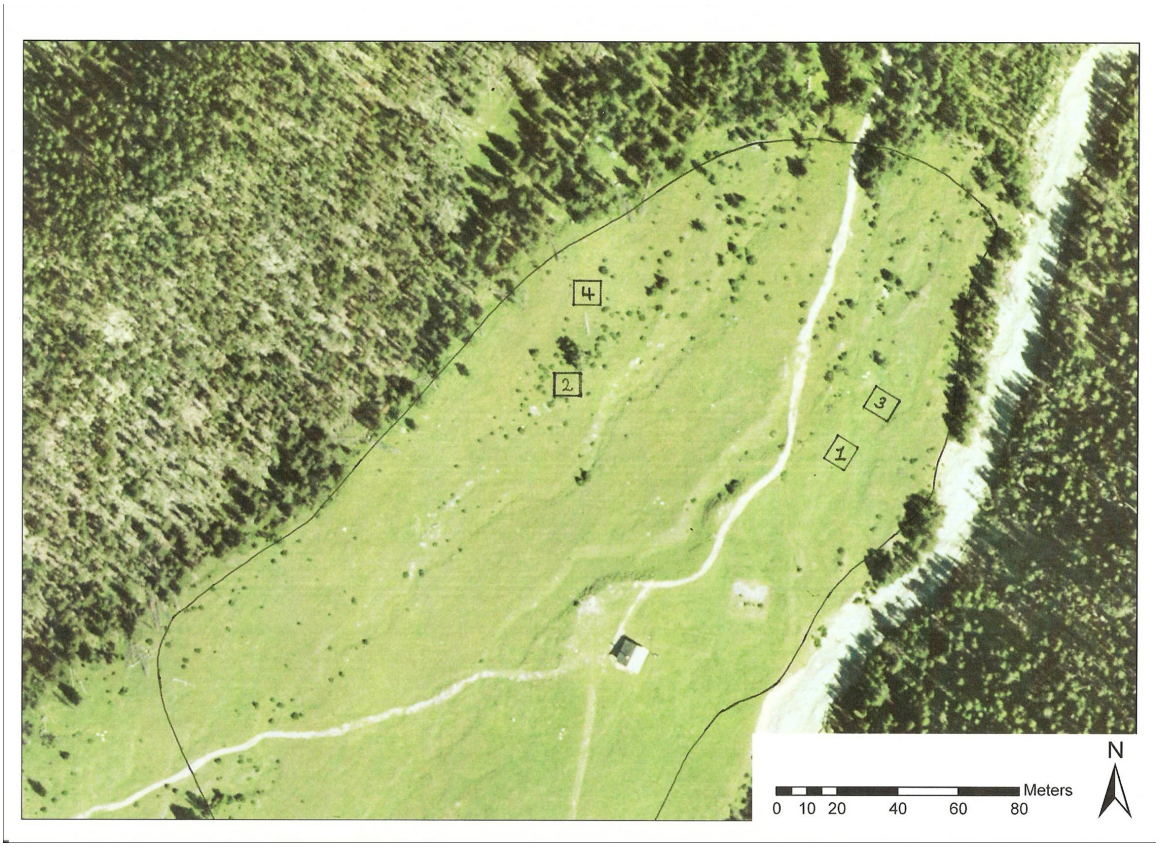


Appendix 3: Raw data of the detailed day recording at Alp Grimmels

Time	Counted Adults	Counted Juveniles	Sitting	Traveling	Grazing	Other	Tourists
07:00	5	0	4	0	1	0	0
07:10	5	0	4	0	1	0	0
07:20	7	1	5	1	2	0	0
07:30	8	2	6	0	4	0	0
07:40	9	2	7	0	4	0	0
07:50	7	2	3	1	5	0	0
08:00	8	4	5	2	5	0	0
08:10	8	3	5	2	4	0	0
08:20	10	3	3	2	8	0	0
08:30	12	4	3	4	9	0	0
08:40	9	4	3	0	10	0	0
08:50	10	4	5	1	7	1	0
09:00	10	4	3	0	10	1	0
09:10	11	4	3	3	9	0	0
09:20	12	5	4	0	13	0	0
09:30	12	5	3	2	12	0	0
09:40	11	3	0	0	14	0	0
09:50	6	3	0	0	6	1	0
10:00	10	3	0	0	13	0	0
10:10	10	3	1	0	12	0	0
10:20	4	2	1	1	4	0	2
10:30	3	1	1	0	3	0	2
10:40	5	2	1	0	6	0	2
10:50	2	4	0	0	6	0	5
11:00	3	4	2	1	4	0	4
11:10	4	1	2	0	3	0	8
11:20	3	2	3	0	2	0	12
11:30	5	2	2	0	5	0	10
11:40	4	2	2	1	2	1	10
11:50	4	2	0	0	4	2	6
12:00	1	2	0	1	2	0	11
12:10	4	1	2	0	3	0	16
12:20	1	2	1	0	0	2	14
12:30	2	1	1	1	0	1	20
12:40	0	3	2	0	1	0	14
12:50	0	2	0	0	2	0	13
13:00	3	2	4	0	1	0	7
13:10	1	1	2	0	0	0	7
13:20	0	3	2	0	3	0	7
13:30	2	0	2	0	0	0	7
13:40	0	1	2	0	1	0	4
13:50	3	0	2	0	1	0	0
14:00	2	1	1	0	2	0	0
14:10	4	2	0	2	4	0	0
14:20	2	3	3	1	1	0	0
14:30	3	0	1	2	0	0	2
14:40	2	2	2	0	2	0	0
14:50	1	3	1	1	0	2	3
15:00	1	0	0	0	1	0	3

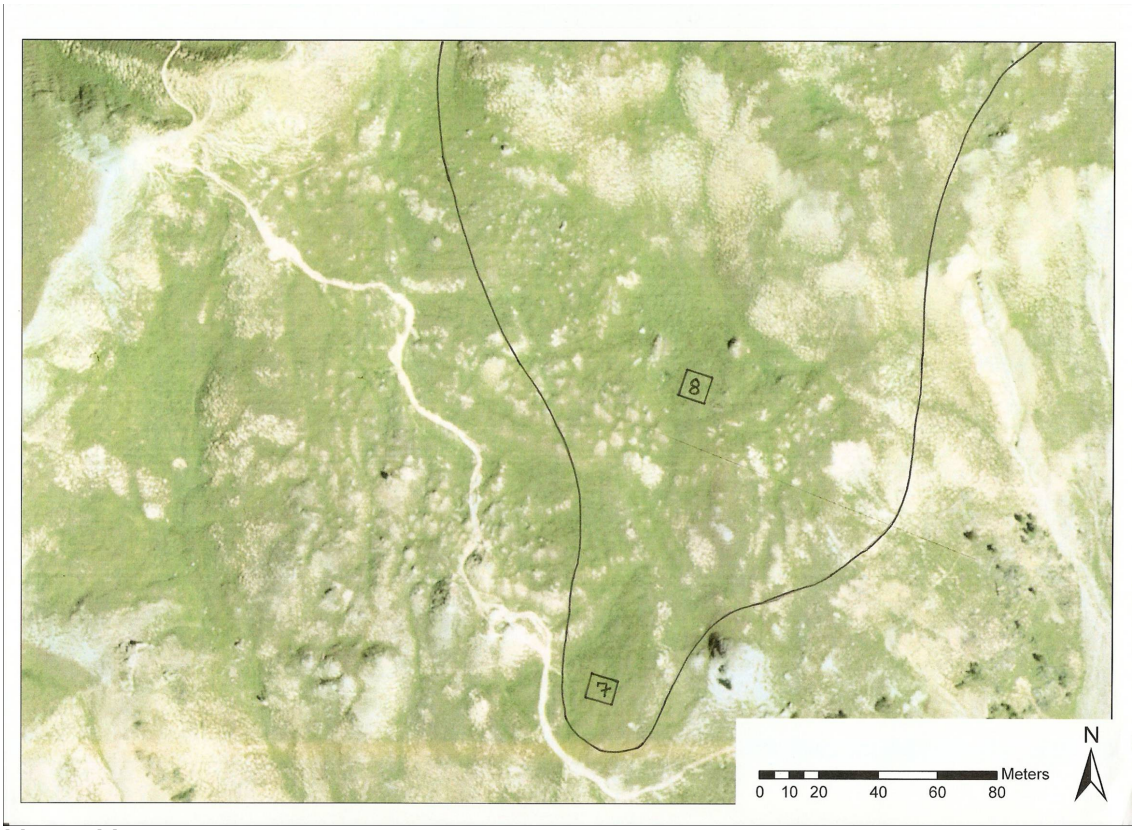
15:10	2	1	1	0	2	0	3
15:20	1	3	3	0	1	0	9
15:30	4	2	3	0	2	1	6
15:40	5	3	2	1	4	0	0
15:50	6	2	1	0	7	0	0
16:00	8	4	0	0	12	0	0
16:10	8	1	7	0	2	0	0
16:20	7	3	8	0	2	0	0
16:30	10	4	3	0	10	0	0
16:40	8	3	3	2	6	0	0
16:50	6	2	2	0	6	0	0
17:00	9	2	2	0	8	1	0
17:10	11	2	2	1	10	0	0
17:20	9	3	1	1	10	0	0
17:30	10	3	0	1	12	0	0
17:40	10	1	1	1	9	0	0
17:50	9	1	1	0	9	0	0
18:00	7	0	3	0	4	0	0
18:10	7	1	3	1	4	0	0
18:20	6	2	3	2	3	0	0
18:30	7	1	3	1	4	0	0
18:40	5	0	3	0	2	0	0
18:50	6	0	2	0	4	0	0
19:00	5	0	3	1	1	0	0

Appendix 3: Possible marmot territories and location of fences



Map 1: Alp Stabelchod

Map 2: Alp Stabelchod Dadaint



Map 3: Margonet

Map 4: Val dal Botsch

Map 5: Alp Grimmels

Map 6: Alp Minger