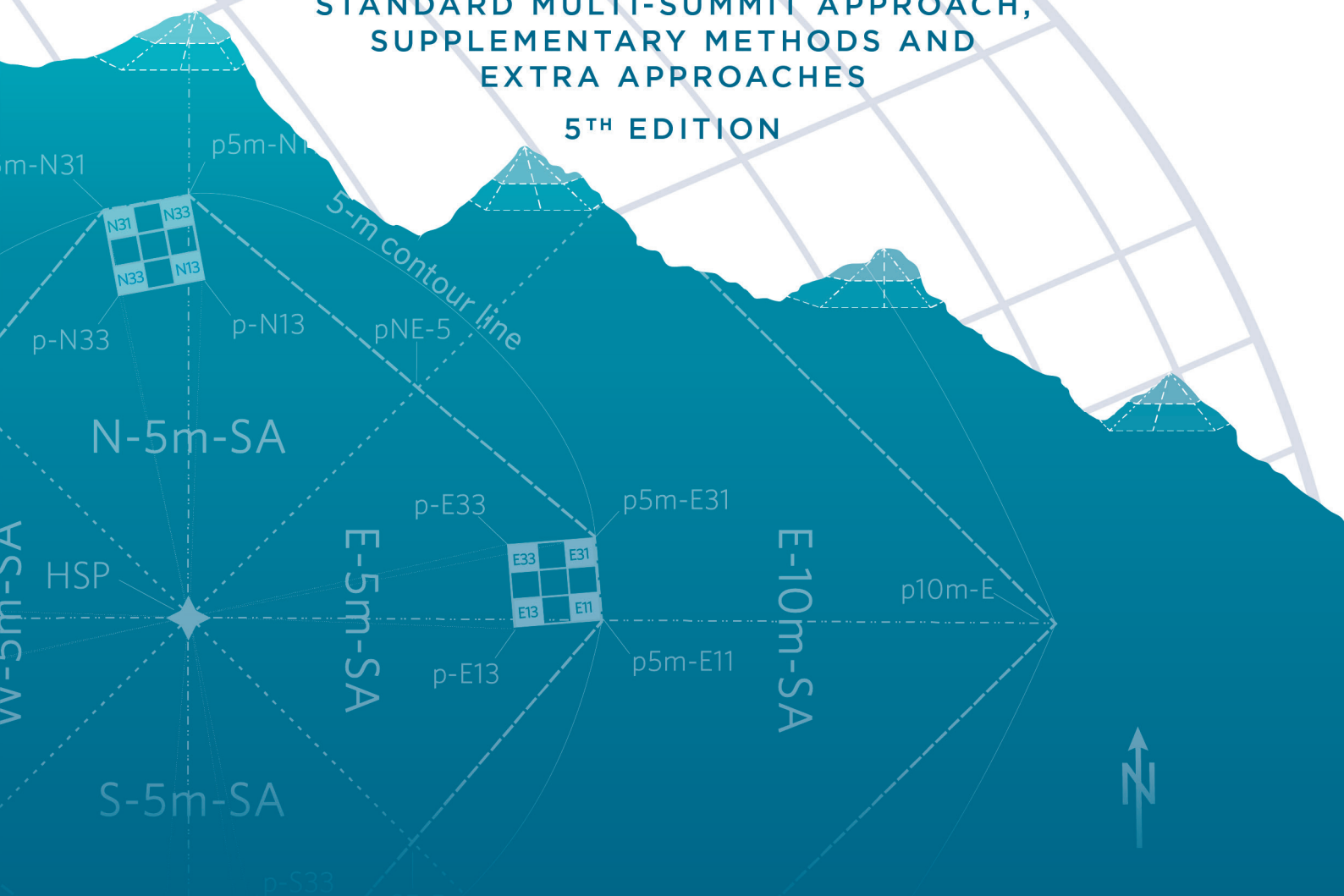


# THE GLORIA\* FIELD MANUAL

STANDARD MULTI-SUMMIT APPROACH,  
SUPPLEMENTARY METHODS AND  
EXTRA APPROACHES

5<sup>TH</sup> EDITION



COORDINATING AUTHORS AND EDITORS

Harald Pauli, Michael Gottfried, Andrea Lamprecht, Sophie Nießner, Sabine Rumpf,  
Manuela Winkler, Klaus Steinbauer & Georg Grabherr

\* GLOBAL OBSERVATION RESEARCH INITIATIVE IN ALPINE ENVIRONMENTS







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1 | Participation in the discussion process for developing the GLORIA standard methods and/or writing parts of the manual of additional activities of GLORIA

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\* Terms in *italics* are explained in the glossary



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# PREFACE

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GLORIA, the “Global Observation Research Initiative in Alpine Environments”, is a long-term observation programme and a rapidly growing international research network to assess climate change impacts on the biological richness of the planet’s high mountain ecosystems. A widely applied sampling design, such as the *Multi-Summit Approach* described here, is an essential prerequisite for collecting comparable data from different mountain regions around the world.

This publication is the fifth and fully revised edition of the GLORIA field manual. The manual contains the detailed description of GLORIA’s basic and standardised sampling design, the *Multi-Summit Approach*, with complete guidelines of the required procedure from site selection, setup and recording to data compilation. Moreover, it includes supplementary optional methods and a description of additional activities that are ongoing or have been recently initiated in the frame of GLORIA. The field manual represents the technical description of GLORIA approaches; it does not include considerations on data analysis or on how to report the results to the scientific community and to the public.

The introductory chapter 1 of the manual outlines the rationale for an international observation network for ecological and biogeographical climate impact research in mountain regions. Chapter 2 focuses on selection criteria for mountain regions and sites. Chapter 3 describes in detail the standardised design and setup procedure of the *Multi-Summit Approach*, chapter 4 the recording methods. Distinct consecutive **WORK STEPS** run across chapters 3 and 4 in alphabetic numbers from **A** to **V**. Chapter 5 contains descriptions of supplementary optional methods that may be applied within GLORIA *summit sites* and chapter 6 deals with data input, handling and management. Chapter 7 depicts ongoing additional activities in GLORIA *target regions*, either focusing on animal organism groups, on transects along mountain slopes, soil studies, on traditional knowledge or on socio-economic changes in GLORIA regions. Boxes provide additional background information throughout. Special terms used in this manual are written in italics and are explained in the glossary.

The previous, 4th edition of the field manual was based on the first Europe-wide field application as part of the GLORIA-EUROPE project of the 5th RTD Framework Programme of the European Union but also involved scientists from other continents. It was published by the Office for Official Publications of the European Communities in 2004 and translated into Spanish and Chinese.

Since then, the number of GLORIA sites has increased almost sixfold with active observation sites in now around

120 study regions (*target regions*) in mountain systems distributed over six continents. The current 5th edition of the field manual accounts for this change from an initially mainly Europe-based to a world-wide network. The standard *Multi-Summit Approach* was revised in the view of its global applicability and, further, this new manual was extended to additional GLORIA-related activities, which already have started in several GLORIA regions. This revised manual is based on thorough discussions and agreements met at the GLORIA conference in Perth/ Scotland in September 2010, which was attended by participants from 34 countries from all continents.

The full list of existing GLORIA *target regions* is displayed on the GLORIA website: [www.gloria.ac.at](http://www.gloria.ac.at). Before starting with the setup of new GLORIA sites (*target regions*), please, see the website for possible changes and we very much recommend to contact the GLORIA coordination prior to establishing a new site.

Many thanks to all colleagues who have contributed to the build-up of the GLORIA long-term observation network and the development, revision and extension of this field manual. All the best for your upcoming mountain fieldwork.

The GLORIA coordination  
Vienna, June 2014

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We acknowledge a range of different financial supporters. Important supporting institutions in the beginning test and development phase were the Austrian Academy of Sciences (ÖAW) through a contribution to the International Geosphere-Biosphere Programme (IGBP), the University of Vienna and the Austrian Federal Ministry of Education, Science and Culture. GLORIA's implementation phase commenced through the European Union's 5<sup>th</sup> RTD framework programme with the pan-European project GLORIA-Europe (EVK2-CT-2000-0056; European Commission officers Alan Cross and Riccardo Casale). Alan Cross' starting statement in 2001 "this project has an enormous potential" can now, a decade after this project ended, be seen as well fulfilled in the view of a sixfold extension of this now global programme. The world-wide extension and resurvey activities were supported through several inter-governmental institutions, such as UNESCO's MaB programme, the European Environment Agency (EEA)/European Topic Centre on Biological Diversity, the European Union's 6<sup>th</sup> RTD framework programme, the Andean Environmental Agenda of the Comunidad Andina (CAN), the Swiss Development Cooperation/Andes Programme, and the International Centre for Integrated Mountain Development of the Hindu Kush-Himalaya region (ICIMOD). National funding was provided in many countries for the setup of GLORIA sites. Among the important supporters were also private foundations and organisations such as the Swiss MAVA-Foundation for Nature Conservation, the National Geographic Society, the Wildlife Conservation Society, NGOs like The Nature Conservancy, Conservation International and a large number of research institutions and consortia including CONDESAN, Missouri Botanical Garden, and CIRMOUNT.

The GLORIA coordination is affiliated with the Institute for Interdisciplinary Mountain Research at the Austrian Academy of Science (ÖAW) and the Center for Global Change and Sustainability at the University of Natural Resources and Life Sciences (BOKU), Vienna, and was supported by the Austrian Federal Ministries BMWF, BMLFUW, the government of Tyrol, and the Swiss MAVA foundation; the latter also provided

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As the majority of GLORIA sites are situated within protected areas, a continued support through and cooperation with conservation management authorities of national parks, UNESCO Biosphere Reserves and regional protected areas is particularly thankworthy.

The development, implementation and maintenance would not have been possible without the sustained commitment of the large number of devoted biologists, mountain geographers, and conservationists who provided advice, contributed to earlier versions of the GLORIA field manual, were acting as communicators, supporters, supervisors of field surveys, and/or were doing alpine field work (around 500 persons were involved in the frame of GLORIA), data compilation and data analysis.

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# 1 INTRODUCTION

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## 1.1 CLIMATE CHANGE AND THE ALPINE LIFE ZONE

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The purpose of GLORIA (Global Observation Research Initiative in Alpine Environments) is to operate a world-wide long-term observation network for the comparative study of climate change impacts on mountain vegetation and its biodiversity (Grabherr et al. 2000, Pauli et al. 2009, Grabherr et al. 2010).

The earth's biosphere is currently experiencing and will continue to experience rapid climate change (Solomon et al. 2007). Since the mid-twentieth century, greenhouse gases globally contributed to 0.85K of warming at a 5–95% uncertainty of 0.6–1K, where at least 74% ( $\pm 12\%$ ) of the observed temperature increase since 1950 was caused by human-induced radiative forcing, and less than 26% ( $\pm 12\%$ ) by unforced internal variability (Huber & Knutti 2012). The last three decades have been progressively warmer than all earlier decades (Hartmann et al. 2013), and the decade 2000–2009 was the warmest in the instrumental record (Arndt et al. 2010). Predictions of global mean surface warming of up to 2.6 to 4.8 °C towards the end of the 21st century, relative to 1986–2005 (Collins et al. 2013), may drastically alter existing biosphere patterns. All ecosystems will experience climate change, but ecosystems of the *alpine life zone* (i.e. the *high mountain environments* above the *treeline*) are considered to be particularly sensitive to warming because they are determined by low temperature conditions (Sala et al. 2000).

Long-term records on the extent of mountain glaciers provide evidence for an ongoing climate warming in *high mountain environments* across biomes (Price & Barry 1997, Haeberli et al. 2007, Vuille et al. 2008). Direct impacts of temperature and precipitation changes as well as indirect effects (e.g. through changes of permafrost patterns and of disturbance dynamics, shifts in biotic interaction) of climate change will affect biodiversity and may lead to declines or even to the disappearance of a variety of species. Model projections of climate change impacts on plant diversity suggest that mountain regions could be among the most vulnerable (Halloy & Mark 2003, Thuiller et al. 2005). Suitable habitats of many high mountain plant species could be drastically reduced or disappear by the end of the 21st century, particularly where climate warming is combined with decreasing precipitation (Van de Ven et al. 2007, Engler et al. 2011, McCain & Colwell 2011, Tovar et al. 2013). Even if alpine plants do not disappear rapidly from increasingly unsuitable habitats, a growing 'extinction debt' will have to be paid later on, after some decades, if plants are unable to adapt to or cope

with changing conditions (Dullinger et al. 2012). Usually light-demanding alpine plants are expected to decline in competition with taller-growing plants in consequence of *treeline* advances (Devi et al. 2008, Harsch et al. 2009, Feeley et al. 2011), where a net-gain of mountain forests would result in a much larger relative shrinking of alpine land area, given the smaller areal extent of the latter (Körner 2012). The severity of such »extinction scenarios« of alpine plants can only be documented by long-term *in situ monitoring*. In contrast to meteorology and glaciology, however, long-term observations for detecting the impacts of climate change on alpine ecosystems are scarce and have been based on incidental historical data from a limited number of sites. Among these few exceptions are old records from summit habitats of the Alps dating back to the 19th century and several historically studied sites in the Scandes and the Scottish Mountains. Resurveys of these historic summit sites showed that vascular plants have been established at higher altitudes than recorded earlier (Grabherr et al. 1994, 2001a, Klanderud & Birks 2003, Britton et al. 2009, Stöckli et al. 2012, Wipf et al. 2013). Walther et al. (2005) showed that an increase in plant species numbers occurred at a faster pace during the recent decades. Thus, it is assumed that an upward migration of plants, induced by anthropogenic climate warming, is already an ongoing and accelerating process. Changes in species' ranges and their ability to compensate climate change-driven habitat losses, however, are expected to vary greatly among species and responses may be nonlinear, which could lead to sudden range contractions or expansions when climatic tipping points are exceeded (Doak & Morris 2010).

Broad-scale analyses and literature reviews provided ample evidence of ecological impacts of recent climate change, from low-temperature determined terrestrial to tropical marine environments (Walther et al. 2002, Parmesan & Yohe 2003, Root et al. 2003). A meta-analysis over a range of different organism groups showed that the rate of upward shifts was two or three times faster than previously reported (Chen et al. 2011).

Although a pronounced geomorphological heterogeneity and a resulting variation in microclimatic patterns (Scherrer & Körner 2010) and a large vertical extension in many mountain ranges may provide local refugia (Gottfried et al. 1999, Randin et al. 2009), repeated GLORIA surveys indicate a progressive shrinking of the low-temperature, high-elevation habitats, and a decline of species numbers in some mountain regions. Recent resurveys of European GLORIA sites provided evidence that alpine vegetation experienced an increase of more "*thermophilic plants*"

(warm-demanding species), which usually dwell at lower elevations and/or a concurrent decline of more “*cryophilic species*” (cold-adapted plant species) occurring at high elevations (Gottfried et al. 2012). This “*thermophilisation*” of alpine plant communities was observable across the continent (Gottfried et al. 2012), as was a general upward shift of plant species (Pauli et al. 2012). In northern and central Europe, this led to an increase in species numbers during the past decade (Erschbamer et al. 2011, Pauli et al. 2012). A decline in species cover, however, was found at the lower distribution margins of extreme high-altitude species in the Alps (Pauli et al. 2007) with a concomitant upward shift of the summer snowline (Gottfried et al. 2011). In Europe’s Mediterranean south, species numbers were stagnating or decreasing on almost all summits (Pauli et al. 2012), where rising temperatures occurred in combination with decreasing precipitation (Mariotti et al. 2008, del Río et al. 2011). Recent results from the Australian Snowy Mountains suggest an increase of taller shrubs on the lower summits and of graminoids across the entire elevation gradient (Venn et al. 2014).

The GLORIA standard programme, being already operational in over 100 mountain regions on six continents, will be extended to all major mountain systems on earth, and the number of sites is planned to be multiplied in core study regions and in those with high and/or unique alpine biodiversity. This effort is in line with international research demands, which were urged by the Mountain Research Initiative (MRI) of the IGBP (Becker & Bugmann 1997, 1999) and by the Global Terrestrial Observing System (GTOS) in the 1990s, and further on, in a wider scope, by the UNEP World Conservation Monitoring Centre (WCMC) and more recent endeavours, such as through GEO BON, a global partnership to help collect, manage, analyse, and report data relating to the status of the world’s biodiversity (Scholes et al. 2008) in the context of the Aichi Biodiversity Targets (UNEP-CBD 2012). GLORIA is also being conducted in close co-operation with the *Global Mountain Biodiversity Assessment (GMBA)* launched by the international DIVERSITAS programme (Körner & Spehn 2002, Spehn 2011).

GLORIA focuses on the *alpine life zone* (or high mountain area), which is defined here as the area above the low-temperature determined *forestline* and includes the *treeline ecotone*, the alpine, and nival elevation zones. The *alpine life zone* represents the only terrestrial biogeographic unit with a global distribution (Körner 2003, Nagy & Grabherr 2009, Körner et al. 2011). In many countries, high mountain vegetation experiences less pronounced or no direct human impacts compared with lower altitudes. For these reasons, the *alpine life zone* offers a unique opportunity for globally comparative *monitoring* of climate change impacts.

A prototype of GLORIA’s standard long-term monitoring design and method (*Multi-Summit Approach*) was first tested in the northeastern Limestone Alps, Austria, in 1998, and in the Sierra Nevada, Spain, in 1999 (Pauli et al. 2003). In 2001, 72 summits were established in 18 study *regions* (*target regions*) throughout Europe, using an advanced design, through the European Union FP-5 project GLORIA-Europe (Grabherr et al. 2001b, Pauli et al. 2004). In 2003 and 2004 the first sites in the western Cordilleras of the USA, in southern Peru as well as in New Zealand and Australia were set up. During the following decade, the site-based network rapidly expanded over six continents and surpassed the number of 115 regions in 2014.

This GLORIA field manual is based on the experience gained through the broad application and implementation. The methods were designed and further developed to be universally applicable in the world-wide range of alpine mountain-top environments from polar to tropical latitudes. The field manual provides the guidelines for a standardised use of the GLORIA *monitoring* methods and gives an overview of additional GLORIA activities related to global and climate change in mountain regions.

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## 1.2 OBJECTIVES AND AIMS

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The aim of GLORIA is to maintain and extend an operative long-term observation network to provide standardised data series on alpine biodiversity and vegetation patterns on a world-wide scale for tracing and understanding the response of alpine biota to climate change. The purpose of GLORIA’s *Multi-Summit Approach* is to build globally usable indicators of the impacts of climate change on the biodiversity of natural to semi-natural environments and, more specifically, to assess regional to large-scale risks of biodiversity losses and the vulnerability of high mountain ecosystems under climate change pressures.

*In situ* observations on the species level appear to be crucial for this purpose, because plant communities will not respond to climate warming as a whole, but single species will respond in different ways (Ammann 1995, Grabherr et al. 1995, Gottfried et al. 1998, Rosenzweig et al. 2008, Vittoz et al. 2009). What is too warm for one species may still be appropriate for another, or where one species may respond by migration another one may have restricted possibilities to move to new habitats. Thus, species migration driven by climate warming can form new assemblages at the current sites and at new locations. Such differential movements of species could result in a disruption of the connectedness among many species in current ecosystems (Root et al. 2003), and may

be accompanied by significant biodiversity losses and changes in ecosystem functioning. Körner (2002) pointed out that one of the benefits of biological richness is that it insures against “system failure”. Intact vegetation provides safety, particularly in mountain environments, where slopes are only as stable and safe as the integrity and stability of their vegetation. Species-rich vegetation or ecosystems may have a certain functional redundancy among their species. The functional roles of species, however, are expected to change in consequence of drastic alterations of the abiotic constraints and, hence, previously redundant functions may become decisive for sustaining ecosystem functioning on fragile mountain slopes.

Therefore, the fundamental objectives of GLORIA’s *Multi-Summit Approach* are to:

- ◆ provide standardised, quantitative data on species richness, plant species composition, cover and abundance, percentage of unvegetated surface, as well as on soil temperature and the snow cover period along the main climatic gradients in mountain systems world-wide.
- ◆ quantify the changes in species and vegetation patterns through long-term observation and *surveillance* in permanent plots at resurvey intervals of five to ten years. Such changes in the patterns of mountain vegetation would have several components, becoming apparent as immigration or disappearance of species, as increase or decrease of cover/abundance of species which have been present before, whether through direct responses to abiotic factors or through biotic factors such as competition.
- ◆ quantify the changes in the abiotic environment such as of the unvegetated surface and the temperature regime. Measured soil temperature series enable the calculation of temperature indices like mean, minima, maxima and temperature sums, annually and/or for certain periods, and allow for the calculation of the length of the growing season through determining snow melt dates and the time when a plot gets snowed in.
- ◆ build globally applicable and comparable indicators of climate change-driven impacts on alpine vegetation and biodiversity in natural to semi-natural environments.
- ◆ assess the risks of biodiversity losses and ecosystem instability due to climate change.
- ◆ provide information for developing conservation strategies and measures to be taken in order to mitigate climate-induced threats to biodiversity.

To support the development of effective indicators, collateral species data such as on species’ vertical ranges and geographical distribution patterns, on life forms, morphology and ecological indicator values (e.g. Halloy 1990, Halloy & Mark 1996, Ramsay & Oxley 1997, Landolt et al. 2010, Klimešová et al. 2011) and on *plant functional traits* (e.g. Cornelissen et al. 2003, Pohl et al. 2011, Venn et al. 2011, Venn et al. 2014) are collected from literature sources and respective data bases. For example, data on vertical species ranges of European mountain plants were standardized as *altitudinal species profiles* which were used to assign *altitudinal species ranks* to calculate a *thermic vegetation indicator* and a *thermophilisation indicator* of mountain vegetation (see Gottfried et al. 2012). Upward or downward movement of species may, alternatively, also be calculated by applying an *altitudinal index*, solely derived from the field data (see Pauli et al. 2012). Literature data on overall species distributions, on endemism in particular, were used to assess the potential risk of biodiversity losses (Kazakis et al. 2007, Fernández Calzado et al. 2012, Pauli et al. 2012, Venn et al. 2012).

For the assessment and interpretation of observed changes in the wider ecological and biogeographic context, we refer to Malanson et al. (2011) and recall their concluding statement: “In monitoring programs such as GLORIA, the assessment of observed changes in alpine tundra over the coming decades will require a more detailed understanding of the relations of species to the environment and the geography of species individually and in combination. The context needed for interpretation is easy to identify (i.e., cross-scale spatiotemporal relations that embed equilibrium and nonequilibrium dynamics), but difficult to capture. Moreover, for potential mitigation in response to climate change, we have only a weak knowledge base. To overcome these limitations we must build on biogeographical theory, for which the past several decades provides a foundation, and also on the methods for assessing similarity which have developed over the same period.” Moreover, past and current influences of human land use are relevant interfering factors in many mountain regions (Baied & Wheeler 1993, Price et al. 2013) which require consideration.

### 1.3 STATING THE ROLE OF GLORIA

Model projections, experimental and process studies as well as long-term observations are important components of a comprehensive assessment of the ecological impacts of climate change on natural and semi-natural ecosystems. GLORIA is taking a core role in the long-term observation component, by running an effective global network of in situ observation sites for terrestrial species communities

in mountain regions. Alpine ecosystems fulfil the requirements of such an endeavour, because they

- ◆ occur on all continents and in all major life zones on earth,
- ◆ are generally determined by low-temperature conditions,
- ◆ are therefore expected to strongly respond to climate warming.

GLORIA takes advantage of the indicative value of sensitive alpine organisms for the documentation of the ecological implications of climate change. The specific use of such indicators depends on ground-based observations and cannot be substituted by space-borne investigations.

Comparability, simplicity and economy were the main considerations in designing the *Multi-Summit Approach*, GLORIA's standard recording design and method for a cost-efficient large-scale network. The low-instrument and low-cost approach, together with the short time required in the field makes the method workable even under expedition conditions (Pauli et al. 2004).

In addition to this basic approach, several supplementary methods and *extra approaches*, e.g. focusing on other organism groups, soil ecology or on socio-economic features, may be applied and are already ongoing in some GLORIA *target regions* or at GLORIA *master sites* (see Box 1.1).

The main focus of the standard approach lies on biodiversity and vegetation patterns. Both changes in species richness as well as changes in species cover and species composition were already detectable at GLORIA sites at time-scales of less than a decade (cf. Erschbamer et al. 2011, Michelsen et al. 2011, Gottfried et al. 2012, Pauli et al. 2012).

The strength of GLORIA's *Multi-Summit Approach* is (1) the large number of sites, arranged along the fundamental climatic gradients in both the vertical and the horizontal dimensions across all major biomes, (2) the consideration of the complete set of vascular plant species occurring in each permanent plot.

The maintenance and further expansion of such a multi-site network is a challenge that can only be met by a world-wide community of committed biologists. It wholly depends on researchers who are willing to consolidate the foundations of a long-term programme, which will yield results for future generations. Maintaining the structures required for an active long-term observation network will also depend on an effective coordination, on a close co-operation with governmental and inter-governmental authorities and with NGOs, on financial means from public and private sources as well as on the transparency to the public.

## BOX 1.1 THE THREE ACTIVITY LEVELS OF GLORIA

◆ *STandard recording Methods (STAM)*: This includes the basic recording procedure that is required in all GLORIA *target regions* in order to build the fundamental globally comparative dataset on vascular plants and soil temperature. It is fully aligned to the *Multi-Summit Approach*, a set of four observation summits in each *target region* (see chapters 3 and 4).

◆ *SUPplementary sampling designs and recording Methods (SUPM)*: These involve any supplementary plant recording procedure on GLORIA *summit sites* that is also fitted to the *Multi-Summit Approach*. It may concern other plant organism groups such as bryophytes and lichens, additional plot designs, additional recording methods in the standard plots (e.g. species frequency in 1-m<sup>2</sup> quadrats, species cover in summit area sections) and/or supplementary 1-m<sup>2</sup> quadrats within the *summit sites* (see chapter 5).

◆ *EXtra Approaches (EXAP)*: Additional recording activities which are performed within a GLORIA *target region*. They are usually spatially not confined to the *summit sites* (apart from a few exceptions) and may deal with animal organism groups, *Downslope Plant Surveys*, soil variability, and socio-economic and cultural aspects (see chapter 7).

Besides the three activity levels, several GLORIA *master sites* were established to carry out scientific investigations which may not be performed at GLORIA *summit sites* or in GLORIA standard *target regions*. Such high-mountain *master sites* are based on existing research capacities and infrastructures (e.g. as part of LTER sites). The research activities may include methodological test trials for GLORIA STAM, SUPM or EXAP activities, studies on snow, permafrost and vegetation patterns, plant phenology, controlled experiments on species physiological performance and modelling approaches with alpine plants. Targeted studies on, e.g. primary productivity, microbial activity in soils, plant propagation, precipitation changes, nitrogen deposition, *grazing impacts* may further be of interest for the interpretation of changes in biodiversity and vegetation patterns. Research at GLORIA *master sites*, however, is not the subject of this field manual.

## 1.4 WHY FOCUS ON HIGH MOUNTAIN ENVIRONMENTS?

High mountains are defined as mountains extending beyond the natural high-elevation and low-temperature determined *treeline* (or its substitutes). In general, high mountain landscapes are shaped by glaciers (glaciation was present at least in the Pleistocene), and frost is an important factor for pedogenesis and soil structure



(compare Troll 1966). Further, a common feature of mountains is steepness, which causes the forces of gravity to shape them and create all those habitat types and disturbance regimes so typical for mountains (Körner et al. 2011); ([www.mountainbiodiversity.org](http://www.mountainbiodiversity.org)).

The global **alpine life zone** is a highly suitable environment or “natural laboratory” for tracing and studying the effects of anthropogenic global climate change, for the following reasons:

- ◆ The *alpine life zone*, as the entirety of *high mountain biomes*, is unique in occurring at all latitudes – it is distributed over all *life zones* or *zonobiomes* (sensu Walter & Breckle 2002) from the tropics to the polar regions. Therefore it is the only terrestrial biome type, where climate-induced changes along all fundamental climatic gradients (in altitude, latitude, and in longitude) can be compared on a global level.
- ◆ High mountain ecosystems are comparatively simple in terms of their biotic components, at least in the upper elevation levels. They are dominated by abiotic, climate-related ecological factors, whereas the importance of biotic factors such as competition decreases with elevation. Therefore, ecosystems at the low-temperature limits of plant life are generally considered to be particularly indicative to impacts of climate change. The effects of climate change may be better distinguishable compared to ecosystems of lower altitudes (Körner 1994).
- ◆ Mountain regions show steep ecological gradients, resulting from the compression of thermal *life zones*. Hence, mountains are hot spots of organismic diversity (Barthlott et al. 1996), often with a high degree of endemism (e.g. Quézel 1953, Hedberg 1969, Pawłowsky 1970, Nagy & Grabherr 2009, Grabherr et al. 2010). The potential biodiversity loss caused by climate change is therefore high.
- ◆ The presence of narrow *ecotones* is a key aspect of mountains. Vegetation patterns and species composition may change over short distances owing to climatic constraints. This makes a boundary shift readily recognisable within a small area.
- ◆ *High mountain environments* comprise real wilderness habitats with ecosystems undisturbed by direct anthropogenic influence. The *alpine life zone* represents the biome with the highest degree of naturalness, at least in many countries or eco-regions. This allows the study of impacts caused by climatic change without or with only minor masking effects caused by human land-use.

◆ Most high mountain plants are long-lived species which are likely to be responding only little to transient climatic oscillations. A sustained change in climate, however, is expected to cause directional changes in the composition of species, shifts in plant distributions and may threaten their long-term survival (see chapter 1.5). Even gradual changes in species composition could be indicative for the magnitude and, through repeated surveys, the velocity of climate change-induced processes.

◆ Because of the predominance of long-lived perennial species, vegetation sampling does not need to be repeated within one season, because all or almost all species can be seen at the height of a single growing season. Note, however, that this does not hold for all mountains (e.g. in mountains of equatorial latitudes, where many species may be seen throughout the year, but some may be absent at any time during the year).

In summary, standardised long-term *surveillance* of alpine biota across many mountain systems will provide (1) much demanded information on how biodiversity changes in environments governed by low-temperature across the planet's major terrestrial *life zones* from tropical to polar regions, (2) in-depth knowledge on how climate affects alpine biota, (3) will serve as an early warning whether species may become threatened, and (4) will help to develop specific conservation strategies and measures.

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## 1.5 VASCULAR PLANTS AS TARGET ORGANISM GROUP

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Among the wide range of organism groups occurring in *high mountain environments*, vascular plants were favoured for a number of reasons:

- ◆ **Availability of experts:** The identification of taxa down to the species level is a crucial requirement for GLORIA's *Multi-Summit Approach*. On the global level, however, this is a challenging task, given the regionally strongly varying situation concerning taxonomical research, available literature for species identification, and experienced field biologists. The situation for vascular plants is one of the most favourable among all organism groups, where the number of experts is larger by magnitudes than, e.g. for bryophytes, lichens or for most invertebrate groups. As sessile and macroscopic individuals, most vascular species can be, at least potentially, readily identified in the field. Nevertheless, even for vascular plants, capacity building such as through floristic training courses for young researchers is of invaluable importance.

◆ **Longevity of individuals:** A common feature shared among most vascular plants dwelling in *high mountain environments* is their longevity (Billings & Mooney 1968, Körner 2003), being often associated with clonal growth (Stöcklin 1992, de Witte & Stöcklin 2010) or cushion life form (Pearson Ralph 1978, Morris & Doak 1998, Aubert et al. 2014). Annuals and short-lived species are nearly absent from or of minor importance in alpine environments. Persistent and long-lived plants display trends by integrating the climatic effects of several years on their growth performance (Grabherr et al. 2010).

◆ **Ecological range and significance in ecosystems:** Vascular plants occur over a wide range of climatically variable high mountain systems from humid to arid regions and commonly form the dominant and most conspicuous organism group. This wide-spread and diverse autotrophic organism group is of fundamental relevance for ecosystem functioning. Alpine and nival plant communities are composed of a variety of morphological and functional traits and life forms (Halloy & Mark 1996, Klimešová et al. 2011, Pohl et al. 2011, Venn et al. 2011, Boulangeat et al. 2012), and their composition may change over short distances, owing to the high local variability of alpine climates (Scherrer & Körner 2010). Further, vascular plant species are often specific for a distinct elevation belt, which is less so the case for bryophytes and lichens (Glime 2007, Vittoz et al. 2010).

◆ **Geographical range:** Many mountain regions host a rather unique vascular plant flora with a large percentage of endemic, narrowly distributed species. This is particularly the case in orographically isolated mountain ranges, such as around the Mediterranean Basin (Blanca et al. 1998, Kazakis et al. 2007, Stanisci et al. 2011), in southwest-Asia (Noroozi et al. 2011), in alpine areas of Australia (Pickering et al. 2008) and on oceanic islands (e.g. Halloy & Mark 2003), as well as in tropical high mountains such as in East Africa (Hedberg 1969) and in parts of the Andean system (Halloy et al. 2010, Cuesta et al. 2012), but locally or disjunctly distributed species are also found in many mountain regions of North America (cf. Billings 1974, Mills & Schwartz 2005), Asia (e.g. Breckle 2007, Ma et al. 2007) and Europe (e.g. Pawłowsky 1970, Dirnböck et al. 2011). In regions where endemic vascular plant species are concentrated in the uppermost bioclimatic zones, the risk of biodiversity losses through climate change is particularly high. In other high mountain regions, a large proportion of vascular plant species

can be rather widespread over the cold habitats of extensive connected mountain systems or in the circum-boreal and arctic regions and, thus, allow for large-scale comparisons of species responses to climate change.

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## 1.6 WHY MOUNTAIN SUMMIT AREAS AS REFERENCE UNITS?

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The tops of mountains, of course, comprise outstanding habitats concerning their geomorphologic position, their climatic conditions, their hydrology, and hence their vegetation. Furthermore, they cover only a small part of the total *alpine life zone*. At a first glance, it may therefore appear to be disadvantageous to focus on mountain summits. Even though, there are several good reasons why summit habitats are suitable and proper reference units for a large-scale comparison of climate change effects (where the term “summit” refers not just to the very top, but to the *summit area* from the top down to the 10-m *contour line*):

◆ Summits are prominent landmarks which can easily be located on subsequent investigations and future reinvestigations.

◆ Summits are well-defined topographic units which provide comparable conditions and features; they comprise habitats of all slope aspects (north, east, south, west) within a small area.

◆ Topography and the orientation to all aspects cause high habitat diversity and species richness. Therefore, a large part of the local species pool can be captured within *summit areas*, where species should be differently distributed in dependence of aspect. Such differences in species composition among neighbouring habitats may enable a rapid recognition of climate-induced shifts in the assemblage of species.

◆ The species composition in *moderately shaped summit areas* is typical for the respective elevation because the flora is not enriched by elements from higher altitudes. This is often not the case in slope situations, and particularly not in avalanche tracks or near to watercourses, where species may immigrate from higher elevations during disturbance events.

◆ On summits, shading effects from neighbouring land features are usually absent or minimised. Therefore, the climatic conditions on a summit are mostly defined by elevation. It is difficult or almost impossible to find such comparable units in any other topographical situation, where diurnal and seasonal variation in insolation much depends

on shading by neighbouring higher points in the landscape.

- ◆ Summit areas are not prone to severe disturbance such as debris falls or avalanches. This enhances the “durability” of permanent observation plots.

- ◆ Finally, summits may function as traps for upward-migrating species due to the absence of escape routes for “*cryophilic species*” (*cold-adapted plant species*) with weak competitive abilities. This is particularly critical on isolated mountains with a high percentage of endemic species occurring only at the uppermost elevation levels (Grabherr et al. 1995, Theurillat 1995, Pauli et al. 2003, Pickering et al. 2008, Fernández Calzado & Molero Mesa 2011, Noroozi et al. 2011).

For these reasons, mountain summits are considered as highly suitable sites for comparing ecosystems along the fundamental climatic gradients. Not every mountain region and every summit terrain, however, may be suitable for applying GLORIA’s standard approach. Chapter 2 provides considerations and criteria for selecting appropriate regions and *summit sites*.

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## 1.7 HOW TO START A GLORIA TARGET REGION

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Joining the GLORIA network requires a responsible permanent institution with a respective research focus, a suitable mountain region, optimally not far from the institution, and committed, experienced field biologists. Consider the following points when starting with GLORIA work:

- ◆ Read the next chapters on *summit selection*, sampling design and recording methods.
- ◆ Make a pre-selection of suitable *summit sites* using detailed topographic maps, photos or any digital sources before going to the field.
- ◆ For a final decision about *summit sites*, an on-site inspection is essential. Select and check all four *summit sites* (i.e. the standard set of a GLORIA *target region*, to be arranged along the elevation gradient), before starting with any setup activity. Take photos of the potential sites so that you can discuss, in case of doubt, their suitability with the GLORIA coordination or with other experienced GLORIA members.
- ◆ We recommend to check the property relations of the targeted area, even though the standard GLORIA approach is non-destructive. Preferably, sites should be established in protected areas or in

regions being remote enough to ensure a long-term operability.

- ◆ Once you have a concrete plan to establish a GLORIA site (GLORIA *target regions* with four *summit sites*), contact the GLORIA coordination (see [www.gloria.ac.at](http://www.gloria.ac.at) for email contacts) with the following details of your *target region* and *summit sites*:

- ❖ the mountain range where your sites are located,
- ❖ the names of the *summit sites*,
- ❖ a three-character code for each *summit site* (please use alphabetic characters),
- ❖ geographical co-ordinates of each summit site (deg., min., sec.),
- ❖ the elevation above sea level (in metres) of each summit,
- ❖ the time (year, months) when you plan the establishment of the sites,
- ❖ name of the responsible person(s) including email addresses,
- ❖ name of the responsible institution(s).

- ◆ The GLORIA coordination will send you a GLORIA-wide unique 3-digit code of your site (*target region*), which is preceded by a 2-digit country code and will register your site with responsible contact person(s) and institutions(s) on the GLORIA website.

- ◆ Prior to the actual fieldwork it is advisable to compile a preliminary species list of the area from regional floras and databases and to collect critical species already during site selection.

- ◆ Prepare for fieldwork, the plot setup and the recording steps along the guidelines in this manual (see chapters 2, 3 and 4 for the basic standard methods). Please also check the GLORIA website for possible recent updates. Check the magnetic declination of your region before leaving for fieldwork.

- ◆ The start of your plot surveys and species recording should be around the mid-growing season, when a maximum of species are easiest to identify. When you have to deviate from this period, it is recommendable to begin slightly later rather than earlier, when some species’ generative parts may not yet be developed. Do the fieldwork, especially the species recording, on all *summit sites* of a *target region* within the same growing season; avoid to stretching it over two seasons.

- ◆ For subsequent data input and handling see chapter 6.



## 2 THE GLORIA SITE SELECTION FOR THE MULTI-SUMMIT APPROACH

### 2.1 THE TARGET REGION

A GLORIA **target region** comprises a **suite of four summits** which represent an elevation gradient from the natural *treeline* ecotone (where existing) up to the limits of (vascular) plant life, or in regions where these limits are not reached, up to the uppermost vegetation zone (see Fig. 2.1). A *target region* is the mountain area in which these four summits are located (see the example in Fig. 2.2).

All summits of a *target region* must be exposed to the same regional climate, where climatic differences are caused by elevation rather than by topographically determined weather divide effects. The four summits of a *target region* should not be distributed across a major climatic shed. For example, summits located on the pronounced windward side of a mountain range cannot be in the same *target region* as those on the pronounced leeward side (see Fig. 2.3), or summits located in the wetter outer part of a mountain system cannot be combined with those located in the dryer inner part. In (larger) mountain systems, showing such climatic differences, two or more different *target regions* are suggested.

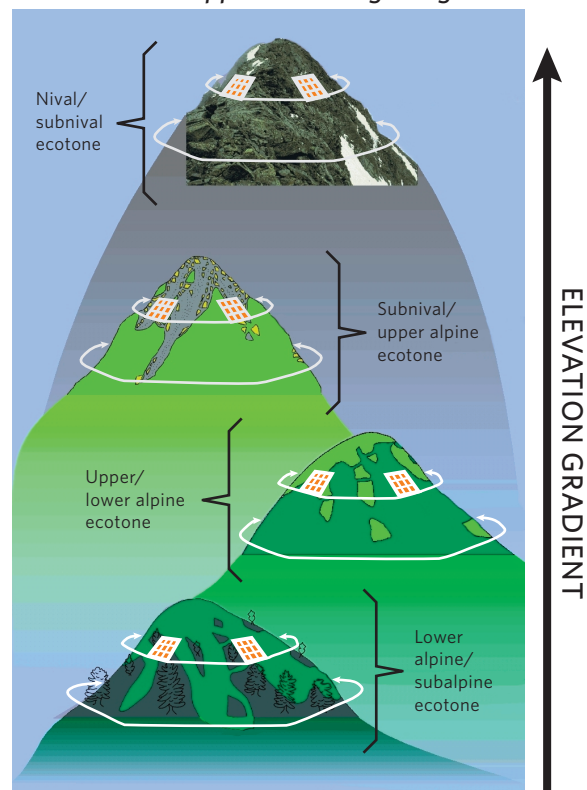
There is neither a minimum nor a maximum limit for the extent of the area of a *target region*, provided that the general climatic situation among the selected sites does not show fundamental differences along a horizontal gradient. Therefore, a *target region* should be as small as possible, but as large as necessary to meet the criteria for *summit selection* given in subchapter 2.2.

### 2.2 SUMMIT SELECTION

The first and crucial task when starting with a new GLORIA *target region* is to select a set of suitable summits, which (1) represent the characteristic vegetation patterns of the mountain region along the elevation gradient (see subchapter 2.2.1), and which, at the same time, (2) fulfil the required preconditions and criteria for *monitoring*, as described in subchapter 2.2.2.

Annex II of this manual contains a sampling form for the *target region* (**Form 0**). This form is included to provide general information about the *target region* and about each selected summit, based on the guidelines and definitions in the following subchapters 2.2.1 and 2.2.2; i.e. indications and comments on the altitudinal vegetation zones or their major *ecotones*, on the bedrock material, protection status and human land use (see chapter 4.6).

#### Multi-Summit Approach – Target region



**Fig. 2.1** The GLORIA *target region*. Four summits of different elevations represent a *target region* (for vegetation zonation compare Box 2.1). The white lines indicate the lower boundaries of the 5-m and the 10-m summit area, respectively; for explanations see chapter 3.1.

Once you have selected your sites, it is advisable to contact the protected area managers or the private land owners to inform them about the intended GLORIA activities.

#### 2.2.1 THE ELEVATION GRADIENT

The ideal altitudinal positions of the four summits would be within the *ecotones* that form the transition between vegetation belts, because climate-induced changes are most likely to become first apparent in these transition zones. Such an arrangement could be, for example: **summit 1:** *treeline* ecotone, **summit 2:** transition between the lower and the upper *alpine* zone, **summit 3:** transition from the upper *alpine* to the *nival* zone, **summit 4:** close to the limits of vascular plant life; see Box 2.1 for definitions

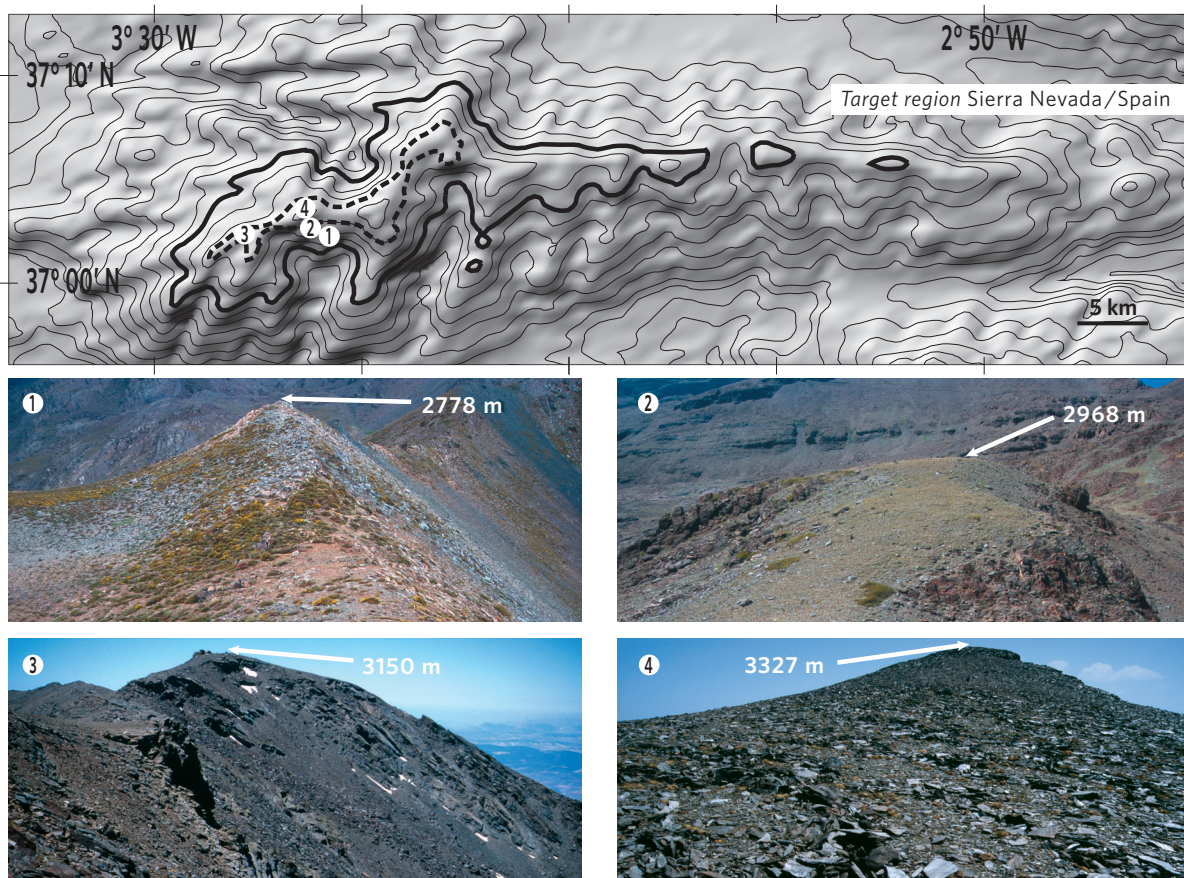


Fig. 2.2 Example of a *target region* with four selected summits of different elevations.

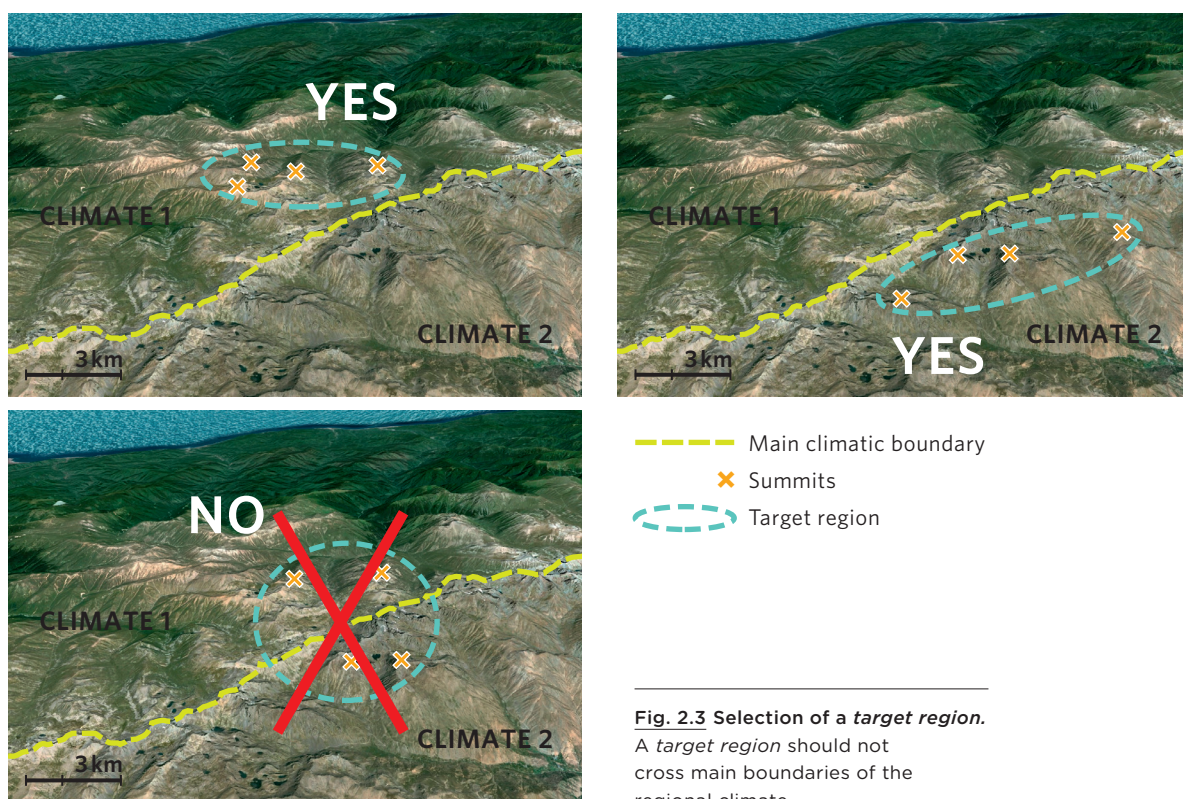


Fig. 2.3 Selection of a *target region*.  
A *target region* should not cross main boundaries of the regional climate.



of vegetation belts. This ideal case, however, may be rather theoretical because obvious boundaries marking the limits of vegetation zones are often lacking. On the other hand, *summit areas* usually represent ecotonal situations anyway, e.g. along the gradient from the northern to the southern slope of the summit. Therefore, the *summit selection* may not lay stress on an exhaustive search for *ecotones*, but should focus on finding a series of summits which **represent an elevation gradient of vegetation patterns, characteristic** for the respective **mountain region**. The *summit sites* may be distributed in equal elevation intervals, as far as this is possible.

Mountain regions, where the *alpine life zone* does not show a clear vertical zonation should not be excluded. This is particularly the case, where mountains only slightly extend into the *alpine life zone* and where alpine biota are restricted to a narrow vertical belt. These biota are considered to be particularly prone to climate-induced

threats. In such cases, the selected summits are to be positioned in short vertical distances to each other.

**Four summits** are required for the basic arrangement within a *target region*. Exceptionally, a *target region* may consist of only three summits, e.g. where three suitable summits are available, but a fourth appropriate *summit site* is really absent. Three summits, however, is the minimum number to represent an elevation gradient, and thus **three summits is the absolute minimum requirement** to be considered as a GLORIA *target region*.

Until this point, any mountain region that extends into the *alpine life zone* is potentially appropriate for a GLORIA *target region*. In addition, however, GLORIA summits must meet several criteria (subchapter 2.2.2) which are crucial for applying standardised and practicable observation settings. Not all mountain areas may meet these criteria – and it is better to shift to another area rather than to establish a *target region* with inappropriate *summit sites*.

## BOX 2.1 VEGETATION ZONATION IN HIGH MOUNTAIN AREAS

The GLORIA *target regions* are restricted to areas extending from the low-temperature determined *treeline ecotone* upwards; i.e. the area which coincides with the *alpine life zone*. Therefore, some definitions (compare Grabherr et al. 2003, Körner 2003, Nagy & Grabherr 2009, Grabherr et al. 2010, Körner et al. 2011, Körner 2012) and considerations are given here.

- ◆ The **forestline** (or timberline), marking the lower limit of the *treeline ecotone*, is defined as the line where closed (montane) forests end.
- ◆ The **treeline** is the line where groups of trees taller than 3m end.
- ◆ The **tree species line** is the line beyond which no adult individuals of tree species, including prostrate ones or scrub, occur.
- ◆ The **treeline ecotone** is the zone between the forest line and the *tree species line*.
- ◆ The **alpine life zone** is the area from the *forestline* upwards and, thus, includes the *treeline ecotone*, the *alpine zone*, the *alpine-nival ecotone*, and the *nival zone*.
- ◆ The **alpine zone** (or alpine belt) is the zone between the *treeline* and the upper limit of closed vegetation (cover >20–40%, but can be less in arid regions), where vegetation is a significant part of the landscape and its physiognomy. The *alpine zone* of some mountain regions is

further subdivided into a **lower alpine zone** (the zone where dwarf-shrub communities are a major part of the vegetation mosaic) and an **upper alpine zone** (where grassland, steppe-like and meadow communities are dominating). For regional variants, different terms are widely used, such as cryoro-mediterranean (Fernández Calzado & Molero Mesa 2011), afro-alpine, high-andean, páramo, puna (Cuesta et al. 2012, Sklenář et al. 2013), which are subsumed here as *alpine zone*.

- ◆ The **nival zone** is the zone of ice, permanent snow, and/or bare bedrock material being mostly uninhabitable by vascular plants. Cryptogam species such as lichens and bryophytes may occur besides few outposts of scattered individual vascular plants or scant patchy vegetation at thermally favourable microsites. Vegetation is not a significant part of the landscape.
- ◆ The **alpine-nival ecotone** (or **subnival zone**) is the transition between the upper alpine and the *nival zone*. The position of this ecotone can be highly related to the duration of summer-snowpack (cf. Gottfried et al. 2011) and might coincide with the permafrost limit in many mountain regions.

**Considerations concerning the *treeline ecotone*:** For an opti-

mal applicability of the sampling methods, the vegetation on the lowest summit of a *target region* should not be dominated by tree species or tall shrubs, because the method is particularly designed for low-stature dwarf-growing alpine vegetation. Thus, for the lowest summit, a site within the upper part of the *treeline ecotone* should be selected, where trees or shrubs occur only sparsely. Further, the summit should lie within the potential natural *treeline ecotone*, and not at the present *treeline*, if the latter has been lowered significantly owing to human interference.

In mountain systems where no *treeline* exists because of aridity, or where the *treeline* is substituted by human land use with pastures, the *alpine life zone* may be defined as that part of the landscape, which was shaped by glaciers (which were present at least in the Pleistocene) and where frost is an important factor for pedogenesis and substrate structure (compare Troll 1966). Finally, the occurrence of ruggedness in the landscape is a crucial determinant of *high mountain environments* and would exclude flat altiplanos, such as found in parts of the southern central Andes or in the Qinghai-Tibetan plateau (Körner et al. 2011).

## 2.2.2 CONSIDERATIONS AND CRITERIA FOR THE SUMMIT SELECTION

GLORIA *summit sites* not only comprise the uppermost peak of a mountain, but the *summit area* down to the 10-m *contour line* below a mountain's highest point. Such *summit sites* may be located around the very top of a mountain system or on a less prominent summit of the mountain system, the latter being often of lesser attractiveness for mountain tourism. Even any hump in a ridge which protrudes more than about 20 elevation metres above the surrounding land features may serve as a suitable *summit site*.

Given the vast geomorphological and ecological variation in alpine mountain top environments, the following six 'criteria' (A-F) are recommendations, rather than strict criteria. Nevertheless, they are important to be taken into account when selecting *summit sites* for the long-term *surveillance* of high-mountain biota.

These criteria are not ranked for their priority but along a sequence starting with those that can be evaluated already in the initial planning phase, just by using maps, aerial and satellite images and literature, to those where a visit of a candidate *summit site* is required. For the final decision, an on-site inspection of each summit is necessary in any case.

**A VOLCANISM** GLORIA sites should lie outside of areas where active volcanism is an obvious factor shaping the prevalent vegetation patterns and species composition. Impacts arising from volcanic processes such as eruptions, ash rain as well as thermal influences of habitat conditions would strongly mask any climate change-related signal and a high frequency of eruption raises the risk of complete loss of permanent plots. Dormant volcanoes may be considered as suitable, if eruption activity dates back long enough to be of negligible influence for the current vegetation patterns.

» Avoid areas with active or dormant volcanism that still influences the prevailing vegetation.

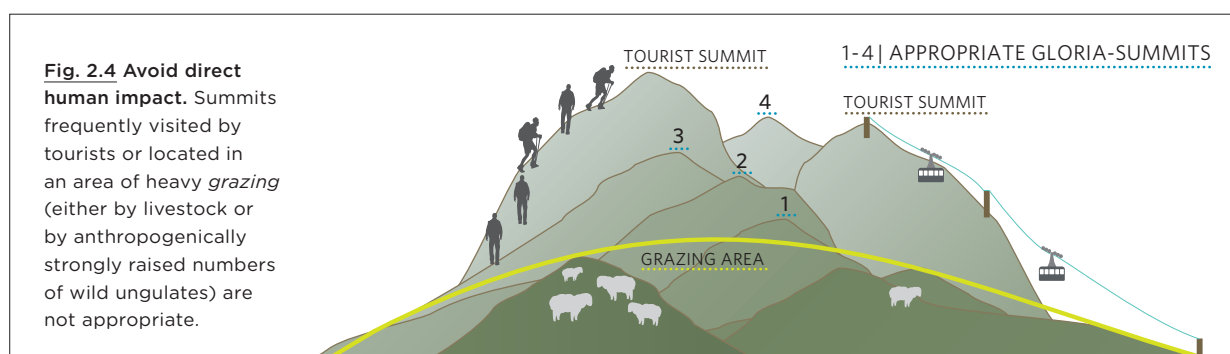
**B CONSISTENT LOCAL CLIMATE** Ideally, all four *summit sites* of a *target region* should be exposed to the same local climate, where the only climatic differences are caused by their different altitudinal positions. It is, however, not trivial to distinguish between climate influences just caused by elevation from those caused by a particular topography and, thus, decisions would be difficult. The main point, however, that can be more easily considered is to avoid that the set of four summits is distributed across a pronounced climatic divide. For example, a *target region's* set of four sites should not include sites in a pronounced windward side as well as sites in dryer and warmer leeward or interior parts of mountain ranges (Fig. 2.3). Instead, each climatically clearly distinguishable part of a mountain system should be treated as different *target regions*.

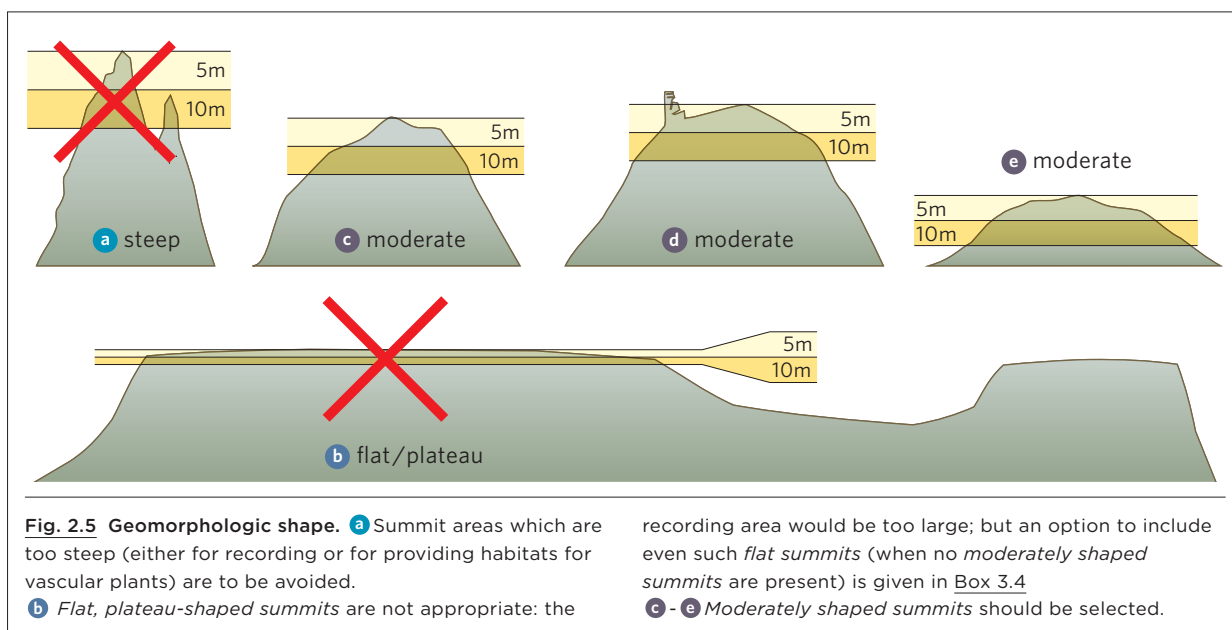
» Avoid that summit sites within a target region are distributed across pronounced climatic divides.

**C BEDROCK OF THE SUMMIT AREA** All summits within a *target region* should be composed of similar bedrock. In particular, the mingling of summits of strongly contrasting bedrock, e.g. calcareous and siliceous, within one *target region* should be avoided, because differences in species richness and species composition would be confounded by substratum-related factors. In regions with nearby occurrences of such different bedrock types, establishing of two '*target regions*' separating the contrasting substrates of the same region, is a valuable solution for comparing different habitats (such as in the Swiss National Park region or in the White Mountains, California).

» Avoid that summit sites within a target region have contrasting bedrock types.

**D HUMAN DISTURBANCE PRESSURE** In the ideal case, GLORIA summits lie in pristine or near-natural environments that are not obviously altered through direct human interference. Areas should not be affected by heavy pressure from human land use (see Fig. 2.4) as impacts by *grazing* animals (trampling, *grazing*, and fertilising) and trampling effects by hikers may cause substantial changes in species composition and vegetation patterns. Such effects are likely to mask climate-induced changes.





In a number of mountain ranges, we still find rather pristine *tree lines* and *alpine zones*, such as in parts of North America and other boreal to arctic regions or in New Zealand and parts of the southern Andes. In many of the European mountain areas, in large parts of the Andes and mountains of Asia and Africa, however, traditional land use – mainly mountain pastoral and/or burning practices – have altered the *treeline ecotone* and, to a minor extent, also the lower *alpine zones* (e.g. Bock et al. 1995, Molinillo & Monasterio 1997, Adler 1999, Bridle & Kirkpatrick 1999, Spehn et al. 2006, Yager et al. 2008a, Halloy et al. 2010). In such cases, the selection should focus on the least affected sites, preferably in national parks or nature reserves, where human disturbance pressure can be expected to remain low in the future (see also Box 4.6). Fortunately, globally around 35% of the little impacted mountain regions are covered by nationally designated protected areas (Rodríguez-Rodríguez & Bomhard 2012, Pauli et al. 2013). A moderate traditional pastoralism, however, is less critical if land use practices remained quite the same over centuries concerning both type and intensity. Such sites may be suitable as GLORIA sites. Heavily overgrazed areas, where plant communities have obviously changed (grazing indicator plants), however, should not be used as GLORIA sites. Further, those areas where type and intensity of human land use changed strongly during recent decades or during the past century should be avoided as far as possible. Such pronounced changes in traditional land use patterns, either through abandonment of mountain farming or its intensification, are likely to cause overlaps with an overall footprint of climate warming.

» Avoid heavily overgrazed sites, tourist summits and areas with strong recent changes in land use practices.

## E GEOMORPHOLOGIC SHAPE OF THE SUMMIT

**AREA** Summits should be of “moderate” geomorphologic shape (for a definition see the glossary under: *moderately shaped summit*). Very steep summits as well as flat tops, forming plateaus, are unsuitable for the application of the *Multi-Summit Approach* (Fig. 2.5). Steep mountain peaks and summits with very unstable substrate should be avoided, first, because of safety reasons. In the usual situation at GLORIA surveys, where several persons work at the same time, great care because of rock falls is necessary. Steep and unstable sites, therefore, must be excluded because of the enhanced accident risk. Second, many steep summits have only few microhabitats for plants to establish, because of the dominance of rocky habitats, and are thus of little use for observing vegetation changes. Third, steep sites would require the use of climbing equipment and, therefore, would prolong the required time. *Flat summit* areas are disadvantageous as the four main aspect situations are absent, and the sampling area becomes larger, the flatter the terrain is. Flat and plateau-like mountain tops, however, are typical for several mountain regions on all continents, where “*moderately shaped*” summits may be difficult to find. In such cases, some modifications of the method, described in Box 3.4, may be considered.

This topography criterion absolutely requires an inspection in the field. Check the steepness of the summit terrain and if distances from the *highest summit point* towards the four *cardinal directions* are reasonable within the uppermost 5 and 10 metres in altitude (less than 50m and 100m in distance, respectively, but see Box 3.4).

» Avoid steep and unstable summits, use flat sites only in absence of alternatives.

**F HABITAT CONTEXT** The prevalent vegetation on a GLORIA summit should be representative for the typical species occurring in the respective elevation belt. The patterns of microhabitats populated by vascular plants or, at the high summits, of potential sites where plants could establish, should be similar to the average situation at the given elevation. Summits dominated by solid rock (irrespective of steepness), by unstable scree fields or by large boulder fields, should be avoided.

» **Avoid summits where habitats or potential habitats for vascular plants are scarce.**

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## 3 STANDARD SAMPLING DESIGN OF THE *MULTI-SUMMIT APPROACH*

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This chapter contains the detailed description of the basic plot design for the *Multi-Summit Approach* and how to establish a *monitoring* site on a mountain summit. The setup procedure is described in detail along [WORK STEPS A-G](#).

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### CONTENT OVERVIEW WITH THE STANDARD [WORK STEPS A-G](#)

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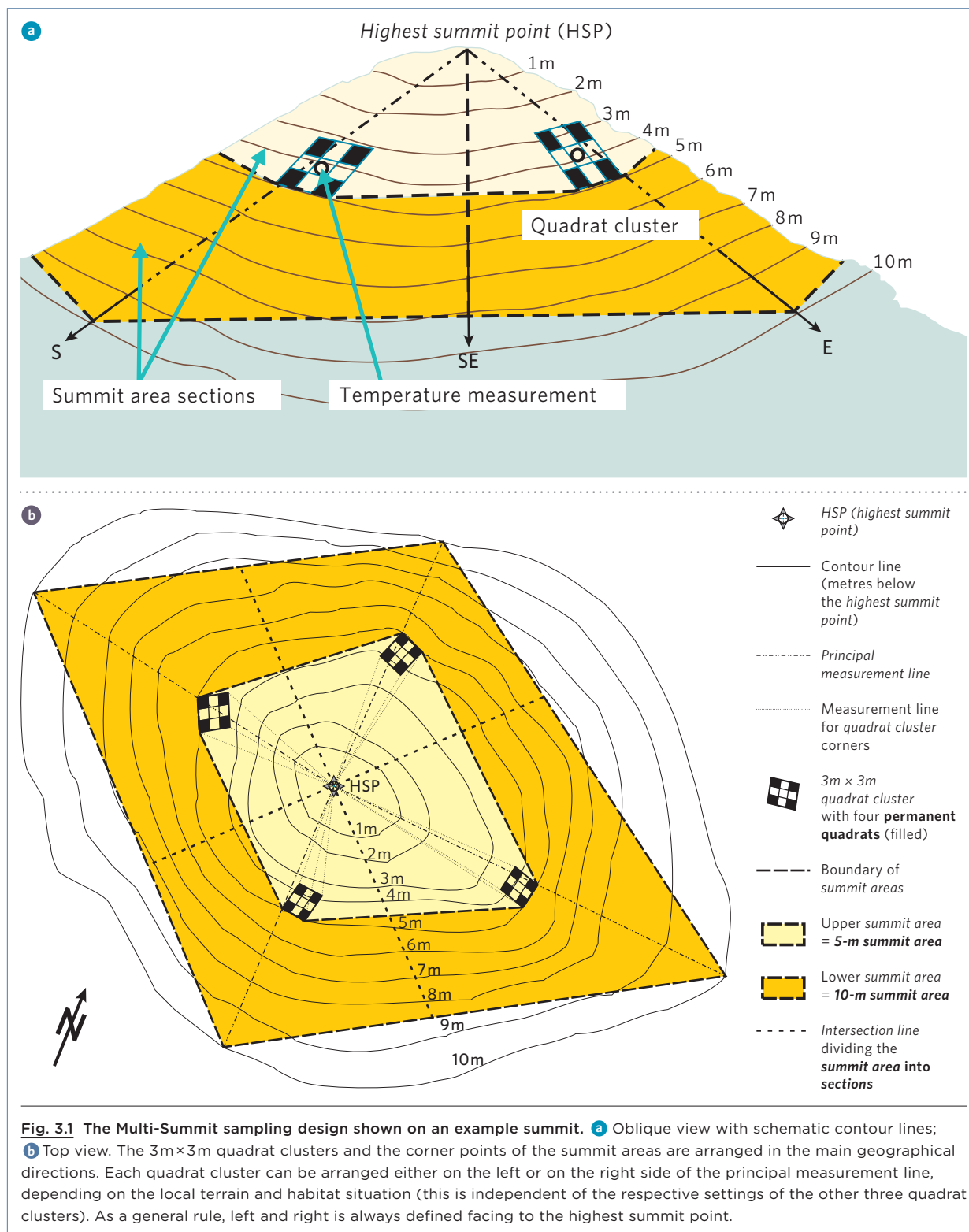
### 3.1 PLOT TYPES AND DESIGN OUTLINE

The sampling design for each summit consists of:

- ◆ **Sixteen 1-m<sup>2</sup> quadrats** (Fig. 3.1), arranged as the four corner quadrats of the four 3m×3m quadrat clusters in all four main compass directions, yielding

16 1-m<sup>2</sup> quadrats per summit (=16-quadrat area).

- ◆ **Summit area sections** (Fig. 3.1), with four sections in the upper summit area (**5-m summit area**) and four sections in the lower summit area (**10-m summit area**). The size of the summit area section is not fixed but depends on the slope structure and steepness.



**Fig. 3.1** The Multi-Summit sampling design shown on an example summit. **a** Oblique view with schematic contour lines; **b** Top view. The 3m×3m quadrat clusters and the corner points of the summit areas are arranged in the main geographical directions. Each quadrat cluster can be arranged either on the left or on the right side of the principal measurement line, depending on the local terrain and habitat situation (this is independent of the respective settings of the other three quadrat clusters). As a general rule, left and right is always defined facing to the highest summit point.

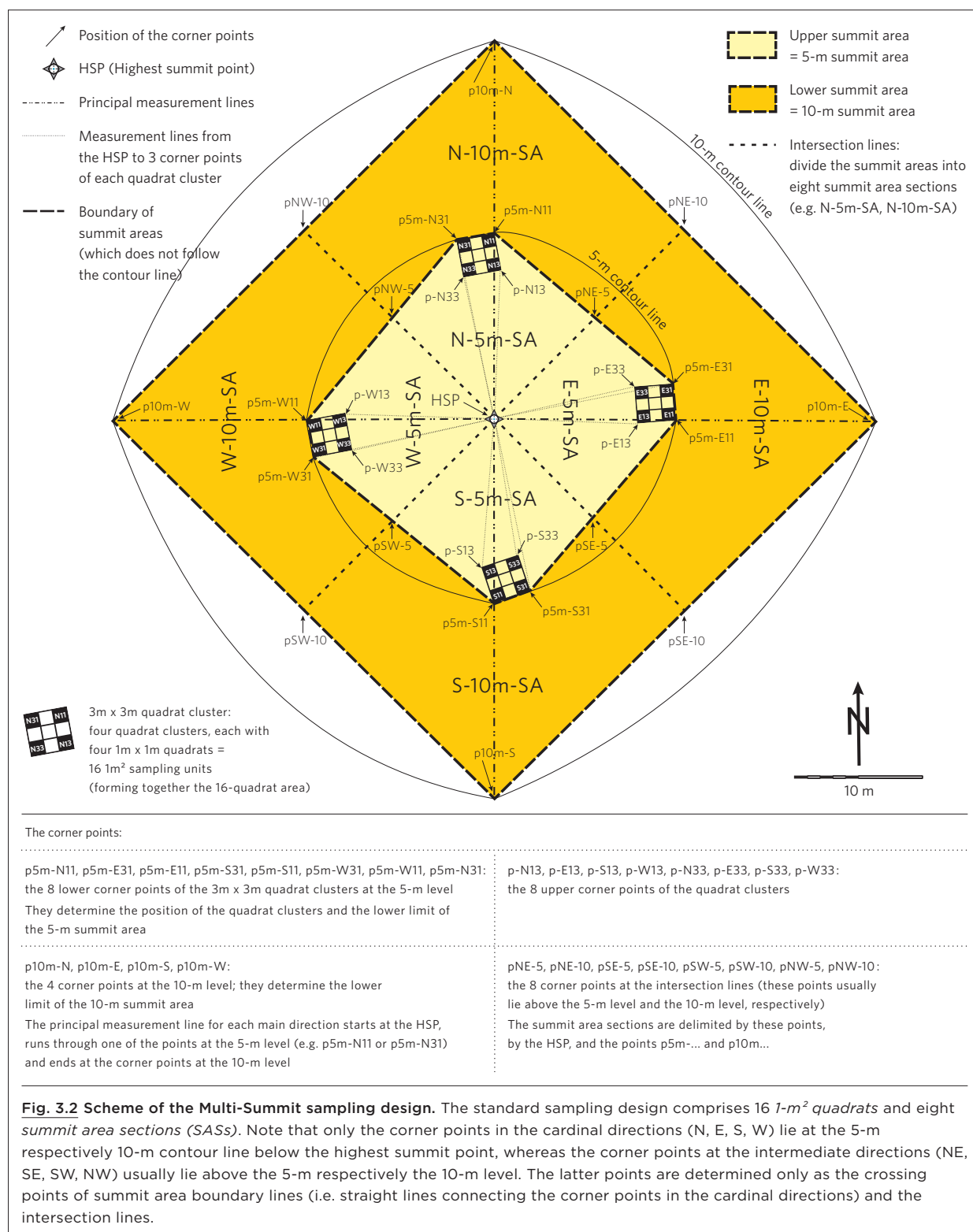


An illustration of the plot arrangements is shown in Fig. 3.1 with an oblique and a top view on an example summit. Fig. 3.2 shows the scheme of the sampling design with the code numbers of all *measurement points* and sampling plots.

The full setup and the standard recording procedure requires between two and about six days per summit for

a team of four investigators (dependent on vegetation density, species richness and site accessibility). This time estimate includes the sampling of vascular plants, but excludes the recording of bryophytes and lichens on the species level.

Note that at least two fieldworkers are absolutely necessary for establishing the permanent recording



areas and settings, but a team of at least four persons is highly recommended. However, be aware of increased disturbance when you have a large team.

## 3.2 MATERIALS AND PREPARATIONS

The following materials and tools are needed for site setup and recording (for your fieldwork preparation see the checklist in Annex I of the field manual):

- ◆ **For measuring the position of plots and corner points of the summit area:** two rolls of flexible 50-m measuring tape (the use of shorter tapes is not recommendable); a *compass* (recommended: Suunto KB-14/360); a *clinometer* (recommended: Suunto PM-5/360PC); two small rolls of measuring tapes (e.g. of 3m length). An altimeter and a GPS may be useful supplementary devices.

- ◆ **For delimiting the 1-m<sup>2</sup> quadrats:** four sampling grids of 3m×3m with 1m×1m cells. These grids should be made of *flexible measuring tapes* fitted together to a grid with small metal blanks or with a strong adhesive tape (for instructions see Fig. AI.1 in Annex I). About 100 pieces of ordinary 100mm nails and thin wire for mounting the sampling grids in the field, adhesive tape to repair the grids in the field.

- ◆ **For delimiting the summit area:** two rolls of thin string (each about 500m long) and four rolls of the same type (about 100 m each); check if strings are on an easy-to-handle spool. The length of these strings depends on the summit shape (the flatter the summit, the longer the string must be). The colour of the string should contrast with the surface colour (e.g. bright yellow is a good choice).

- ◆ **For permanent marking:** per summit about 80 aluminium tubes (0.8 or 1 cm in diameter) in various lengths (between 10 and 25 cm) or other material appropriate for the relevant substrate (e.g. durable white or yellow paint) and a small chisel (for marking the *highest summit point*).

- ◆ **For photo documentation** (see chapter 4.4): a digital camera for high-resolution photos, wide-angle and standard lenses or a zoom wide-angle to standard lens (wide-angle for depicting a 1-m<sup>2</sup> area from a top-view position); a small blackboard (e.g. 15×20cm) plus chalk for writing the plot number and date; a signal stick or rod (1.5 to 2 m) to mark the corner points on the photos.

- ◆ **For the recording procedures** (see chapters 3 and 4): sampling sheets in a sufficient number of copies: the *Forms 0, 1, 2, 3, 4* in Annex II and downloadable from the GLORIA website under

'Methods'); *compass*, *clinometer* or *electronic spirit level* (i.e. the same devices as used for plot positioning); transparent templates for cover estimations (see Fig. AI.3a & b in Annex I); one wooden (or aluminium) *grid frame* of 1m×1m inner width and 100 *crosshair points* distributed regularly over the plot (see Fig. 4.2 and Fig. AI.2 in Annex I); a *sampling pin* of 2mm diameter for point recording (e.g. a knitting needle of 2mm diameter).

- ◆ **For permanent temperature measurements** (see chapter 4.3): miniature *temperature data loggers* (four per summit, i.e. 16 per *target region*), logger protocol sheet (*Form 4*), watch, gardening trowel, for data readout: laptop, dongle.

- ◆ **For supplementary methods** (see chapter 5) Use a wooden (or aluminium) *frequency grid-frame* of 1m×1m inner width (Fig. 5.1) for *subplot-frequency counts*, which has a different arrangement of strings than the *pointing frame*, and the sampling sheet *Forms 5-S* in Annex II.

For the supplementary 10m×10m squares you need additional *flexible measuring tapes*: one roll of 50m (for delimitation) and one of at least 10m (for *line-pointing*) and the sampling sheet *Form 6-S* in Annex II.

## 3.3 SETUP OF THE PERMANENT PLOTS

Setup and measurements of plot positions such as distances and *compass bearings* from the *highest summit point (HSP)* to the plot corners must be made carefully and all entries into the measurement sheet (*Form 1*) should be double-checked. The data entered into *Form 1* are crucial for the automated calculation of the area size of the *summit area sections (SAS)* and the processing of outline drawings.

### 3.3.1 THE HIGHEST SUMMIT POINT (HSP): DETERMINATION OF THE PRINCIPAL REFERENCE POINT

The *highest summit point (HSP)* is the starting point of all measurements. The *HSP* is usually the middle of the *summit area of moderately shaped summits*. Rocky outcrops at one side of the *summit area*, which may exceed the elevation of the middle culmination point (compare Fig. 2.5d), should be ignored.

#### WORK STEP A Marking the HSP

This point should be marked with a small cross cut into the solid rock by using a chisel (Fig. 3.3). For sites lacking a

A photograph of a rock sample, likely a fossil, embedded in a light-colored, textured rock matrix. A black rectangular label is placed over the sample, containing the text 'GR-LEO-CHO', 'HSP', and '20010614' in white. To the right of the text on the label is a white arrow pointing upwards, labeled 'N' for North. The rock surface is rough and uneven, with some darker, possibly fossilized, areas visible.

### 3.3.2 ESTABLISHING THE 1-m<sup>2</sup> QUADRATS IN 3m x 3m QUADRAT CLUSTERS AND THE SUMMIT AREA CORNER POINTS

**Quadrat clusters:** In each of the four main directions (i.e. the true geographic N, E, S & W) a  $3\text{ m} \times 3\text{ m}$  *quadrat cluster* has to be positioned (see [Fig. 3.1](#) and [Fig. 3.2](#)). Each *quadrat cluster* consists of nine  $1\text{-m}^2$  *quadrats*, delineated by a grid of *flexible measuring tape* (as prepared before fieldwork). The lower boundary of each *quadrat cluster* should lie at the 5-m *contour line* below the summit (with a tolerance of  $\pm 0.5\text{ m}$ ). The lower left **or** the lower right corner point of the *quadrat cluster* should be arranged in the main *geographic direction* (N, E, S, or W) as seen from the *highest summit point*. Thus, the *quadrat cluster* can either lie to the right or to the left side of the line indicating the main *geographic direction* (compare [Fig. 3.1](#)) to be decided separately for each *cardinal direction* depending on the particular terrain and habitat situation.

- ◆ too steep terrain to allow safe work or trampling would cause excessive damage, or
- ◆ it falls on a bare outcrop or boulder field, where potential area for plant establishment is largely absent.

**p10m-N**  
(corner point at the  
10-m level below summit)

**Principal measurement line  
for the north direction**  
meets one of the two 5-m corner points of  
the quadrat cluster (in this example  
the **p5m-N31**) and the 10-m point **p10m-N**

**p5m-N31**  
(5-m level  
below summit)

**p5m-N11**  
(5-m level  
below summit)

**p-N33**

**p-N13**

**Measurement lines  
for the other  
corner points of the  
quadrat cluster**

**HSP = Highest summit point**  
(the principal reference point)

10 m

the *intersection lines* (i.e. lines delimiting the *summit area sections* at the exact geographic NE, SE, SW, and NW directions). Wherever possible, *summit sites* where shifts from the exact *cardinal direction* are necessary should be avoided. Otherwise, always comment on the rationale for such shifts.

**Summit area corner points:** The lower corner points of the  $3m \times 3m$  quadrat clusters also mark the lower limit of the upper summit area (= the 5-m summit area).

The four lower corner points of the lower *summit area* (= the 10-m *summit area*) lie along the straight line connecting the *HSP* and the 5-m corner point (= the *principal measurement line*), at 10m elevation below the *HSP* (compare Fig. 3.1 and Fig. 3.2).

The suggested working sequence described in this subchapter must be repeated for each main geographical direction (N, E, S, & W) and is demonstrated here for the N-direction with the following **WORK STEPS B - D** (compare with Fig. 3.2, Fig. 3.4 and Fig. 3.5; see also the measurement protocol sheet (*Form 1*)).

#### **WORK STEP B** Determination of the *principal measurement lines* (the *compass direction*, the *vertical extension*, and the *length*)

i.e. from the *HSP* straight down through a point at the 5-m level to the endpoint at the 10-m level.

- ◆ Person A measures the eye-height of person B (i.e. the distance from the sole of the boots to the eyes).
- ◆ Person A stands with a *compass* and the measurement protocol (*Form 1*) at the *HSP* and fixes a 50-m measuring

tape at this point. He/she points out the **geographic N-direction** (see Fig. 3.4, Fig. 3.5 and Box 3.1).

- ◆ Person B begins walking in the indicated geographic N-direction unwinding the measuring tape and focusing on the *highest summit point* with a *clinometer*. When reaching an exact horizontal view of the *HSP*, a temporary marker is placed on the ground. The elevation difference between the marker and the *HSP* equals the eye-height (i.e. the body length from feet to eyes) of person B. This process is repeated until the 5-m point is reached (see Fig. 3.5).
- ◆ When reaching the 5-m level, person B (or both) decides if the location is appropriate for spreading the 3m×3m *grid*. If not, another location at the 5-m level, positioned as close as possible to the exact geographical N-direction, should be chosen. Whenever such a deviation is necessary, always stay within the area delimited by the NW and the NE intersections lines which will be established later in **WORK STEP C**.
- ◆ The determined point at the 5-m level (this will be either point *p5m-N11* or *p5m-N31*, see **WORK STEP C**), will

### **BOX 3.1 COMPASS MEASUREMENTS**

The magnetic N-direction can deviate considerably from the geographic N-direction in some regions and can change in comparatively short periods of time. Therefore, the *magnetic declination* (i.e. the angle between the direction of the **geographic North Pole** and the **magnetic North Pole**) has to be identified and indicated on the measurement protocol sheet (*Form 1*).

Check the region's *magnetic declination* before starting fieldwork.

The current *magnetic declination* of any place on the globe can be obtained, for example, from the web site of the US-National Geophysical Data Center, Boulder: [www.ngdc.noaa.gov/geomag-web/#declination](http://www.ngdc.noaa.gov/geomag-web/#declination)

To fix, for example, a point in the geographic N-direction the measuring person defines:

- ◆ the magnetic N-direction with the *compass*,
- ◆ corrects it for the *magnetic declination* and
- ◆ guides the person, who fixes the points, to the corrected geographic N-direction.

This applies to all directions (N, E, S, W as well as to NE, SE, SW, NW; see also below in this box).

**Magnetic declination:** The *magnetic declination* should be indicated in degrees (360° scale) with its correct sign (+ or -) at the top of the measurement protocol (*Form 1*).

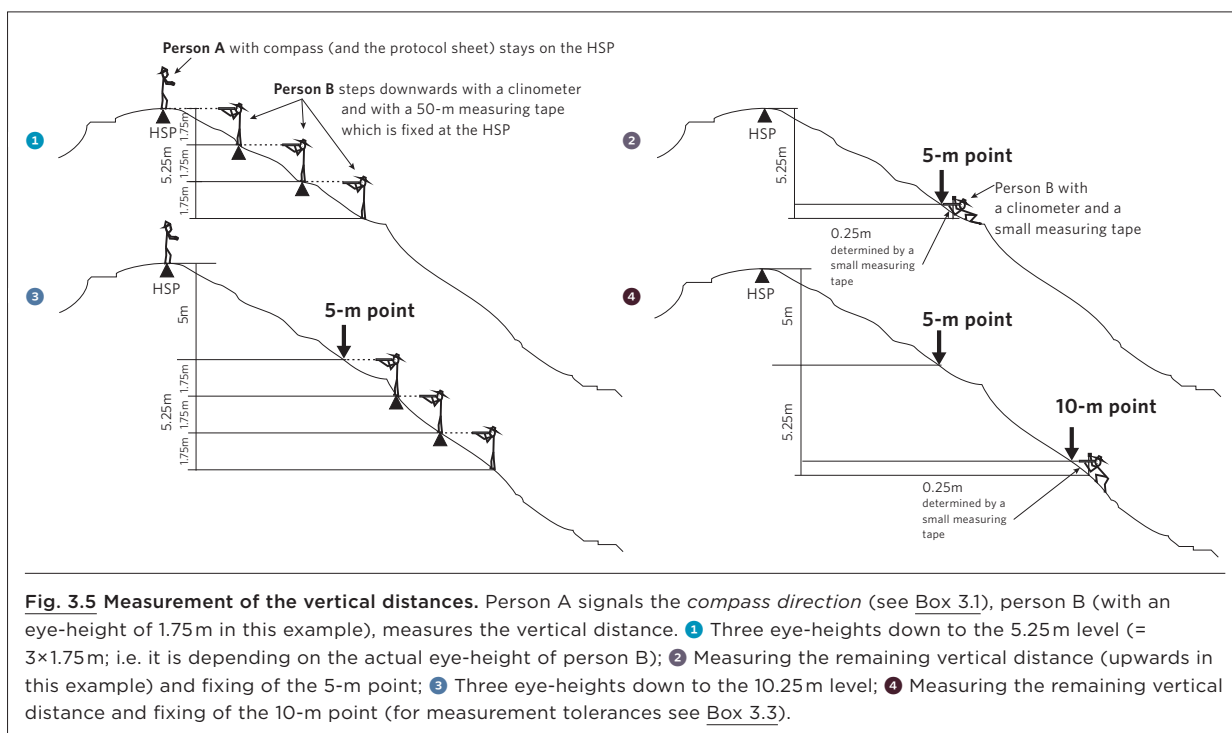
For example, **-6** (= 6° W = 6° west of the geogr. North Pole), **+20** (= 20° E = 20° east of the geogr. North Pole). In southern Europe and in the European Alps, the *magnetic declination* is currently only between -1° and +4°. There are larger declinations, e.g. in N-Sweden or in the Central Caucasus (currently between +6 and +7°), Southern Ural (about +12°), Northern Ural (+24°), Tierra del Fuego, Argentina (+13°), Central Brooks Range, Alaska (about +20°) or on central Ellesmere Island, N-Canada (about -54°). These examples show that it is important to consider the *magnetic declination* for establishing the permanent plots, when using a field *compass*.

**The magnetic declination must be considered for the determination of all four principal measurement lines as well as for the four intersection lines.** For example, the corrected

*compass bearings* at a given *magnetic declination* of **+5** (5° E) are 355° for true/geographic N, 085° for E, 175° for S, 130° for SE; the corresponding values at a *magnetic declination* of **-10** (10° W) are: 010° (for true N), 100° (E), 190° (S), 145° (SE). That means, e.g. for the N-direction and a *magnetic declination* of +5: use the *compass bearing* 355° to fix the *principal measurement line* and the N-cluster (see Fig. 3.4).

**Please note: In any case, only the measured magnetic compass bearing has to be entered into the protocol sheet (*Form 1*), i.e. degrees on the 0-360° scale as indicated on the *compass* (see also Fig. 3.4).** This is relevant for all numeric indications of directions in the sampling protocols. For example, at a *magnetic declination* of +8 (8° E) write into your protocol sheet: 352° for the proper *compass bearing* of the true north direction, 37° for the true NE direction, 82° for the true east direction, and so forth.

For measuring *compass directions*, an accuracy of ± 2° can be normally reached with an ordinary field *compass* or ± 1° with a Suunto KB-14/360 *compass*.



be marked with a small aluminium tube and with some stones to aid the further setup procedure (in **WORK STEP C**).

- ◆ From the point at the 5-m level, person B continues downward to the 10-m level, being guided by person A. Note that the HSP and the finally determined position of the points at the 5-m and the 10-m levels (e.g. HSP, p5m-N11 and p10m-N) must lie on the same straight line. The 10-m point (p10m-N) will be marked again with a small aluminium tube and some stones.
- ◆ Person B tightens the 50-m measuring tape (held by person A to ensure that the tape is straight through the marked 5-m point), and calls the distance read from the measuring tape at the 10-m point (see Box 3.3).
- ◆ Person A enters the distance value into the protocol (**Form 1**).
- ◆ Person A (standing on the HSP) focuses the *compass* on person B (standing on the 10-m point) and reads the magnetic *compass direction*. If person B is not visible to person A, person B holds up a signal rod perpendicularly.
- ◆ Person A enters the (magnetic) *compass bearing* into the protocol sheet (compare Box 3.1). ▲

#### **WORK STEP C** Fixing the $3\text{m} \times 3\text{m}$ quadrat clusters

After the *principal measurement line* with the positions at the 5-m and at the 10-m levels is determined, the  $3\text{m} \times 3\text{m}$  quadrat cluster can be placed at the 5-m level (Fig. 3.2). This should be done by two persons. Particular care is required at this step to avoid trampling impacts in the plot area (see also Box 3.2).

#### **BOX 3.2 TRAMPLING IMPACTS BY THE INVESTIGATORS**

Trampling impacts during the setup and removal of plot grids as well as during the sampling should be minimised.

Strictly avoid stepping into the permanent  $1\text{-m}^2$  quadrats. Particular care must be taken, e.g. in some lichen- or bryophyte-dominated communities, snowbed and tall meadow vegetation or in unstable scree fields.

Sleeping pads, such as those commonly used by campers, may be useful during sampling, where terrain is appropriate.

- ◆ As shown in Fig. 3.1, the measured 5-m point is either the left lower (e.g. p5m-N11) or the right lower corner (e.g. p5m-N31) of the  $3\text{m} \times 3\text{m}$  grid. In the case of p5m-N11, the grid is placed on the right side of the *principal measurement line*, in the case of p5m-N31, on the left side (in view to the HSP). The decision depends on suitability of the local terrain and habitat situation. Both points (p5m-N11 and p5m-N31) have to be on the 5-m level such that the left and right boundaries of the quadrat cluster are more or less parallel to the slope.
- ◆ The corner points of each  $1\text{-m}^2$  quadrat of the grid should be fixed at the surface as far as possible (some corners may stay above the surface in a rugged terrain). This can be done with ordinary 100 mm nails put through the hole of the blanks (eyelets at the crossing points of the  $3\text{m} \times 3\text{m}$  grid) or through the outer tape material, and/or with stones or a thin wire.
- ◆ In addition, short aluminium tubes should be



positioned at the corners of the quadrats as permanent marks, where applicable. Only the upper 1-2cm of these tubes should protrude above the surface in order to avoid easy detection by hikers and mountaineers. Where aluminium markers cannot be mounted (e.g. in shallow soil or on solid rock), a small white or yellow point can be painted with durable paint. Permanent marking with durable material is essential in taller-growing vegetation such as in alpine meadows, or in páramo and puna vegetation, if solid rock is absent. ▲

#### WORK STEP D Measuring the distances and the magnetic compass directions from the HSP to the quadrat cluster corner points

After the  $3\text{m} \times 3\text{m}$  grid is fixed, person A, standing directly on the HSP, reads the compass directions for the four outer corner points of the  $3\text{m} \times 3\text{m}$  quadrat cluster, assisted by person B, who signals the position of each point and measures the distance to the HSP (see the measurement protocol sheet, *Form 1* and Box 3.1).

- ◆ Repeat the procedure for distance and compass measurements described in **WORK STEP B** for each corner point of each quadrat cluster in the remaining cardinal directions.
- ◆ After entering the four distances and the four compass readings (of the cluster corner points) into the protocol, the scribe (person A) should check the relevant box in the measurement protocol (*Form 1*) to indicate whether, e.g. point *p5m-N11* or point *p5m-N31* lies on the principal measurement line.

**Note:** always write the magnetic compass bearings (i.e. the degree as indicated on the compass). ▲

### 3.3.3 ESTABLISHING THE BOUNDARY LINES OF THE SUMMIT AREAS AND THE SUMMIT AREA SECTIONS

#### THE DESIGN

The **summit area** is divided into an upper and a lower part, each subdivided into four sections.

A string around the summit, connecting the eight corner points at the 5-m level, delimits the upper **summit area** (= **5-m summit area**). The corner points at the 5-m level will be connected around the summit in straight surface lines. Thus, the 5-m **summit area** reaches the 5-m level below the *highest summit point* only at the four clusters, and lies usually above the 5-m *contour line* between the clusters (compare Fig. 3.1 and Fig. 3.2). The “straight-line boundaries” facilitate a rapid setup, an accurate re-establishment at future resurveys, and helps to keep the area to a reasonable size, particularly

at elongated summits. An exact delimitation along the 5-m *contour line* is rejected because it would multiply the working time required for both setup and recording without enhancing the quality of the data substantially.

The corner points at the 10-m level, connected in the same manner, mark the lower limit of the lower **summit area** (= **10-m summit area**), which forms a zone around the 5-m **summit area**. The 10-m **summit area** does **not** include (or overlap with) the 5-m **summit area** (see Fig. 3.6, compare Fig. 3.1 and Fig. 3.2).

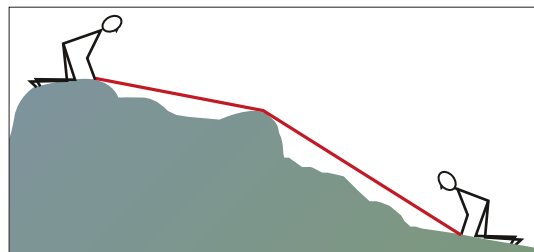
The distances between the corner points of the 5-m **summit area** (e.g. between *p5m-W31* and *p5m-S11*) and between the corner points of the 10-m **summit area** (e.g. between *p10m-W* and *p10m-S*) are **not** measured.

**Summit area sections:** Each of the two **summit areas** is to be subdivided into four **summit area sections** by straight lines running from the HSP to the **summit area** boundary lines, in the NE, SE, SW and NW directions (four *intersection lines*; see Fig. 3.6). The exact *geographic direction* is to be determined and the distance from the HSP to the points, where the two **summit area** boundary lines cross with the *intersection lines*, is to be measured.

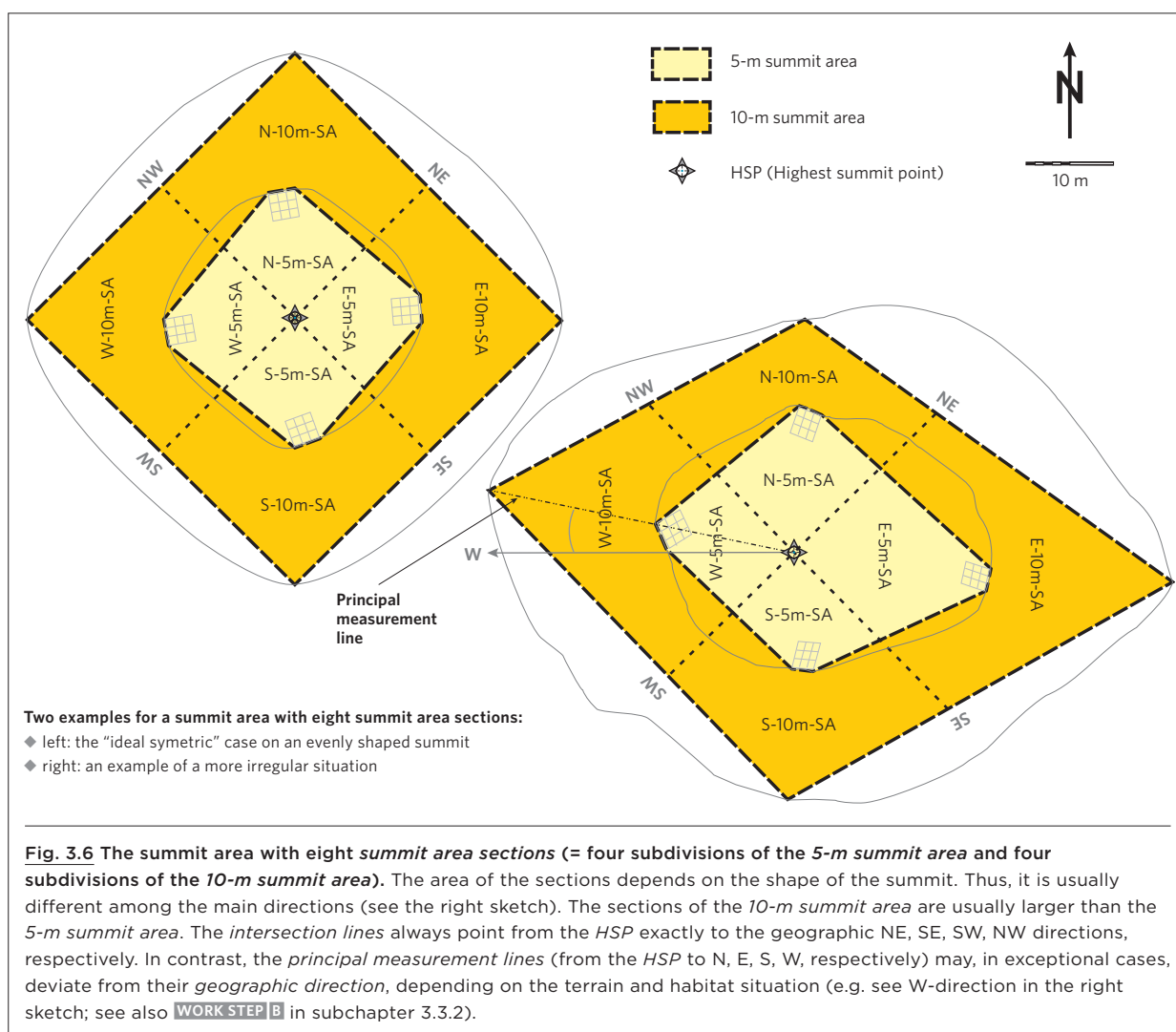
#### BOX 3.3 MEASUREMENT ACCURACY AND TOLERANCES

It is important to double-check all measurement entries on the measurement sheet (*Form 1*), because these data are essential for calculating the area sizes of the **summit area sections** and for re-positioning plots in cases where the *photo documentation* of plots and corner points are insufficient.

- ◆ Distances are to be measured in m to the nearest 1cm (e.g. 13.63 m). Although this is “over-accurate” on most surfaces and with long distances, there is no reason to round up to lower resolutions. Distances are always measured in the shortest straight line from the HSP to a corner point with the measurement tape tightened. However, all measurement distances are surface distances and not top view distances.



- ◆ Compass directions measured with the field compass from the HSP to each corner point are to be indicated with an accuracy of at least  $\pm 2^\circ$ .
- ◆ The **corner points** (at the cardinal directions) of the 5-m and the 10-m **summit area** are to be set up with a tolerance of  $\pm 0.5$  vertical metres.



#### BOX 3.4 MODIFICATION OF THE SAMPLING DESIGN FOR FLAT SUMMIT AREAS

Some mountain ranges may be dominated by *flat, plateau-shaped summits*, and “moderately” shaped summits may be difficult to find. The sampling area at *flat summits* would be much larger when setting the  $3\text{ m} \times 3\text{ m}$  grid at the 5-m level below the *highest summit point* and the lower corner points of the 10-m summit area at the 10-m level. This would significantly lengthen the measurement work for setting up the plots and for *summit area* sampling. Furthermore, these large summit areas would be not ideal for summit comparisons.

*Flat plateau summits*, therefore, should be avoided whenever possible. But in the absence of alternative sites, the following modifications to the general protocol must be applied:

If the 5-m level is not reached within 50-m surface distance from the *highest summit point (HSP)*, establish the “lower” side of the  $3\text{ m} \times 3\text{ m}$  grid at the 50-m surface distance point. Similarly, if the 10-m level is not reached within 100 m, put the 10-m point at the 100-m surface distance point measured from the HSP.

Please note that in these flat terrain situations, the distance measurement with the measuring tape must be done immediately after measuring the vertical distances and before fixing the  $3\text{ m} \times 3\text{ m}$  grid and the 10-m point.

Under changing flatness-conditions, the “50-m” and “100-m” rule is to be applied specifically for each of the two vertical levels:

For example, when the upper part of a summit is flat and, thus, the lower boundary of the  $3\text{ m} \times 3\text{ m}$  grid has to be established above the 5-m level at the 50-m surface distance from the HSP, the 10-m point, nevertheless, can be established at the actual 10-m level if the terrain steepens and, thus, the level is reached in a shorter than a 100-m surface distance from the HSP. This would mean, in this case, that the 10-m point lies more than 5 m in elevation below the  $3\text{ m} \times 3\text{ m}$  grid, but exactly 10 m below the HSP.

Make a note in the comment field of your measurement protocol (**Form 1**) if you did apply the “50-m” and/or the “100-m” rule due to flat terrain.

#### WORK STEP E Establishing the boundary line of the

##### 5-m summit area

This must be done by at least two persons, but three are often recommendable in a more rugged terrain.

- ◆ Person A fixes a string at one of the lower corner points of a  $3\text{ m} \times 3\text{ m}$  quadrat cluster (e.g. the lower left of the N-quadrat cluster: at point  $p5\text{m-N11}$ ).
- ◆ Person A then walks with the string to point  $p5\text{m-E31}$  of the E-quadrat cluster. When this point is reached, the string must be tightened and fixed, to connect the two points ( $p5\text{m-N11}$  and  $p5\text{m-E31}$ ) in the shortest straight line possible.
- ◆ Person B, and in a rugged topography a further assistant, help person A to keep the string in the shortest straight line.
- ◆ This procedure continues by fixing the string also at  $p5\text{m-E11}$  of the E-quadrat cluster and by heading further to the S-quadrat cluster and so forth, where the same work is repeated until the N-quadrat cluster is reached again at its lower right corner ( $p5\text{m-N31}$ ). ▲

#### WORK STEP F Establishing the boundary line of the

##### 10-m summit area

In the same manner, the four corner points at the 10-m level (from  $p10\text{m-N}$  to  $p10\text{m-E}$ ,  $p10\text{m-S}$ ,  $p10\text{m-W}$ , and back to  $p10\text{m-N}$ ) will be connected with straight strings. ▲

#### WORK STEP G Dividing the summit areas into sections by establishing intersection lines

- ◆ Person A takes position at the HSP and indicates the appropriate compass bearing for the intermediate directions, e.g. starting with the NE direction. The same correction for magnetic declination should be taken into account as used for setting up the summit area corner points (see Box 3.1).
- ◆ After attaching one end of a roll of string to the HSP, Person B follows the exact geographic NE direction indicated by person A. At the point where the tightened string crosses the boundaries of the upper summit area, a marker is placed (in the NE direction, this is point  $p\text{NE-5}$ ); where it crosses the lower summit area boundary another marker is placed (this is point  $p\text{NE-10}$ ). Small aluminium tubes or stones may be used as markers. The procedure is repeated for the remaining three directions. This results in a N, E, S, & W section of the 5-m summit area as well as of the 10-m summit area, respectively (see Fig. 3.6).
- ◆ Finally, person A rechecks the compass readings from the HSP to the marked points (where person B stands as compass bearing target) and writes them into the protocol sheet (Form 1). Person B, supported by person

A, measures the surface distance between the HSP and the two marked crossing points along each of the four intersection lines (e.g. the distance from the HSP to  $p\text{NE-5}$  and the distance from HSP to  $p\text{NE-10}$ ) and person A enters them into the protocol sheet.

On completing this step, the summit areas and quadrats are ready for recording.

- ◆ Before starting the recording, check that all entries have been completed on the measurement protocol (Form 1). The “checkboxes” on Form 1 for photo documentation of the  $1\text{-m}^2$  quadrats and the corner points (see WORK STEPS O to R and T in chapter 4.4) are usually filled out later on by the person responsible for the photo documentation. For measurement tolerances, see Box 3.3; for the reasoning behind these measurements, see Box 4.5.

If all measurements were made correctly, the size of the summit area sections is calculated automatically later on, when you enter your data by using the GLORIA data input tool (chapter 6.2). Sketches of the actual summit design will be produced by the GLORIA coordination once data are uploaded to the central GLORIA database. Therefore, it is crucial that the measurement protocol (Form 1) is completed in the field, without any missing measurements – please double-check. ▲



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## 4 STANDARD RECORDING METHODS (STAM)

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The recording methods described in this chapter form the *Multi-Summit Approach*'s basic set of field sampling procedures, to be performed in each GLORIA *target region*. Data yielded by these required procedures build the fundamental globally comparative dataset on vascular plant patterns and soil temperature. These standard components of the *Multi-Summit Approach*, therefore, should be applied by all teams in all *target regions*.

The recording methods for the different plot types are described in detail along **WORK STEPS H-V**, continuing the **WORK STEPS** of the plot setup in the previous chapter.

**Forms 2, 3 and 4** are used as sampling sheets for the *standard recording methods* (see Annex II, downloadable from the GLORIA website under 'Methods').

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### CONTENT OVERVIEW WITH THE STANDARD **WORK STEPS H-V**

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## 4.1 RECORDING IN THE 1-m<sup>2</sup> QUADRATS

Each 3m × 3m *quadrat cluster* consists of nine 1-m<sup>2</sup> *quadrats*, as set out by the grid of *flexible measuring tapes*. The vegetation is recorded in the four corner *quadrats* only (see Fig. 4.1), as the others may become damaged through trampling by the investigators during recording. This yields vegetation data for 16 *quadrats* of 1-m<sup>2</sup> per summit, defined as the **16-quadrat area**.

In each of the 16 1-m<sup>2</sup> *quadrats*, the *top cover of surface types* (*vascular plant cover*, *solid rock*, *scree*, etc.) and cover of each vascular plant species are recorded. The aim is to provide a baseline for detecting changes in species composition and in vegetation cover.

Two methods of cover recording have to be applied for the required GLORIA standard (STAM):

- ◆ Visual cover estimation (to be done first) and
- ◆ *Pointing with a grid frame* (after completion of the visual cover estimation).

For considerations and reasoning for using these methods see Box 4.1. For resurveys, do not use the species list of former surveys (see Box 4.5).

**Note:** In the period 2001 to 2010, *subplot-frequency counts* in 1-m<sup>2</sup> *quadrats* were also part of the standard protocol. Frequency counting, however, is now considered as a *supplementary recording method* that may be applied as an extension to the basic standard methods (see chapter 5.1.2), but see Box 4.1, bottom, for further considerations.

### 4.1.1 VISUAL COVER ESTIMATION IN 1-m<sup>2</sup> QUADRATS

Both *percentage cover of surface types* and *percentage cover of each vascular plant species* are to be recorded by means of visual cover estimation. This is an effective method for recording all species occurring within the plot, including those with cover values of less than one percent. For general considerations on cover recording in 1-m<sup>2</sup> *quadrats* see Box 4.1.

#### BOX 4.1 CONSIDERATIONS FOR VEGETATION RECORDING IN THE 1-m<sup>2</sup> QUADRATS

##### ◆ **Top cover of surface types**

The *surface types* defined under **WORK STEP H** characterise the habitat situation of the plot, based on easily distinguishable surface patterns.

##### ◆ **Species cover sampling**

A key advantage of cover as a measure of vegetation or of a species occurrence is that it does not require the identification of the individual (as density does), yet it is an easily visualized and intuitive measure and, compared to density and frequency, it is the most directly related to biomass (Elzinga et al. 1998). The main general disadvantage of cover measures is that cover might fluctuate over the course of a growing season. This, however, is of inferior relevance in most types of high mountain vegetation which are predominantly composed of long-lived and slow-growing species. Recording during the peak growing season (at least outside of humid tropical regions) will potentially capture the large majority of species and cover of most species is not expected to markedly change until the end of the season.

##### ◆ **Visual species cover estimation**

The visual estimation is the most

effective method for detecting all vascular plant species. Particularly in low-stature high mountain vegetation it is easily applicable and works fairly rapid.

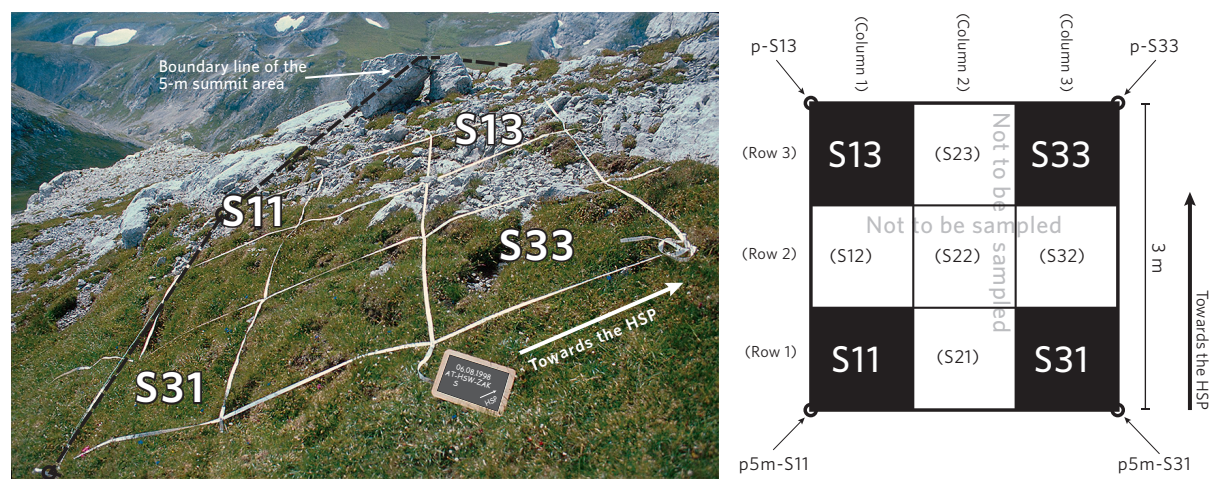
In GLORIA permanent *quadrats*, *species cover* should be estimated as precisely as possible on the percentage scale. Cover categories or cover-abundance scales used for vegetation relevés (e.g. Braun-Blanquet 1964) are not suitable because they are too coarse for this purpose. For example, low cover values of species (< 1%), which are often put into one class, still show large differences, in alpine environments in particular. Even adult or flowering individuals of a species can cover less than 0.01% of a *quadrat* (i.e. < 1 cm<sup>2</sup>), whereas other species with the same number of individuals may cover an area which is 100 times or more larger. See also Box 5.2 for further considerations on categorical versus continuous cover estimation.

The visual estimation of species *percentage cover* involves a degree of inaccuracy and may be criticised as being too subjective for long-term *monitoring* where fieldworkers change over time. At GLORIA *quadrats*, however, the scale on the

measuring tapes delimiting the plot and the unvarying size of 1m<sup>2</sup>, increase the precision of the *percentage cover* estimation. A particular area covered by a species can easily be transformed into *percentage cover* values (e.g. an area of 10 × 10 cm equals 1%, 1 × 1 cm equals 0.01%). Transparent templates, showing the area of 1%, 0.5% 0.1% etc., facilitate the estimation process and should be used particularly when starting to take records of a new vegetation type (see Figs. A1.3a/b in Annex I). *Species cover* estimation for broad-leaved species and cushions works well, especially in open vegetation, while the estimation of graminaceous species and of species in multi-layered and dense vegetation requires experience. Working in observer pairs is recommended, as it was found that this reduces the proportion of overlooked species (Vittoz & Guisan 2007).

The reproducibility of a method among different observers is of importance for detecting changes in species composition and cover. Previous studies showed that changes smaller than about 20% are usually attributable to variation

[...] See next page



**Fig. 4.1 The 3m x 3m quadrat cluster.** Left, example from the NE-Alps (2250m), *quadrat cluster* in the S-direction; right, scheme of the *quadrat cluster* with the quadrat codes and numbers of the *measurement points* (corner points). The quadrat codes consist of three digits: The first digit is a letter which denotes the main *compass direction* of the whole *quadrat cluster*, the second digit is a number referring to the column of the cluster numbered from left to right (left and right always defined in the sight to the summit), the third digit is a number referring to the row of the cluster numbered from bottom to top (in the sight to the summit). For example, S31 is the *quadrat* in the southern *quadrat cluster* positioned in the third column (i.e. the right side) and in the first row (i.e. the lower side; see also [Box 6.1](#) for coding).

#### BOX 4.1 [...] Continued from page 38

between observers (Sykes et al. 1983, Kennedy & Addison 1987, Nagy et al. 2002). Therefore only changes larger than that may be attributed to causal factors. For comparisons of *monitoring* data and the estimation of the power of statistical change detection (Legg & Nagy 2006), however, it is crucial to know if we have to deal with a systematic or with a random observer error. Systematic errors arise when a particular person is notoriously over- or under-estimating the cover of species, i.e. an error that is invariant within an observer, but varies between observers, as opposed to random errors one and the same observer makes from one estimate to the next. Recent field trials with 14 persons independently recording the same GLORIA test plots of 1 m<sup>2</sup> in different types of alpine vegetation showed that random errors contribute by far more to the overall observer variance (~ 95%) than systematic errors (~ 5%), (Gottfried et al. 2012, Futschik et al. in prep.). This suggests that different plots can be considered as being sampled independently, irrespective of the observer. Consequently, the continuity of the observing persons across two or

more *monitoring cycles* is of inferior importance. Furthermore, the power for the detection of changes depends much on the number of samples.

◆ **Cover recording with point-framing (pointing with a grid frame)**  
Point-framing (Levy & Madden 1933) is considered to be an objective method for measuring species cover (Everson et al. 1990). A key disadvantage of point-framing, however, is that points rarely intersect the less common species (compare Sorrells & Glenn 1991, Meese & Tomich 1992, Brakenhielm & Liu 1995, Vanha-Majamaa et al. 2000). This is intuitively obvious: a species with 1% cover would likely only be intercepted once or twice (or not at all) in a sample of 100 points. A comparison of point-framing and visual cover estimation in open low-stature subnival vegetation (vegetation *top cover* of ~ 50% or less) showed that, at species cover values above 0.7%, the two methods did not show significantly different results (Friedmann et al. 2011). Consensus among the two methods, however, may deviate in more complex vegetation. Yet, point-framing missed 40% of the species found by visual

cover recording (Friedmann et al. 2011). Point-framing, nevertheless, is considered to yield reliable reference cover values for the more common species and is a rapid method when just using 100 points.

The combined application of visual species cover estimation and cover recording through *point-framing* allows for validation and assessment of observer variation of visually estimated values of the dominant and the more common species.

#### ◆ **Subplot-frequency counts**

This method is now shifted to chapter 5, dealing with supplementary recording methods (see chapter 5.1.2), because sampling can be very time-consuming in species rich and/or multi-layered vegetation. At sites, however, where baseline data of *subplot-frequency counts* are available, it is advisable to retain this monitoring component at future resurveys. Admittedly, this causes considerable additional work load. When time of your field campaign is limited, you might decide to postpone *subplot-frequency counts* to the next resurvey cycle, i.e. to repeat this more laborious method at longer time intervals.

Use sampling sheet **Form 2** for visual cover estimation in the  $1\text{-m}^2$  quadrats (make sure to fill in all fields in the form's header).

#### WORK STEP H Recording of habitat characteristics

In each quadrat, the *top cover* of each *surface type* is visually estimated. *Top cover* is the area coverage as seen from a top view (or rather perpendicular to the slope angle) of each *surface type* and adds up to 100%, whilst cover, or *species cover* (see below) takes overlaps between layers into account. In closed vegetation the latter is usually > 100% (cf. Greig-Smith 1983).

##### ◆ Surface types and the estimation of their top cover (%):

- ❖ **Vascular plants:** Top cover of vascular plant vegetation
- ❖ **Solid rock:** Rock outcrops – rock which is fixed in the ground and does not move even slightly (e.g. when pushing with the boot); large boulders which do not move should be considered as *solid rock* and not as *scree* (if you are in doubt whether a boulder is *scree* or *solid rock*, add it to *solid rock*)
- ❖ **Scree:** Debris material – this includes unstable or stable scree fields, as well as single stones of various size, lying on the surface or are ± fixed in the soil substrate; the grain size is bigger than the sand fraction (as opposed to *bare ground*)
- ❖ **Lichens on soil:** Lichens growing on soil which are not covered by vascular plants
- ❖ **Bryophytes on soil:** Bryophytes growing on soil which are not covered by vascular plants
- ❖ **Bare ground:** Open soil (organic or mineral), i.e. earthy or sandy surface which is not covered by plants
- ❖ **Litter:** Dead plant material

Each of these types represents a fraction of the  $1\text{m}^2$ -area; this means that the sum of the *top cover* values of all present *surface types* adds up to 100%.

##### ◆ Subtypes for top cover estimation:

- ❖ **Lichens below vascular plants:** Lichens growing below the vascular plant layer
- ❖ **Bryophytes below vascular plants:** Bryophytes growing below the vascular plant layer
- ❖ **Lichens on solid rock:** Epilithic lichens on rock outcrops
- ❖ **Bryophytes on solid rock:** Bryophytes growing in micro-fissures on rock where soil material is not visible (as opposed to *bryophytes on soil*)
- ❖ **Lichens on scree:** Epilithic lichens growing on scree or on single stones
- ❖ **Bryophytes on scree:** Bryophytes growing in micro-fissures on scree or stones where soil is not visible

Each of these subtypes represent a fraction of one of the following *surface types*: *vascular plants*, *solid rock*, or *scree*.

The subtype cover is to be estimated as a percentage of the respective *surface type* cover. For example, in a quadrat where 40% is covered by *solid rock* and half of the rock is covered by lichens, enter the value 50% for the subtype “lichens on solid rock” into the sampling form (and not 20%, which would be the percentage referring to the whole quadrat).

- ◆ The average aspect of the quadrat (in the categories N, NE, E, SE, S, SW, W, or NW) is recorded by using a compass. For the average slope (in degrees,  $360^\circ$  scale) use a clinometer. ▲

#### BOX 4.2 THE REQUIRED LEVEL OF TAXONOMIC IDENTIFICATION AND HERBARIUM MATERIAL

**Vascular plants** should be identified in the field as accurately as possible and at least to the species level (or in taxonomically complex cases to the species aggregate level); if applicable and possible, plants should be identified down to the subspecies or variety level. Be aware that some species may only occur vegetatively, without showing any generative parts. Such cases also must be identified.

Given the long-term perspective of alpine plant monitoring (*surveillance*) with 5 to 10 year intervals of resurvey, it is mandatory to make herbarium vouchers for each of your species found within the four *summit sites* of your *target region*. In any cases of doubtful identification, a herbarium documentation is crucial. Herbarium material, archived as a GLORIA collection at the respective institution, would facilitate the work of future field teams and reduces possible observer errors caused by misidentification. Use standard herbarium labelling with accurate geographic indications.

**Note:** Please strictly avoid collecting plant specimens from inside the  $1\text{-m}^2$  quadrats or even from inside the  $3\text{m} \times 3\text{m}$  quadrat clusters.

**Cryptogam species.** The identification of bryophytes and lichens would be desirable to the species level. However, as identification of some cryptogams may not be possible in the field, and the estimation of individual *species cover* values is very time-consuming, the sampling of bryophytes and lichens is **not obligatory** for the standard dataset of the *Multi-Summit Approach*.

In some mountain regions, where cryptogam species contribute substantially to the phytomass, their recording on a species level is recommended if experts are available. In the case that somebody decides to record cryptogam species, he/she should be aware of a significant extension of the fieldwork period and of the risk of additional trampling impacts caused by the investigators.



#### WORK STEP I Recording of the species composition and cover

- ◆ The cover value of each vascular plant species is visually determined. The recording of bryophytes and lichens on the species level is optional. Cover values are estimated by using a percentage scale relative to the total *quadrat* area of 1m<sup>2</sup>. The *percentage cover* should be estimated as precisely as possible for *monitoring* purposes, particularly for the less abundant species. To calibrate yourself, use transparent templates that show different area sizes (see Figs. AI.3a/b in Annex I).

**Note:** The total cover sum of all vascular plant species may exceed but should not fall below the *top cover* estimated for *vascular plants* in **WORK STEP II** due to overlapping vegetation layers.

See [Box 4.1](#) for general considerations on this method. For considerations concerning the determination of vascular plants with regard to the taxonomic level and concerning cryptogam species see [Box 4.2](#). ▲

#### 4.1.2 POINTING WITH A GRID FRAME IN 1-m<sup>2</sup> QUADRATS

In each of the 16 1-m<sup>2</sup> *quadrats*, a point intercept method (point-framing) is applied, using a *grid frame* of 1m×1m inner width and 100 *crosshair points* distributed regularly over the plot. The aim is to provide a baseline for detecting changes in the cover of the more common species. See also [Box 4.1](#) for general considerations on cover recording.

The sampling sheet is combined with that for visual cover estimation so that there is no need to list the species names again (see [Form 2](#)).

**Note:** Point-framing must be done after the visual cover estimation to avoid any bias when estimating the *percentage cover*.

For the construction of the *grid frame* see [Fig. 4.2](#) (note that the arrangement of strings deviates from the design used for *frequency counts*, the latter now being considered as an optional supplementary method described under 5.1.2).

#### WORK STEP J Pointing of surface types and vascular plant species

Use a wooden (or aluminium) *grid frame* of 1m×1m inner width and 10 strings tightened in each direction. The resulting 100 *crosshair points* (see [Fig. 4.2](#); for construction see [Fig. AI.2](#) in Annex I) will be used for the point-framing.

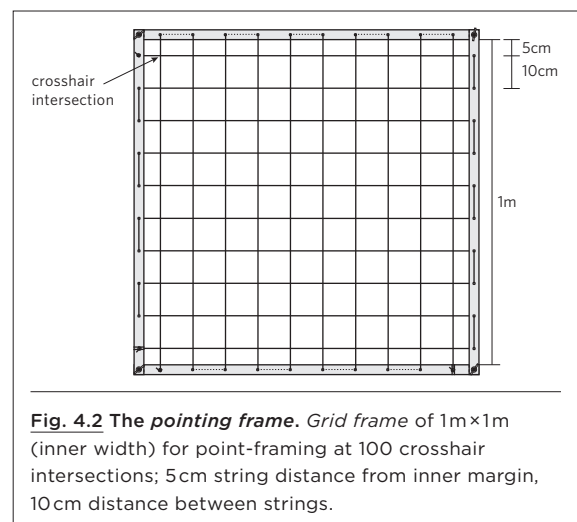
- ◆ Mount the frame on the plot so that the inner edges optimally lie above the measuring tapes that delimit the plot.
- ◆ Use a *sampling pin* of 2mm diameter (e.g. a thin knitting needle) for the point-framing.

- ◆ Lower the pin perpendicularly to the slope (i.e. perpendicularly to the plane of the *grid frame*) at each *crosshair point*.

- ◆ Hits are tallied (noted with a stroke) when the pin has contact with a plant or with the ground:

- ❖ Where vascular plants are absent, make a stroke for the *surface type* that you hit below the *crosshair point* (these are already listed on your recording sheet: *solid rock*, *scree*, *lichens on soil*, *bryophytes on soil*, *bare ground*, *litter*).
- ❖ When you hit a vascular plant species, make a stroke in the respective line on your sampling sheet.
- ❖ Continue to lower down the pin and make a stroke for any other vascular plant species that are hit below the uppermost one. At any point, where you have hit a vascular plant, do not make a stroke for the *surface type* which is below vascular plants.

The recording of any vascular plant that is hit by the pin (including those growing in the lower layers), enables to calculate the *percentage species cover* that can be compared with the *species cover* determined through visual estimation. Total *top cover* of vascular plant vegetation can be calculated as 100 minus the sum of hits of *surface types*. ▲



**Fig. 4.2 The pointing frame.** Grid frame of 1m×1m (inner width) for point-framing at 100 crosshair intersections; 5 cm string distance from inner margin, 10 cm distance between strings.

#### 4.2 RECORDING IN THE SUMMIT AREA SECTIONS

The four sections of the 5-m *summit area* together with the four sections of the 10-m *summit area* form a set of eight sampling areas covering the total *summit area* (compare [Fig. 3.6](#)). The required standard method to be applied in each of the eight *summit area sections* (SASs) includes:

- ◆ A **complete species list** plus the estimation of the **abundance of each species** along an ordinal scale in five *abundance categories* (see below under **WORK STEP K**).
- ◆ The visual estimation of **percentage top cover of surface types**.

Any more detailed recordings in the *summit area sections*, such as of species cover (see chapter 5.2.2 and **Box 5.2**) pointing in *10m×10m squares* (see chapter 5.3) are considered as optional and may be applied supplementary.

#### BOX 4.3 CONSIDERATIONS FOR RECORDING IN SUMMIT AREA SECTIONS

*Top cover* values of *surface types*, species lists and species abundance data obtained from the *summit area* are used to compare the altitudinal differences of habitats and vegetation cover across the different *target regions*. The subdivisions into sections allow for analyses of exposure effects on species and vegetation patterns. The most important purpose, however, is to provide a baseline to monitor changes in species richness in order to assess the disappearance and invasion of species. Thus, it is **crucial to detect all species**.

A precise recording of species abundance or of *species cover* can potentially be very time consuming because, depending on the topography of the summit terrain, SASs can strongly vary in size. Therefore, the **obligatory basic standard method only requires a rough estimation of the abundance of each vascular plant species along the verbally defined five abundance categories** described in **WORK STEP K**. This was decided after a thorough discussion at the GLORIA conference in Perth/Scotland in September 2010. This rapid method of abundance estimation is therefore considered as the current global standard – it is by far more rapid and less trampling-intensive than visual *percentage cover* estimations of species in the SASs. See, however, **Box 5.2** (chapter 5.2.2) for considerations on *abundance categories* versus continuous cover values and rationale on advantages of the latter.

Optionally, supplementary recording methods may be applied in the SASs, where personnel capacities are available and vegetation patterns are suitable. These may include:

- ◆ A visual estimation of *percentage species cover* (such as made in the *1-m<sup>2</sup> quadrats*).
- ◆ A combined cover sampling method using a *point-line intercept method* for the more common species and the estimation of *area cover* (i.e. the actual area a species covers) for the rarer species; *PAF* method (Halloy et al. 2011) as it is widely applied at GLORIA sites in South America (see chapter 5.2.2 and **Box 5.2**).
- ◆ A pointing method in *10m×10m squares* as first applied at GLORIA sites in California, which includes parts of each upper and lower SAS in each *cardinal direction* (see chapter 5.3).

The main focus lies on data of the **species pool of a summit site** and in **detecting changes in species richness**.

Cover records on *top cover surface types* characterise the habitat situation and the vegetation coverage within the *summit area*. Complete species lists of vascular plants (bryophytes and lichens are optional) are crucial for assessing species invasions into and disappearances from the *summit area*.

For general considerations concerning species recording in the *summit area sections* see **Box 4.3**. For resurveys, do not use the species list of former surveys (see **Box 4.5**).

Use sampling sheet **Form 3** for recording in the *summit area sections* (make sure to fill in all fields in the form's header).

#### WORK STEP K Complete species list with an estimated abundance of each species in ordinal abundance categories

- ◆ Make a careful observation in each entire *summit area section* in order to record all occurring vascular plant species. It is important to capture each species in order to provide a baseline to detect changes of species richness, i.e. disappearance and immigration of species.
- ◆ Once you have completed the species list, make a rough estimation of the abundance of each vascular plant species.

The five **abundance categories** are defined as:

- ❖ **r! (very rare)**: One or a few small individuals;
- ❖ **r (rare)**: Some individuals at several locations that can hardly be overlooked in a careful observation;
- ❖ **s (scattered)**: Widespread within the section, species can hardly be overlooked, but the presence is not obvious at first glance; individuals are not necessarily evenly dispersed over the entire *summit area section*;
- ❖ **c (common)**: Occurring frequently and widespread within the section – presence is obvious at first glance, it covers, however, less than 50% of the SAS's area;
- ❖ **d (dominant)**: Very abundant, making up a high proportion of the phytomass, often forming more or less patchy or dense vegetation layers; species covers more than 50% of the area of the SAS (this is the only *abundance category* which is entirely related to cover).

**Note:** The species lists of the upper *summit area sections* (SASs) must also contain all species found in the *quadrats* that lie within this section. Therefore, crosscheck your sampling sheets of the *quadrats* and the respective SAS for possibly overlooked species. Do this already in the field, so that you are able to enter up proper abundance values for such cases. ▲

#### WORK STEP L Percentage top cover estimation of surface types (all surface types together should sum up to 100%):

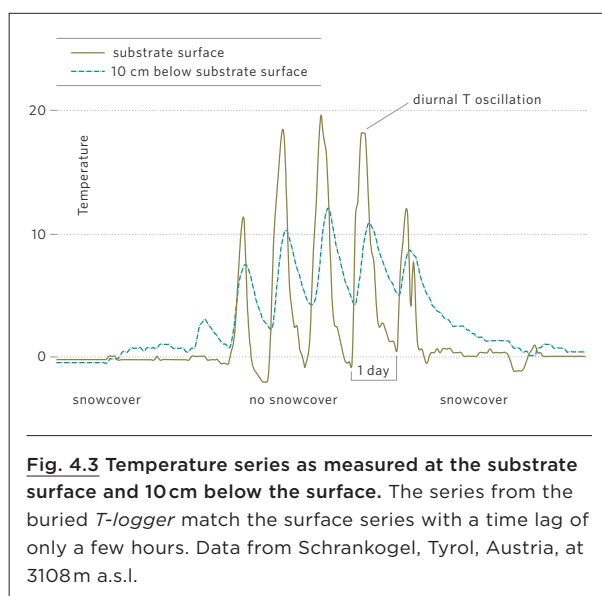
- ◆ Vascular plants
- ◆ Solid rock
- ◆ Scree
- ◆ Lichens (excluding epilithic lichens)
- ◆ Bryophytes
- ◆ Bare ground
- ◆ Litter

These surface types are the same as used in the 1-m<sup>2</sup> quadrats (for definitions see **WORK STEP H** in subchapter 4.1.1). In the SASS, we suggest to do the top cover estimation of surface types after having completed the species list and species abundance recording. ▲

## 4.3 CONTINUOUS TEMPERATURE MEASUREMENTS

### 4.3.1 TEMPERATURE DATA LOGGERS

Among the main climatic features shaping an ecosystem, high mountain biota are particularly controlled by temperature and the duration of snow cover. Parameters related to their regimes are relatively easy to measure (directly for temperature, indirectly for snow) by using miniature *temperature data loggers* (*T-loggers*) buried in the substrate. Whether a distinct location is covered by snow or not can be inferred from the shape of the diurnal temperature oscillation (Gottfried et al. 1999, 2002), even when measured at 10cm substrate depth (Fig. 4.3). In contrast to air temperature, measuring temperature at 10cm soil depth is a feasible and invisible way of obtaining



continuous climate data which is directly relevant for alpine plant life. Soil temperature still is buffered but still influenced by solar radiation and conduction through the soil, which of course varies with soil texture and moisture. Soil temperature therefore and because of its dependency of micro-topography, which also determines snow patterns, must be interpreted with care as it does not directly follow linear adiabatic lapse rates of air temperatures (Wundram et al. 2010).

In the GLORIA programme such data will be used **(a) to compare summits along the altitudinal gradient within and between target regions according to their temperature and snow regimes** and **(b) to detect mid- to long-term climate changes**.

### 4.3.2 DEVICES CURRENTLY IN USE



Currently two instrument types are used by the majority of GLORIA groups, **GeoPrecision MLog5W** ([www.geoprecision.com](http://www.geoprecision.com)) and **Onset TidBit v2** ([www.onsetcomp.com](http://www.onsetcomp.com)).

The first have the benefit of wireless data access, so after installation measuring is possible for years without disturbance of the covering soil column. These loggers offer a user replaceable battery good for at least five years of hourly measurement, so on the long run this is a very cost effective device (a guideline for the battery change can be downloaded from the method section on the GLORIA website, [www.gloria.ac.at](http://www.gloria.ac.at)). As the frequency of 433 MHz is not free everywhere (e.g. not in the USA), the Onset TidBit v2 logger is an alternative. This logger is connected via USB to a computer, thus needs to be excavated for data access. Onset TidBit v2 loggers have a producer-stated lifetime of five years, but experience showed that many devices died after 2 ½ years in the cold environment of GLORIA summits. So the safe measuring period for these loggers in the field is two years. See Table 4.1 for specifications. Onset loggers with similar specifications as the TidBit v2 loggers, but with replaceable batteries, might be available in the meantime.

### 4.3.3 PREPARATION OF TEMPERATURE LOGGERS

Logger preparations must be made before you start the fieldwork. You need the installation programme of the logger device on your computer and access to the internet. Guidelines can be downloaded from the methods section on the GLORIA website ([www.gloria.ac.at](http://www.gloria.ac.at)). For the **GeoPrecision Mlog-5W** you can also find the software



Table 4.1 Comparison of technical specifications of GeoPrecision MLog-5W and Onset TidBit v2 (given by the producer)		
	GeoPrecision Mlog-5W	Onset TidBit v2
<b>Temperature Sensor</b> ♦ Range ♦ Accuracy ♦ Resolution	-40°C to +85°C ± 0.1°C at 0°C 0.01°C	-20° to +70°C 0.2°C above 0° to 50°C 0.02°C
<b>Memory</b>	2048kB non volatile. Up to 500.000 temperature measurements	64kB non volatile. Approx. 42.000 12-bit temperature measurements
<b>Data Access</b>	Wireless access – no hardware connection to the computer required at 433MHz for Europe (including Russia), Andean countries, Africa and China. For other countries check local regulations	Hardware connection to the computer via optic couple and USB required
<b>Battery</b>	2400mAh Lithium, user replaceable, good for 5-8 years	3 Volt lithium, non-replaceable, producer stated lifetime of 5 years, but usually less in GLORIA environments
<b>Shape</b>	dimensions: 14 cm×2 cm 	diameter: 3 cm 

**GP5W-Shell** for launching, handling and data read out. Preferably, however, check the Geoprecision website for the most recent version.

*Temperature loggers* must be programmed/launched for the correct logging interval (sampling rate) and date/time. The GLORIA standard is 24 measurements per day, i.e. a logging interval of **one hour at each full hour**.

GLORIA-wide, loggers are set to measure in UTC (Coordinated Universal Time). For analysis purposes, this can later be easily transformed to ‘true solar time’ by your *target region’s* longitude for calculating temperature indices such as daytime and nighttime temperatures.

Use **Form 4** for the documentation of logger settings. It serves for both the first logger installation (upper table) and for data readout, battery or logger change (lower table).

#### WORK STEP M Logger settings and preparations before fieldwork

- ♦ Set the clock of your computer to **UTC** (Universal Coordinated Time) that is GMT (Greenwich Mean Time) without daylight saving time, so that all GLORIA sites use the same time zone. Do this as exactly as possible, accurate to a second, by using a reliable reference (e.g., <http://www.worldtimeserver.com/>). Make sure that your

PCs’ clock will not re-adjust the time automatically, as some network computers do.

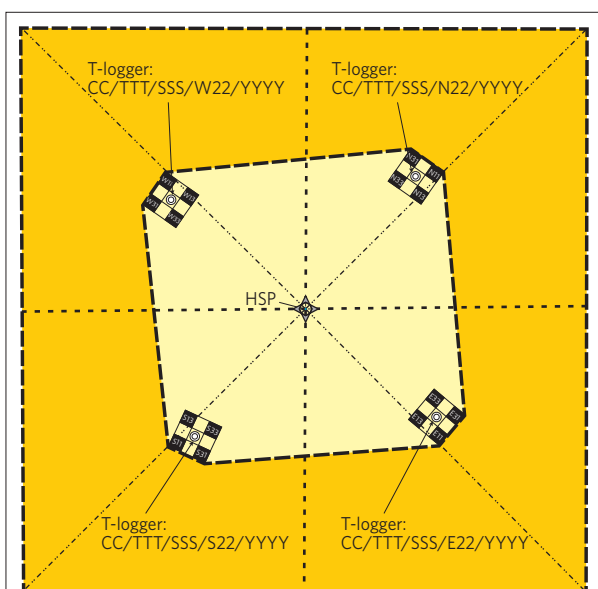
- ♦ Launch the appropriate software for the device used and synchronise the logger’s clock with your computer.
- ♦ Set the logging interval to one hour, measured at the full hour: see [www.gloria.ac.at](http://www.gloria.ac.at) under ‘Methods’, ‘Download forms’, ‘Guidelines for installing and changing loggers’ for specific instructions for different logger types (helpfiles for either device). ▲

#### 4.3.4 POSITIONING OF TEMPERATURE DATA LOGGERS ON GLORIA SUMMITS

Four *T-loggers* are positioned on each summit, one in each *3m×3m quadrat cluster* (see Fig. 4.4). This design should provide information on the climatic situation and on snow pack duration in the four *cardinal directions*.

The *T-loggers* should be installed in the substrate (with the logger sensor at 10 cm soil depth; see Fig. 4.5) for two reasons:

- ♦ They are shaded from direct solar insolation and therefore microsite-specific deviations are buffered.
- ♦ They are hidden from mountaineers or any visitors who might remove the instrument.



**Fig. 4.4 T-logger positioning.** In each cardinal direction of a summit site, one T-logger is positioned within the central quadrat of the 3m x 3m quadrat cluster (see **WORK STEP N** for alternative logger positioning, if necessary). See **Box 6.1** for the full-length-logger codes.

#### **WORK STEP N** Positioning and photo documentation of the data loggers

- Within each 3m x 3m quadrat cluster, look for a suitable logger position within the central quadrat (e.g. N22) where a logger can be buried 10 cm below the substrate surface. This position should represent an

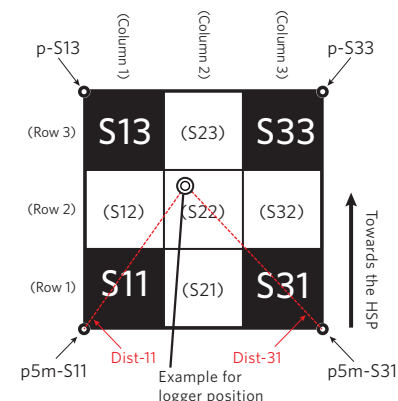
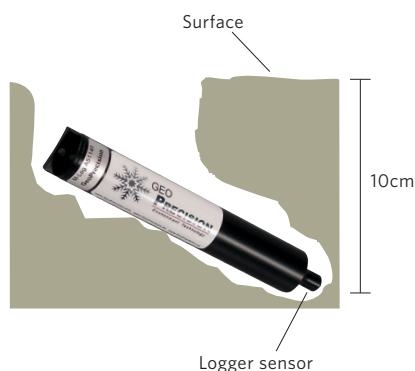
average surface and habitat situation of the 3m x 3m area. Therefore, avoid deviating locations, such as, e.g. directly aside a protruding rock or a boulder. Where the logger cannot be positioned in the central quadrat, choose a proper position in another quadrat (e.g. in the quadrats N12, N21, N23, or N32, for quadrat numbers compare Fig. 4.1) but never put a logger inside the four corner quadrats where you do the species recordings.

» Generally, the logger position should represent the average microclimate situation of the 3m x 3m quadrat cluster.

- Dig a small, 10-cm-deep hole and take care not to destroy the surrounding substrate texture.
- Write the logger position and installation year onto the logger body: the scheme CC-TTT-SSS-QQQ-YYYY (i.e., CC, country; TTT, target region; SSS, summit; QQQ, quadrat; YYYY, year). Use a waterproof marker for writing on the logger.
- Enter the quadrat code, logger serial number, and logger type into the protocol (**Form 4**).
- When using Onset Tidbit loggers, fix a short string of approx. 10 cm length onto the T-logger – this will help to find the device again in the future. This may also be useful for Geoprecision loggers.
- Put the logger into the hole. Make sure that the logger's sensor (see Fig. 4.5, lower left) lies approximately 10 cm below the surface level.
- Measure the distance (in metres with two decimal places) from the centre of the logger's hole to the lower

**Fig. 4.5 Installation of a temperature logger.**

Upper left, the logger may be positioned horizontally or obliquely (as shown in the example), but the sensor always must be at 10 cm below surface and the uppermost parts should be covered by several centimetres of substrate material. Lower left, logger position uncovered, lower right, logger covered with soil material (gardening trowel points to the position of the sensor). Upper right: Example of a logger position in the center quadrat of a 3m x 3m grid with measurement lines to the lower corner points of the 3m x 3m quadrat cluster.



corner points of the  $3\text{m} \times 3\text{m}$  quadrat cluster (e.g. p5m-S11 and p5m-S31; see Fig. 4.5, lower right) and enter the data, i.e. the distance values 'Dist-11' and 'Dist-31', into the protocol (*Form 4*).

- ◆ Take a photo of the open hole. Insert a blackboard with date (YYYY-MM-DD), code (CC-TTT-SSS-QQQ-LOG) and an arrow pointing to the HSP or to any cardinal direction. Check the photo checkbox on the field form (*Form 4*). See Fig. 4.5 and also chapter 4.4 for general remarks on photo documentation.

- ◆ Carefully refill the hole. Make sure that the short string tied to the logger (as used in the case of Onset Tidbit loggers) does not extend to the surface, where it could be detected by animals or mountaineers. It should aid to find the logger again after digging 2-3 cm into the substrate.

- ◆ Take two or more photos of the closed situation (one including the plot boundary, and one more detailed close-up); always place a marker (such as a pencil or a trowel) in the picture that points to the exact logger position. Photos will be crucial for the precise detection and repositioning of loggers when retrieving data or changing the battery. Check the photo checkbox on *Form 4*.

- ◆ Write the installation date and time (in local time) into the protocol and note the difference to UTC (*Form 4*). The difference to UTC at the moment of installing and deinstalling the loggers has to be given to extract the meaningful part of the resulting temperature time series. ▲

## 4.4 THE PHOTO DOCUMENTATION

The photo documentation is **crucial for the accurate reassignment of the plots and for documenting the whole visual situation of the quadrat** (see also Box 4.4). For the photo documentation it is vital to stick exactly to the GLORIA coding scheme (see Box 6.1). Position a blackboard near any item to be photographed, which contains the following information: date (YYYY-MM-DD), code CC-TTT-SSS-itemcode (i.e., CC, country; TTT, target region; SSS, summit), and an arrow pointing towards the HSP or to any cardinal direction. Once photos are taken, check the boxes in *Form 1* to make sure that all of the following items are depicted.

### WORK STEP O Photo documentation of the highest summit point (HSP)

Although this point will be marked permanently, this principal measurement point must be carefully documented with photos (detail photos, see Fig. 3.3, as well as photos showing its position from the distance; see WORK STEP P for coding; item code = HSP). ▲

### WORK STEP P Photo documentation of the $1\text{-m}^2$ quadrats

Photographs must be taken of all 16 quadrats from a top view position (approximately at a right angle perpendicular to the slope angle, as far as this is possible in irregular topography). High-resolution digital cameras can now be considered as standard. Check your camera for its focal length so that you can depict an area of  $1\text{ m}^2$  from a top-view position even in irregular terrain (see also Box 4.4). It is **highly recommendable** to take the **photos in diffuse light under clouded sky** because direct sun light causes extreme contrasts, which is unfavourable for depicting surface structure and texture.

One high-quality top-view photo of each  $1\text{-m}^2$  quadrat is required. Plot delimitations (*flexible measuring tapes*) must be completely visible on the photo on all four sides. The *pointing frame* should not be mounted when taking the photo (see Fig. 4.6). The photo will be crucial for a rapid and precise reinstallation of the plot delimitations for future monitoring investigations.

The following information has to be included in the photograph (best on a small blackboard positioned near the left or the right side of the quadrat; do not position the blackboard within the plot area): all obligatory code elements (see Box 6.1 and Annex III), i.e.: date, country code, target region code, summit code, item code (e.g. the plot code N31, S11, etc.), and an arrow pointing towards the north direction or towards the HSP. White boards are not recommended because writing may not be visible on the photo.

Optionally, detailed photos (e.g. each quarter of a quadrat) may be taken additionally for a photo-monitoring of easily visible species such as cushion plants. ▲

### WORK STEP Q Photo documentation of the $3\text{m} \times 3\text{m}$ quadrat clusters

Overview photos should be taken of each  $3\text{m} \times 3\text{m}$  quadrat cluster from various sides (see the example in Fig. 4.1). Do not forget a blackboard with the codes (coding as in WORK STEP P; item codes = N, E, S, or W, respectively) and an arrow towards the north direction or towards the HSP. ▲



Fig. 4.6 Top-view plot photo ( $1\text{-m}^2$  quadrat) taken under clouded sky.



#### WORK STEP R Photo documentation of the corner points of the summit area sections

The following items have to be documented:

- ◆ The *highest summit point (HSP)* made in **WORK STEP O**.
- ◆ The four 10-m points: coding as in **WORK STEP P**; item codes = *p10m-N*, *p10m-E*, *p10m-S*, and *p10m-W*, respectively.
- ◆ The eight *summit area points* in the intermediate directions: coding as in **WORK STEP P**; item codes = *pNE-5*, *pNE-10*, *pSE-5*, *pSE-10*, *pSW-5*, *pSW-10*, *pNW-5*, and *pNW-10*, respectively.

The corner points should be marked with a signal stick or rod (1 to 1.5m length) to make them visible on the photo: the small aluminium tubes and/or stones used as permanent markers may be insufficient for this purpose (see Fig. 4.7). A detailed photo as well as an overview photo should be taken of each point, always with the blackboard included with the relevant code, date and an arrow pointing towards the north direction. ▲



**Fig. 4.7** A corner point of a *summit area section*. The 10m-point (*p10m-W*) on Pico del Tosal Cartujo (Sierra Nevada/Spain, 3150m a.s.l.) is marked with a signal rod for *photo documentation*.

#### WORK STEP S Photo documentation of the entire summit

Take a photo of the summit (e.g. from a neighbouring hump in the ridge or from an opposite place at the other side of a valley if distances are not too large) to show the geomorphologic shape and the general situation (see examples in Fig. 2.2). Use a blackboard including the codes if possible (use *SU-OV* as item code; see Annex III for codes). Do not forget the arrow towards the north or any other cardinal direction. ▲

#### OPTIONAL WORK STEP T Other detail photos

If you think that it might be important to do more detailed *photo documentation*, e.g. of the position of *intersection lines* and other lines, such photos are highly appreciable. For coding of these details use the next-lying obligatory item (compare **WORK STEPS O - R**). If this item is not seen on the photo view, add an arrow on the blackboard pointing from the written code in the direction of the item to which the code belongs. Also do not forget the north or HSP arrow. ▲

#### BOX 4.4 PHOTO DOCUMENTATION - GENERAL CONSIDERATIONS

Photographs or paper copies of the photos have proven to be the most important reference for a fast and accurate reassignment of plots.

- ◆ Photos allow the plots to be re-established without repeating the time-consuming measurements.
- ◆ Moreover, photos are much more than instruments to relocate the plots. They document the entire visual situation of the permanent plots in ways that are of great comparative value, e.g. for tracing of local distribution patterns of particular species over many years or decades.
- ◆ For both the above reasons, all photos must be retaken at each *monitoring cycle*.
- ◆ The *photo documentation* should be done carefully and, whenever possible, under clouded sky to avoid hard contrasts.
- ◆ Use the camera's high-resolution adjustment.
- ◆ Ensure that each photograph is labelled with its full-length photo code (see Box 6.1) written on a blackboard which has to be included in the picture wherever applicable, but put the board outside of the 1-m<sup>2</sup> plot.
- ◆ Mark the »photo checkboxes« in the *Forms 1* and *4* to control whether all obligatory photos were taken.
- ◆ Store your photos using consistent labels. See chapter 6.3 and Annex III and use the provided software (GPDM, GLORIA Photo Data Management) for standardised names of your JPEG photo files.

#### FOCAL LENGTH OF LENS

For depicting the full 1-m<sup>2</sup> *quadrats* a wide-angle lens is required. Please check **before fieldwork** if your camera is suitable for depicting an area of 1 m<sup>2</sup> from a top-view position in different terrain conditions – also check if this fits to the body size of the person in charge of the *photo documentation*. Photos of the corner points and loggers may be taken with a standard or any appropriate focal length.

## BOX 4.5 CONSIDERATIONS FOR FUTURE REASSIGNMENTS AND RESURVEYS

### PHOTOS AND MEASUREMENT DATA FOR THE REASSIGNMENT OF PLOTS

The fast and accurate reassignment (re-establishing) of the plots for *monitoring* investigations will usually be accomplished only by using printed photographs of the *quadrats* and the corner points of the *summit area sections*. Thus, there is usually no need to repeat the time-consuming measuring work, described in chapter 3.3, at the beginning of the resurvey.

Measurements of plot positions made during the first site setup are nevertheless essential for the following purposes:

- ◆ The determination of exact *geographic directions* and the *5-m* and *10-m* levels.
- ◆ For the re-establishment of plots in cases where this is not possible only by photographs. This may be the case, e.g., in uniform and closed grassland or in vegetation dominated by taller growing forbs. Unexpectedly rapid vegetation changes, e.g., through shrub encroachment, may be a further reason to repeat the measurements of plot corner points.
- ◆ Re-establishing after severe disturbance events. This can lead to the loss of the previous habitat or to a pronounced relocation of the vegetation patch. In such cases, re-measurements may be necessary as well as a careful documentation of the disturbance. Plots exposed to more continuous slow-pace disturbance, such as through solifluction that may not strongly and rapidly distort the habitat and vegetation patterns, usually should be detectable and reassignable just with the photo.
- ◆ A detailed outline of the actual summit area and plot positions can be produced from the measurement data. Printouts of outline sketches can aid to find the corner points of the *summit area sections*, but also can help to evaluate your previous measurements. For example, implausible shapes of *summit area sections* should be checked again (re-measured) in the field.

- ◆ Finally, measurements enable the calculation of the area size of each *summit area section* for subsequent data analysis.

### RESURVEY INTERVALS AND TIMING

*Monitoring cycles* are performed at intervals of five to ten years. Globally fixed or concerted intervals might be desirable but are difficult to arrange due to logistic and financial constraints. Starting dates of baseline investigations vary and the expansion of the GLORIA network through new *target regions* is still ongoing at a rather steady, unabated pace. Therefore and because of regional and northern/southern hemisphere differences, and of tropical peculiarities, a worldwide coordination of *monitoring cycles* seems to be impracticable. Funding uncertainties and time constraints are a further reason for varying resurvey intervals. For example, the first broad-scale re-recording campaign on the European level was conducted in 2008, seven years after the baseline investigation and the second is planned for 2015. Yet, a number of sites in North America and in Australasia were resurveyed after five years. Shorter intervals of *monitoring cycles*, such as every year, might be of interest for determining inter-annual variability which, however, is expected to be rather low due to the long-lived nature of the large majority of alpine plant species. Besides the considerable extra effort and expense, short intervals can also cause interfering disturbance due to increased trampling by the investigators.

More important than internationally concerted *monitoring cycles* is a good timing of the resurvey campaign within the growing season. Resurveys should be conducted at the same date or period as the baseline investigation, which, in seasonal climates, should be around the mid-growing season. Particularly deviating late or early onsets of the growing season, however, should be taken into consideration when you plan your resurvey campaign. Generally, it is advisable to start not too early in the season, when generative or even vegetative

parts of species may not yet be well developed.

### RESURVEY PROCEDURE

At resurveys, the fieldwork procedure is principally the same as at the baseline investigation. The only difference is that you usually do not need to re-measure distances and *compass angles* from the *HSP* to the plot corner points. Print all your photos of the *quadrats* and corner points for the exact re-establishments of plots, but also your measurement protocol for the case that positions cannot be properly identified with the photo (e.g. in taller-growing dense vegetation). Photos, nevertheless, are essential for precisely re-establishing the *1-m<sup>2</sup> quadrats* and the delimitations of the *summit area sections*.

All standard recording procedures in the *1-m<sup>2</sup> quadrats* and in the *summit area sections* must be repeated 'blind', i.e. without any aid of old data in order to keep an unbiased comparability of, e.g. species occurrences, cover values or turnovers. Neither the previous plot data such as species lists or cover values, nor photos of the *quadrats* are used during resurveys. Apart from this, however, the resurvey team, particularly if consisting of new members, should be familiar with all species occurring in the region, and therefore, the overall species list of your *summit sites* and previous herbarium materials could be of much help. Previous species lists of *quadrats* and *SASs* only can be used after having completed recording, e.g. to aid the identification of doubtful species.

In summary, use the same materials, equipment and blank sampling forms for your resurvey campaign. For re-establishing the plots, bring printouts of all photos and the measurement data of plot positions including outline sketches of the *summit sites*.

For reading out temperature data and for servicing your data loggers, bring the logger installation data (all data you entered in *Form 4*) and, if you have to dig out loggers for readout, battery change or replacement, the photos of the logger installation, some spare loggers and service equipment are needed.

## 4.5 REMOVAL OF PLOT DELIMITATIONS AND CONSIDERATIONS FOR FUTURE REASSIGNMENTS AND RESURVEYS

Given the multi-year intervals between resurveys and the long-term dimension of GLORIA summit observations, any non-durable parts of plot delimitations are to be removed before you leave the *summit site*. Only small aluminium tubes (or other appropriate markings) at the plot corners and the buried *temperature data loggers* remain at the site.

Box 4.5 gives a brief view on what will be needed for future repetitions of your summit work.

### WORK STEP U Removal of plot delimitations

Before you remove any delimitation, check **Forms 1 and 4** to ensure that all plots/items have been documented with photographs and check if recording is completed in all plots. The *3m×3m grids* and all strings delimiting the *summit area sections* have to be removed after all recording and the *photo documentation* is finalised. ▲

## 4.6 GENERAL INFORMATION ON THE TARGET REGION

This chapter focuses on information concerning the entire *target region*, i.e. the area within which all four *summit sites* are situated. The overall altitudinal zonation of vegetation belts, bedrock material, and the land use history should be described. We suggest to fill in the respective sampling

form when you are still in the field, as far as possible, but it might be completed later on, e.g. if additional information on land use history is required.

See the sampling sheet **Form 0**.

### WORK STEP V Provide information about the

#### target region

◆ Estimates of the altitudinal position in metres above sea level of:

❖ the *forest line* (i.e. the line where closed forests end, as seen from the distance); enter both the potential natural and the current *forest line*.

❖ the *treeline* (i.e. the line where closed groups of trees taller than 3m end); enter both the potential natural and the current *treeline*.

❖ the *alpine-nival ecotone* (i.e. the transition between the upper *alpine* and the *nival zone*) in your *target region*.

❖ Where required, make comments on these major ecotonal zones, e.g. deviations from the average altitude and make a note if a boundary line does not exist in the *target region* and on any reason for its absence.

◆ Describe the bedrock material of the *summit sites* of the *target region*, which should be consistent throughout the four summits, i.e. consistent regarding the influence of the bedrock on the species composition. In addition, make a rough estimate on the average soil pH (e.g. acidic: <4.5, intermediate: 4.5-6.5, neutral/alkaline: >6.5).

### BOX 4.6 HUMAN LAND USE AND GRAZING IMPACTS

As mentioned in subchapter 2.2.2, human trampling, grazing by livestock or other anthropogenic influences may mask possible climate-related changes. Thus, sites being strongly affected by human land use should be avoided, e.g. if grazing-indicator species are common or dominant, tracks and droppings of livestock are obvious. In many mountain regions, however, it is difficult to find grazing-free, 'pristine' summit habitats. Therefore, it is important to take land use impacts and particularly any pronounced changes in land use practices under consideration when analysing climate-induced vegetation changes. A difficulty in recording land use features is that these may be very region-specific and changes in land use practices may not be easy to

detect. Information on such land use changes, however, appears to be more relevant than an indication of the current land use intensity. Moderate traditional grazing over centuries is expected to produce less background noise than pronounced changes, e.g. within the past 50 or 100 years. A high grazing intensity, further, may be assessed by particular species that indicate *grazing impacts*.

Systematic field recording of anthropogenic factors that may impact alpine vegetation and species composition is not a core focus of the standard protocol.

For *summit area sections* (**Form 3**), however, comments on livestock grazing impacts such as occurrence of dropping, traces of trampling, and of browsing damage are requested.

The supplementary *sub-plot frequency counts* in *1-m<sup>2</sup> quadrats* include recording of these grazing effects in 100 subplots (**Form 5-S**, chapter 5.1.2).

Comments on the land use history in relation to the current situation are requested on **Form 0** for the general region description. Comments should be based on regional historical records or reliable local informants and should consider, depending on the region, a range of possible factors such as pastoralism, burning practices, hunting, agriculture, tourism, mining, or any other relevant more specific influence. Attempts on a systematic recording and assessment of land use factors, along with socio-economic aspects in GLORIA regions are outlined in chapter 7.6.



- ◆ Provide a short description of the *target region*, particularly regarding the land use history and the current land use situation. Indicate if the situation is pristine or in a near natural state. If this is not the case, indicate what kind of human land use has or had an impact on the present vegetation. Wherever possible, comment on the extent of land use impacts and provide information on the long-term and recent land use history. Of particular interest are more recent changes (e.g. within the past 50 years) in the grazing/land use regime that may still continue to have an effect on current vegetation changes (see also Box 4.6).
  - ◆ Enter the vegetation zone or *ecotone* in which the summit is located: only the following entries are possible: *treeline ecotone*, lower alpine, lower/upper alpine ecotone, upper alpine, *alpine-nival ecotone*, nival; see Box 2.1 and Nagy and Grabherr (2009) for definitions.
  - ◆ Make comments on the situation of the particular summit if the above zonation scheme is not properly applicable and describe the deviations. Further, comment on any other pronounced deviation from an 'ideal' standard summit situation (compare chapter 2.2 on *summit selection* and Box 2.1 on definitions of vegetation zones). ▲
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## 5 SUPPLEMENTARY SAMPLING DESIGNS AND RECORDING METHODS (SUPM)

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Several supplementary methods were applied in a subset of GLORIA *summit sites* and are considered as an extension of the standard *Multi-Summit Approach*. All these supplementary methods described here are directly related to the standard GLORIA sampling design. They follow various focuses, such as additional recording methods (*subplot-frequency counts* in  $1\text{-m}^2$  quadrats, species cover recording in SAs, pointing in  $10\text{m} \times 10\text{m}$  squares), an extended number of  $1\text{-m}^2$  quadrats per *summit site* in order to enhance the power of statistical change detection, and/or the inclusion of organism groups like bryophytes and lichens. Some of these further recording procedures were previously regarded as GLORIA standard methods and were recently shifted to the optional level.

Whenever you plan to apply supplementary methods on your *monitoring* summit, consider that this may be a source of additional disturbance through enhanced trampling impacts. This particularly applies for sites with steeper terrain and/or unstable scree habitats or for disturbance-sensitive vegetation such a plant communities dominated by cryptogam species. Further, consider the additional time effort that should not go on the expense of a careful completion of the standard approach.

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## 5.1 SUPPLEMENTARY RECORDING IN 1-m<sup>2</sup> QUADRATS

### 5.1.1 RECORDING OF BRYOPHYTES AND LICHENS IN 1-m<sup>2</sup> QUADRATS

Bryophytes and lichens are each considered as entire organism group in the *top cover* sampling of the obligatory standard recording procedure (chapter 4). Recording of cryptogams (bryophytes and lichens) on a species level, however, is only treated as an optional supplementary activity, because of the following considerations: Recording of cryptogams on the species level often is hampered by the very low number of experts; bryologists and lichenologists who may be able to identify the bulk of species already in the field may not be available. Additionally, the smaller size of individuals and, therefore, their often large numbers, require considerable extra time or a larger team. The resulting increase of the trampling impact has to be taken into account.

The decision of doing lichen and bryophyte species recordings in the 1-m<sup>2</sup> quadrats, further, depends on their regional importance in terms of species numbers, biomass and vegetation cover.

**Note:** For cryptogam species, the same field sheets can be used as for vascular plants (*Form 2* for recording in 1-m<sup>2</sup> quadrats) for visual cover estimation and pointing.

### 5.1.2 SUBPLOT-FREQUENCY COUNTS IN THE 1-m<sup>2</sup> QUADRATS

Subplot-frequency counts, previously a standard method of the *Multi-Summit Approach*, is now only considered as an optional supplementary. The main reason for this is the extensive time and labour required for this method and the associated trampling impact. In a global context, where many sites lie in remote areas, the time-consuming method hardly can be considered as a feasible component of the basic approach.

Frequency counts of vascular plant species (and of obvious *grazing impacts*) are made in all 16 1-m<sup>2</sup> quadrats. The aim is to **detect changes of vegetation patterns on a fine-scaled level** (compare Box 5.1).

As a general rule, frequency counting should not be made in those particular quadrats where the *grid frame* cannot be properly mounted, to avoid inexact results. This can be the case on summits within the *treeline ecotone*, where small trees or shrubs may occur within the quadrats or in any tall-growing vegetation.

## BOX 5.1 FREQUENCY COUNTS - GENERAL CONSIDERATIONS

Records on the presence of species obtained by the 100-cells *grid frame* are used to monitor changes in vegetation patterns on a fine-scaled level. An accurate relocation of the *grid frame* at each successive recording is a precondition for reliable *monitoring* records. Therefore, when you apply subplot frequency recording take an additional photo of the 1-m<sup>2</sup> quadrat with the *grid frame* mounted.

Subplot *frequency counts* are sensitive for clustered species distribution patterns (e.g. for cushion plants and compact tussocks) and less so for scattered or highly dispersed occurrences. Time-consuming counts of species with large numbers of small-sized and dispersed individuals (as this is typical for many bryophyte but also for a number of vascular plant species) usually result in high frequency values, even if their species cover is low. See Friedmann et al. (2011) for a comparison of subplot *frequency counts* with visual cover estimation.

In addition, features indicating the presence of grazing mammals are recorded. Three grazing-related features are distinguished:

- ◆ faeces/droppings,
- ◆ browsing damage (clipped shoots, leaves and/or inflorescences), and
- ◆ trampling (e.g. hoof marks, foot prints, broken lichens, and/or scuffed tussocks).

For the sampling sheet see *Form 5-S* in Annex II.

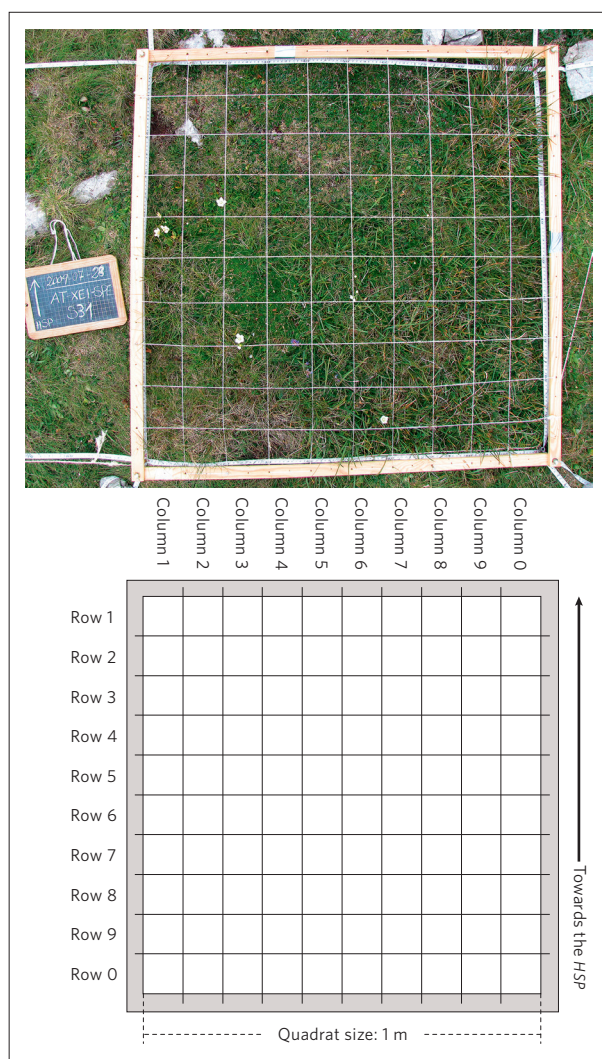
### RECORDING PROCEDURE

- ◆ A wooden (or aluminium) *grid frame* with 100 cells of 0.1m × 0.1m, delimited by thin white strings (see Fig. 5.1 and Fig. A1.2 in Annex I for construction details; note that covering differs from the *pointing frame*) will be used for the *frequency counts*.

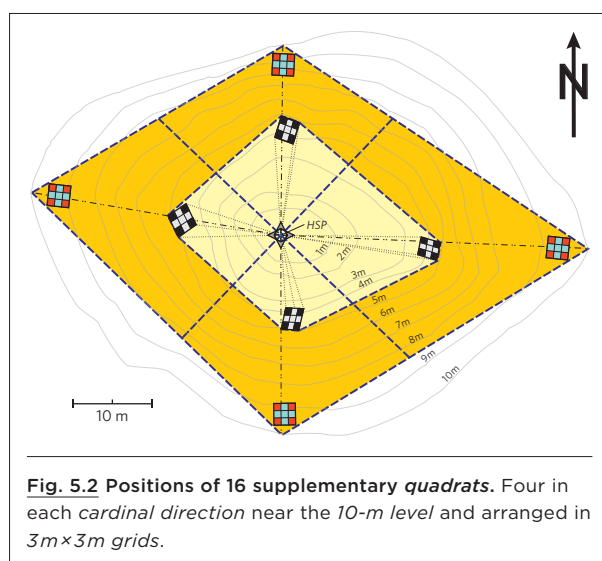
- ◆ In each cell, presence of vascular plant species and of grazing features will be recorded. All species seen inside a grid cell must be recorded as present for that particular cell. Thus, a species is considered as present when plant parts can be seen within the boundary strings of the 0.1m × 0.1m grid cell, regardless of where it is rooted.

**Note:** Recording must always be done perpendicular to the slope angle (i.e. perpendicular to the grid frame plane). Particular care should be taken on uneven relief, where the grid frame cannot be positioned flat on the surface.

- ◆ Take a photo of the plot with the grid frame mounted so that it can be properly reinstalled at resurveys. ▲



**Fig. 5.1** Grid frame for species frequency counts. Upper, grid frame mounted on a plot; lower, scheme of the 1m×1m grid frame, subdivided into 0.1m×0.1m cells for recording species presence and grazing-related features in each cell. Please note that the frequency grid frame is different from that used for point-framing (compare Fig. 4.2).



**Fig. 5.2** Positions of 16 supplementary quadrats. Four in each cardinal direction near the 10-m level and arranged in 3m×3m grids.

### 5.1.3 SUPPLEMENTARY 1-m<sup>2</sup> QUADRATS AT THE 10-m LEVEL

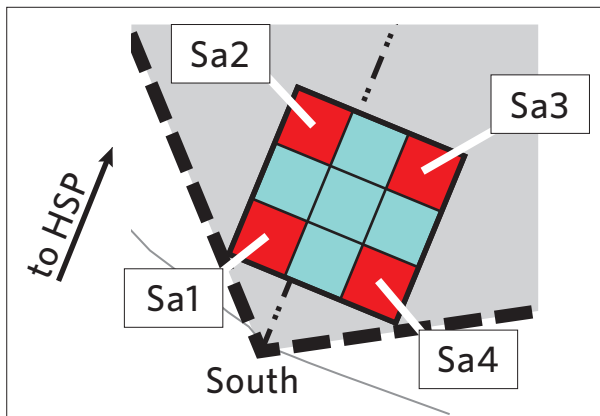
JEAN-PAUL THEURILLAT<sup>1,2</sup> & PASCAL VITTOZ<sup>3</sup>

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A larger number of 1-m<sup>2</sup> quadrats on each GLORIA summit would be desirable in order to enhance the statistical power for the detection of small changes. This is especially of interest for assessing slight shifts of species cover on a local to regional level or when focusing on changes of individual species. The consequences of the increased effort (more time or more observers are required), however, must be carefully considered in alpine environments, where the peak growing season usually is short and often interrupted by adverse weather conditions. Doubling the number of plots would not only mean twice as much time for species recording, but also for the plot setup and *photo documentation*. A team of four persons, therefore, may not be able to complete these supplementary quadrats within one growing season. Establishing additional plots should certainly not go on the expense of the required standard procedures. Supplementary quadrats, thus, should only be established after all standard procedures in the obligatory 16 quadrats and in the eight summit area sections were carefully completed. More 1-m<sup>2</sup> quadrats, further, would mean more disturbance caused by the investigators.

#### SAMPLING DESIGN AND RECORDING PROCEDURE FOR SUPPLEMENTARY PLOTS

- ◆ **Positioning:** Supplementary plots are also arranged in a 3m×3m grid, where the four corner quadrats should be used as permanent plots. In each cardinal direction, one supplementary 3m×3m grid should be placed at the 10-m level below the HSP and should be aligned parallel to the slope. The lower line of the 3m×3m grid lies somewhat above the respective p10m-point (i.e. the 10-m points of each cardinal direction) so that the lower corner points of the 3m×3m grid touch the lower boundary lines of the 10-m summit area section (see Fig. 5.2). The sharper the angle of the lower SAS boundary lines, the greater is the distance of the 3m×3m grid from the 10-m point.
- ◆ **Coding:** The supplementary quadrats must have a 3-character alphanumeric code. This is necessary to enable administrative compatibility with the coding for standard plots in the central GLORIA database. The coding scheme: e.g. Na1, Na2,...Wa4; **N, E, S, or W** stands for the respective cardinal direction, **a** is the indication as a supplementary



**Fig. 5.3 Coding of supplementary quadrats at the 10-m level** (here, codes of the southern 3m x 3m grid are shown).

plot, **1, 2, 3, or 4** the plot number in clockwise order, starting with the lower left quadrat (see Fig. 5.3).

◆ **Recording:** For species recording in supplementary quadrats the same methods and procedures are to be applied as in the obligatory standard quadrats (see chapter 4.1). ▲

## 5.2 SUPPLEMENTARY RECORDING IN SUMMIT AREA SECTIONS

### 5.2.1 RECORDING OF BRYOPHYTES AND LICHENS IN SUMMIT AREA SECTIONS

See the considerations under 5.1.1.

**Note:** For cryptogam species recording in *summit area sections* the same field sheet (*Form 3*) as for vascular plants can be used. Also estimate the abundance of cryptogam species along the *abundance categories* described in chapter 4.2.

### 5.2.2 RECORDING OF SPECIES COVER IN SUMMIT AREA SECTIONS WITH POINT AND FLEXIBLE AREA (PAF) SAMPLING METHOD

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MERCEDES IBÁÑEZ<sup>1</sup> & KARINA YAGER<sup>3</sup>

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The obligatory standard recording procedure in *summit area sections* (SAS) involves a complete species list (all

vascular plant species) and an estimation of species' abundances by using five verbally defined classes as well as a *percentage cover* estimates of the main *surface types* (compare chapter 4.2). This can be done in reasonable time and, thus, most effort can concentrate on capturing all species that occur within one SAS.

More precise data on the area coverage of each species, however, would be preferable in principle if sufficient time and/or observers are available. Data on *species cover* would allow for more advanced statistical analyses, such as obtaining species-area curves, deriving rank-abundance curves and their respective analyses, as well as the calculation of indices such as the Shannon-Weaver diversity index, equitability, distance to a lognormal fit ( $\Delta L$ ), etc. (see Magurran 1988, Halloy & Barratt 2007); see also the considerations in Box 5.2.

A difficulty in cover estimation in *summit area sections*, however, is that these recording areas may greatly vary in size (a few 100 m<sup>2</sup> to several 1000 m<sup>2</sup>), shape and topography. This complicates a straight-forward and time-saving recording of species cover, particularly in complex mosaics of patchy vegetation and where species richness is high.

There are several approaches on how to determine species cover and the suitability of one or another method depends on the abundance of a species, their growth form and distribution pattern. Therefore, a combined approach using classical *point-line intercepts* (Scott 1965, Dickinson et al. 1992) as well as a flexible area is suggested here (e.g. Halloy et al. 2011).

#### METHODS AND RECORDING PROCEDURE

##### ◆ *Point-line intercepts*

The *point-line intercept method* is used here to measure the cover of the more common species and of the main *surface types*. A 50-m sampling line is established within the *summit area section*, randomly positioned across the centre of the section, e.g. using a 50-m measuring tape. Every 50 cm along the line, a pointing stick (e.g. a stick or a knitting needle of 2 mm diameter) is brought down vertically until it touches the first object, may it be a plant or soil or rock. In shrubby vegetation, this point may be above the string. The idea is to consider the first point that a drop of rain falling vertically would hit. This is the point that a satellite would 'see', and therefore the point that will be integrated (into the average of much larger pixels) in the spectral signature of the satellite image (such as measured with NDVI ratios). The combination of all points (*percentage cover*) represents the 'image' of the vegetation as seen from above. For each point of contact, a stroke (or bar) is marked on the field data sheets (e.g. species A: II, species B: I, scree: IIII, solid rock: II, bare ground: I, etc.). In the end we should have 100 strokes on our sampling sheet



for the 100 sampled points. The proportion of each item in those 100 points represents its abundance or *percentage cover* (e.g. species A: 2%, species B: 1%, scree: 4%, etc.).

In large SASs and/or in those with discontinuous vegetation, the length of the line can vary or additional lines may be placed, but consider this when calculating the *percentage cover* from the number of hits (e.g. when

you have 300 points and species A was touched 21 times, its resulting cover would then be 7%). In smaller sections, it is quite appropriate to do several shorter segments, e.g. 12 m, 16 m, 15 m, 7 m, as long as the minimum 100 points are achieved.

Measuring cover by *point-line intercepts* is simple and may take less than a half hour per SAS or less than one

## BOX 5.2 CONTINUOUS, CATEGORICAL, AND THE MEASURE OF RARE SPECIES

As there is considerable debate and misunderstanding in regards to field methods of quantifying vegetation, it is important to clarify a few points – particularly in regards to time and search effort versus precision of results. There is no way around the fact that whatever way you write down the numbers, you will first have to observe the vegetation. Once you have observed, the rest happens in your mind. Most methods are simply mental crutches to help make sense of what you have observed. One could of course in theory measure every single plant and calculate abundance and cover. As this is impractical, both in terms of field time and effort, as well as in environmental damage (trampling), all other methods incorporate visual best estimates. We have a choice of a quick estimate of the most abundant species, or delving deeper and trying to find all species. Because GLORIA is about understanding changes, we accept the additional time and effort to attempt to find all species (e.g. see above and [Box 4.1](#) for  $1\text{-m}^2$  quadrats). Since we assume the necessary time to find all species we then have some choices of how we mind-process the data without losing additional field-time.

### Continuous versus categorical

Estimates of *species cover* can be reported as continuous numbers (e.g. measures of area or percentage of area, 1, 4, 6, 25, 50 etc.), or as categories (e.g. ordinal, as in [WORK STEP K](#), chapter 4.2; or a, b, c, where a=cover of 1–7, b=8 to 15, etc.). Supporters of categorical reporting argue for (1) saving time, and (2) estimates are imprecise at best, so why give a false impression of precision by giving a number?

Reporting continuous numbers, as long as it is explicitly recognized that

there should be no false impression of precision, does not require more time, as the processing is done in the mind with exactly the same information as for categories. And despite imprecisions, it is more likely to approximate reality. For example, suppose plant x has an actual cover of 49%. And you have pre-established categories  $d \geq 50\%$ , with mid-point at 60% and  $c < 50\%$  with mid-point at 30%. As you process in your mind, you may correctly categorize as c, or you may err by 1% and categorize as d. If you later try to transform these categories to percentages, your error with respect to reality would be at least 9 and up to 21%. If you attempt recording as continuous percentage, you might have erred by 2 or 3% either way and still be a lot more precise than using categories.

**Point-line intercepts** (such as *line-pointing* or *pointing with a grid frame* in  $1\text{-m}^2$  quadrats) take away some of this uncertainty by providing more objective estimates of cover, although still limited by the amount of sampling.

### Rare species estimates

The PAF (*Point and Flexible Area sampling*) method allows for estimation of the remaining rare species not touched in a line intercept. It is important not to spend inordinate amounts of time in estimating these areas, but rather to utilize the same concepts as mentioned above: We assume that you have explored the area enough to be satisfied that you have recorded all species (or as close to that as you can get in the given time), as this is a requirement of the method. Since you have this list, now you have to recall what exactly you saw and imagine how big or small an area they cover. This does not mean going back and measuring every plant. As for the

abundant species cover, you will have in your mind a visual record of the plants you saw. As a mental crutch, imagine cutting all those plants and putting them in a square. How much would that square cover? Help yourself with your hands, imagining from here to here, and that means approximately  $20 \times 20$  cm, or  $60 \times 60$  cm, or the size of your clipboard, etc.

In our field training, the main hurdle is the observer's shyness to express a number, a fear of making a mistake, of imprecision. It requires a bit of training, like the boldness to start speaking a new language even when you know the words but are afraid to stumble. We have the visual capacity to estimate areas, all we need is to report those as approximate numbers. This requires recognition that there will be a degree of error, of imprecision. But whatever imprecision there is, it will be considerably less than the imprecision of lumping all rare species into a  $<1\%$  category. For example, in a  $200\text{m}^2$  area, we may have 10 or more species covering less than 1%. We lose considerable amount of information by lumping all of those as  $<1\%$ , when in fact they may differ in abundance by several orders of magnitude. Species x might be  $1\text{cm}^2$  (0.00005%), species y may be  $10 \times 10\text{cm}$  ( $100\text{cm}^2$ , 0.005%), while z is  $100 \times 100\text{cm}$  ( $10,000\text{cm}^2$ , or  $1\text{m}^2$ , 0.5%). We are likely to err and estimate  $12 \times 12\text{cm}$  where it was really  $8 \times 8\text{cm}$ , however we are still much closer to reality than by saying  $<1\%$ .

Rare species are likely to change considerably with climate change as well as with climate variability and other impacts (such as grazing). An approximate estimate of their abundance is therefore of great importance to a correct understanding of long-term changes.



hour per larger and more irregular SAS. Typically, the *line-pointing* in SASs is done with a 'reader/call' and a 'scribe'. Working with two or three teams of two persons, several replicate lines can be done simultaneously, increasing statistical power. However, in unstable habitats and fragile vegetation, a more severe trampling impact must always be balanced against a more extensive recording.

#### ◆ Estimation of the cover of rare species

The rarer a species is in a SAS, the less likely it will be captured by *point-line intercept methods*. Therefore, the cover of those species not touched at the point-lines has to be estimated by area (*area cover*).

The measure of surface cover of these species may follow two different approaches according to the types of plants; in either case, however, the entire area of the SAS is to be carefully explored in order to estimate the cover of each species:

- ❖ For plants with defined outlines (cushions, rosettes, shrubs) and relatively regular shapes, one can estimate or measure the size of an average individual plant, and multiply times the estimated number of individuals of that species. On the field sheets, this would be noted, for example, as 5 cm × 5 cm × 14 individuals, or 12 cm × 10 cm × 8 individuals, or 20 cm × 13 cm × 3 individuals. Alternatively, in cases where a species occurs in a large number of different sized individuals, one may recognize more than one size-class within the same species, for example 1 cm × 1 cm × 250 individuals + 5 cm × 5 cm × 65 individuals, etc. The number of size-classes and the size of each class are not fixed, but depend on the particular species and on the particular local pattern. Bear in mind that increasing the number of measures will not necessarily increase overall precision (see Box 5.2).

- ❖ For plants which are dispersed or have very irregular shapes (some grasses, herbs, annuals, creeping plants) one can do a mental evaluation of how much surface all the individuals within the SAS would cover if they were all grouped together. On the field sheets this could be noted as 25 cm × 30 cm, for example. Eventually, if it is very difficult to estimate the combined area, partial areas may be summed: e.g. 2 cm × 3 cm + 5 cm × 4 cm, etc., although such an approach is more time consuming and may lead to larger errors.

Both approaches of cover estimation will result in an area (in cm<sup>2</sup> or m<sup>2</sup>) covered by a species within a SAS. It is recommended that all measures are noted in the field as linear measures (e.g. 5 cm × 5 cm) rather than surface areas (e.g. do not write 25 cm<sup>2</sup> instead). This reduces the error which inevitably arises from trying

to do mental calculations in the field. Surfaces will be calculated from these numbers when input into the electronic spreadsheets. The *percentage cover* of species can then be calculated when the size of the SAS is computed from the distance and *compass-angle* measurements that were made during the site setup.

Labour and time needed for cover estimations of the rarer species depends on the type of terrain, vegetation, species richness as well as on the shape and distribution type of species. Although no average time required for this can be given, a two-person team will take approximately 20 to 80 minutes to complete a 50 m long, 100 point, PAF (*Point and Flexible Areas sampling method*) including *point-line intercept* and cover estimates for rare species (Halloy et al. 2011). This has been the case in a variety of vegetation types from relatively poor to species rich paramo (humid-tropical alpine) and monte (shrub-dominated steppe vegetation) in the Andes. With practice this method can be as rapid as the standard procedure (i.e. species list plus verbally defined *abundance categories*), **since in each case all species must be sighted and a mental image has to be made** in the researchers mind. Efforts for the determination of *species' cover* should not be a trade-off of the time needed for recording the presence and *abundance category* of all vascular plant species occurring within the SAS, i.e. the standard procedure. When time is limited, the latter has a clear priority. Trampling impact must always be a consideration when deciding on work methods within the *summit area sections*.

Both *point-line intercept* and *area cover* sampling are noted in **Form 3** of the field manual (column headed 'cover'). The conversion from *area cover* indications into *percentage cover* will be calculated later on in the office. Always note the number of recording points for each SAS, as this may deviate depending on the size of the SAS. ▲

## 5.3 LINE-POINTING AND SPECIES RECORDING IN 10 m × 10 m SQUARES

This supplementary method, to be applied within the *summit area* in each of the four *cardinal directions*, should serve for two purposes:

- ◆ for a comparison of species data among the four cardinal aspects from regular 100-m<sup>2</sup> plots (as opposed to the SASs of irregular size that are directly attached to each other),
- ◆ for linking to an additional GLORIA activity: the *Downslope Plant Survey* that uses 100-m<sup>2</sup> transects at 25 m vertical intervals downhill of GLORIA summits (see chapter 7.1).

The original intention of using  $10\text{m} \times 10\text{m}$  squares, (as designed by A. Dennis, J. & C. Bishop, et al. at the GLORIA sites in the White Mountains, California) was to facilitate a percent cover estimation of species in the SASs. A  $10\text{m} \times 10\text{m}$  square, however, would hardly be representative for the SASs of irregular size. Therefore, the method, in a modified and simplified version, is now considered as a separate supplementary component of a GLORIA setting (Fig. 5.4). A particular strength of the  $10\text{m} \times 10\text{m}$  squares-design is to compare plant diversity patterns among the four *cardinal directions*, as the squares are centred in these directions, as are the  $3\text{m} \times 3\text{m}$  grids, but the squares cover a much larger area.

#### SETUP OF A $10\text{m} \times 10\text{m}$ SQUARE

- ◆ Start at the lower corner point of the  $3\text{m} \times 3\text{m}$  grid that lies on the *principal measurement line*; this point is the midpoint of the  $10\text{m} \times 10\text{m}$  square.
- ◆ Measure a distance of 7.07 m uphill along the *principal measurement line* and fix the upper corner point of the  $10\text{m} \times 10\text{m}$  square; measure (again from the midpoint) 7.07 m downhill along the *principal measurement line* and fix the lower corner point of the  $10\text{m} \times 10\text{m}$  square (14.14 m is the diagonal of the square).
- ◆ Fix a 50 m measurement tape with the 0-m mark at the upper corner point and the 20 m mark at the lower corner point; tighten this 20-m piece of the tape so that the 10-m mark forms the third corner point; do the same for the other side of the  $10\text{m} \times 10\text{m}$  square by fixing the 40 m mark of the tape at the upper corner point of the tape and tighten it so that the 30-m mark forms the fourth corner point (Fig. 5.5, upper). ▲

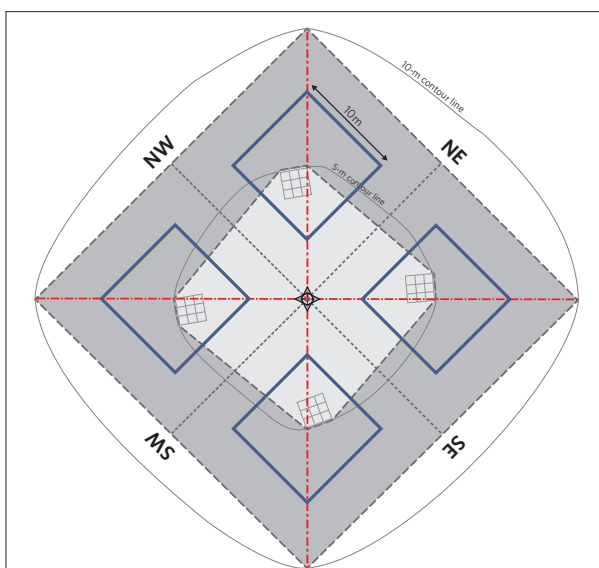


Fig. 5.4 Positions of the  $10\text{m} \times 10\text{m}$  squares within the summit area.

#### 5.3.1 LINE-POINTING OF VASCULAR PLANTS IN $10\text{m} \times 10\text{m}$ SQUARES

Shift 0.25 m inward from a boundary line of the  $10\text{m} \times 10\text{m}$  square and tighten a 10 m measuring tape parallel to the boundary line – this is the first recording line out of 20 such lines per  $10\text{m} \times 10\text{m}$  square (Fig. 5.5, lower).

For the recording along each of the 20 lines, set the first point increment along the line at 0.25 m from the boundary and continue to make point measures at each 0.5 m distance (Fig. 5.5, lower) using a stick with a narrow tip, so that you end up after 20 points at 0.25 m from the opposite boundary. As *sampling pin* you may use an ordinary knitting needle of some 30-50 cm length; important in any such point methods is its diameter: use a diameter of 2 mm.

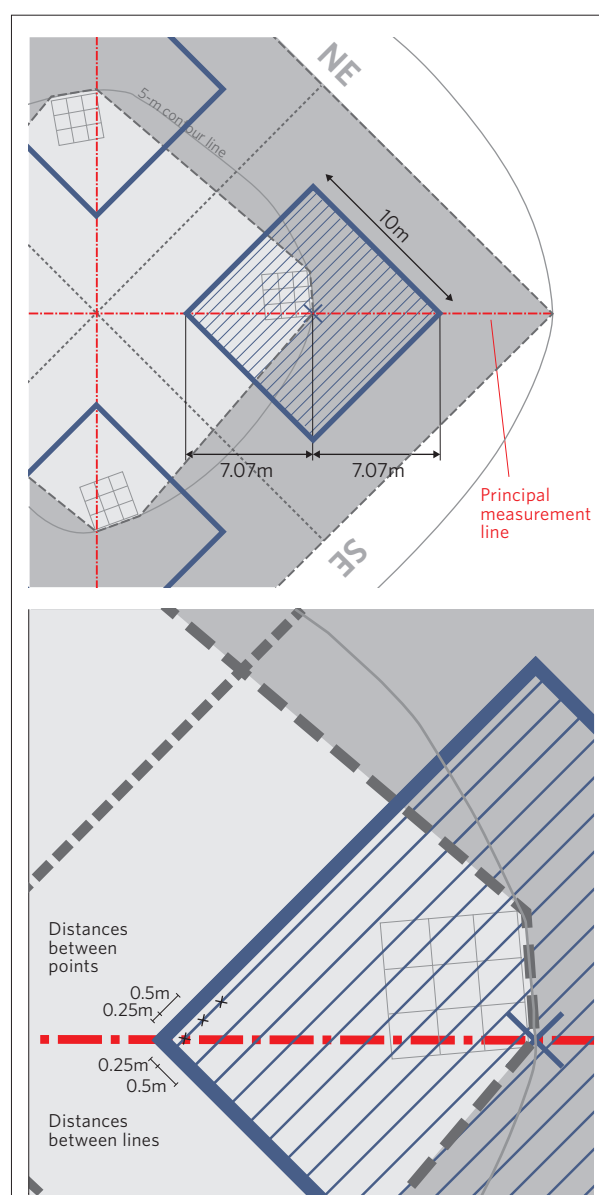


Fig. 5.5 Recording lines for point measures in the  $10\text{m} \times 10\text{m}$  square.

At each point note the species or the *surface type* you hit (for details see below).

After having finished recording along this line, shift the tape by 0.5m further inward, and so forth; in total recording is to be made along 20 such lines.

Finally you end up with 400 point measures being regularly distributed over the  $10\text{m} \times 10\text{m}$  square. ▲

#### HOW TO DO THE RECORDING AT EACH POINT

Hold the *sampling pin* (or stick) at its top so that you hit the point perpendicularly to the ground. Note what is hit by the needle by making a stroke into the relevant cell on the data sheet. This can either be one of the *surface types* already listed on the datasheet (*Form 6-S*, Annex II) or a vascular plant species. When hitting a *surface type* without vascular plants, make a stroke at one of the listed *surface types* (only one stroke per point is possible in this case). When hitting a vascular plant, write the species name and make a stroke in the respective recording line. In some cases the needle may touch more than one species, e.g. when having several vegetation layers. Make strokes for each species you hit. Thus, you may end up with more than 20 strokes per line and more than 400 strokes out of your 400 points per square. But do not record any of the *surface types* that lie below a vascular plant.

**Note:** that one cell on the sheet can have a maximum of 20 strokes, e.g. if all points on a line fall on *solid rock* or if the same species is encountered on all points.

As we are primarily interested in species cover, it makes sense to record all species you hit with the needle (and not only the taller growing top-most ones). Even when having more than 400 strokes, you can still calculate (later on) a percent cover value for each species hit in the  $10\text{m} \times 10\text{m}$  square: percent species cover = strokes per species/4. Or: total top cover of vascular plants = (400 minus the sum of strokes of *surface types*)/4.

◆ **Starting points and procedure:** In principle, you can start with the first line from any of the four corners in either of the two possible directions. It is more comfortable, however, to work uphill; therefore only four options remain, which are illustrated on *Form 6-S* (see Annex II). For resurveys it is advisable to repeat the procedure in the same way. Therefore, make a check mark on *Form 6-S* (upper right corner) at one of the four options.

Record along the 20 lines in the following manner: On the first line start in the direction as indicated on the marked sketch, and begin the next line from the opposite end of the square, and so forth.

◆ **Possible implications:** In steep and rugged terrain it may be difficult to setup the  $10\text{m} \times 10\text{m}$  square or to apply the *line-pointing*. When terrain is unsuitable because of steepness, we recommend to skip this method. If a

$10\text{m} \times 10\text{m}$  square could, nevertheless, be spread over a rugged terrain, the square may be distorted and, thus, recording lines may not properly fit within the boundaries. Irrespectively of this, always make 20 points per line, start at 0.25m from the square boundary and continue at 0.5m intervals.

The  $10\text{m} \times 10\text{m}$  square stretches over the  $3\text{m} \times 3\text{m}$  grid area, where trampling within the four corner-*quadrats* must be strictly avoided. Therefore, leave the  $3\text{m} \times 3\text{m}$  grid mounted to keep this area visible when doing the *line-pointing*.

There are some implications when you also record bryophytes and lichens on the species level (optional): when you hit a bryophyte or a lichen, make a stroke at the respective species, but also a stroke at the respective *surface type* (either '*lichens on soil*' or '*bryophytes on soil*'); if you hit the cryptogam species at a point where you also hit a vascular plant, do not make an extra stroke at the *surface type*. ▲

#### 5.3.2 RECORDING OF ADDITIONAL SPECIES IN $10\text{m} \times 10\text{m}$ SQUARES

Once you have completed the *line-pointing*, make a list of vascular plant species which were not captured by the *pointing*. Before doing this, add all additional vascular plant species which were found in the four  $1\text{-m}^2$  *quadrats* – so keep in mind to do the *quadrat* recording first. All additional species in the  $100\text{-m}^2$  area, on average, do not cover more than 0.25%. Their capture, however, is of relevance for comparing species richness at different nested spatial levels ( $1\text{-m}^2$ ,  $4\text{-m}^2$ ,  $100\text{-m}^2$ , and the larger area of the combined upper and lower SAS).

The basic recording in the  $10\text{m} \times 10\text{m}$  squares only involves *line-pointing* and an inventory (list of species) of all vascular plant taxa which were not hit by *line-pointing*, but not their visual cover estimation. More detailed species inventories in  $1\text{m} \times 10\text{m}$  bands can be made supplementally, especially when doing the *Downslope Plant Survey*. For details see the note on additional sampling in  $10\text{m} \times 10\text{m}$  squares in chapter 7.1. ▲

For the sampling sheet see *Form 6-S* in Annex II.

## 6 DATA HANDLING AND MANAGEMENT

### 6.1 THE SPECIES LIST

The first step of the data entry procedure is the preparation of a complete list of all (vascular plant) taxa found on the four *summit sites* of a GLORIA *target region*.

Use the GLORIA "*Taxa input sheet (xls)*" for entering all your species data. Table 6.1 explains the fields to be filled out for each taxon. The *Taxa input sheet* can be downloaded from the GLORIA website ([www.gloria.ac.at](http://www.gloria.ac.at)) and an example is appended in Annex II, Part 2.

Carefully check your sampling sheets in order to capture all taxa that were recorded on the *summit sites*. This includes both the sampling sheets of the *summit area sections* as well as of the *1-m<sup>2</sup> quadrats*. Make sure that all taxa are properly identified. Make one single list that contains all taxa found on the four *summit sites* of your GLORIA *target region*. While entering your taxa, also check the over-all GLORIA species list at [www.gloria.ac.at](http://www.gloria.ac.at) for already listed "accepted" names and synonyms. Where applicable, use the names listed in the over-all GLORIA species list even though they might be outdated.

Doubtful and incomplete identifications:

Cases where the identification remained doubtful should be treated in the same way as the clearly identified taxa in the species list. In such cases, however, do not forget to tick "cf." (confer) later on when you do the actual data input by using the GLORIA *data input tools*.

For taxa which could not be identified down to the species level, see the example sheet *Taxa input sheet* example (Annex II, Part 2) on how to enter such cases. Both unidentified species and species where identification is doubtful require at least one herbarium specimen (but not collected within the permanent plots).

Send the completed *Taxa input sheet* to the GLORIA coordination ([office@gloria.ac.at](mailto:office@gloria.ac.at)). The file should be renamed as: CC\_TTT\_GLORIA\_TAXA\_INPUT\_YYYYMMDD.xls with CC country code, TTT *target region* code, YYYYMMDD current date (year month day).

The GLORIA coordination will check all taxa names for consistency and synonymy in order to achieve an unambiguous GLORIA-wide list, which usually requires consultation with the field team. All fields will be checked for completeness and consistency so that data can be entered into the *central GLORIA database (CGDB)*. Please be very careful when preparing your taxa list, i.e. strictly stay with the formats shown in the example sheet "*Taxa input sheet EXAMPLE (xls)*" and clean up your file from any special formats, hyperlinks, etc. Add the *target region* code and the contact person on the excel sheet.

**Table 6.1** The *GLORIA taxa input sheet* (see an example in Annex II)

FIELD	FIELD DESCRIPTION
FULL_NAME	Full taxon name including the taxon author(s) or his/her/their abbreviation(s)
PLANT_TYPE	V = vascular plant, B = bryophyte, L = lichen
RANK	Taxonomic rank; possible standard entries: "species", "subsp." (subspecies), "var." (variety); in cases where the species cannot be identified, use: "agg." (aggregate species), "genus", or "family"
FLORA	Abbreviation of the flora (literature) used; in addition give the full citation of the flora. Where ever possible, please use floras with a large geographical coverage, preferably with checklists accessible in the internet
FAMILY	Plant family
GENUS	Genus name
SPECIES	Species name (epithet)
TAXON	If RANK is "species" or "agg.", enter again the name of the species (or of the aggregate species); if RANK is a lower taxonomic level, enter the name of the subsp. or var. In all cases higher than species (genus, family etc.) enter the full Target Region code (e.g. ATHSW)
REFERENCE	The nomenclatural reference; i.e. the reference of the first publication of the name.
SYNONYMS	Where applicable, add synonymous names of the taxon, particularly when widely used ones exist (including the taxon author (s) or abbreviation(s) - if more than one synonym, divide by a semicolon (;)
SPECIES_No_in_FLORA	The code number (numerical or alphanumerical) which is used in the flora reference which you entered in the column "FLORA", (where applicable)
B_LIVERWORT	Only relevant for bryophytes: enter "true" if the bryophyte is a liverwort, "false" if it is a moss
COMMENT	Text field for comments; e.g. on taxonomical details in the case of a critical taxon
HERBARIUM_SPECIMEN	Enter the code of your herbarium voucher: Herbarium acronym, collector, voucher number (this is obligatory for doubtful cases) - further, indicate the name of the herbarium and its location (on the herbarium voucher write the summit code)

Your species information will then be transferred to the central GLORIA data base (CGDB).

A data input tool package (GDIT – the GLORIA Data Input Tool), where all your taxa are incorporated, will be provided for the entry of your field data. Please use this GDIT tool so that your data can be properly checked for consistency and complied in the CGDB, but do not enter your data in EXCEL sheets or in any other formats.

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## 6.2 DATA INPUT, DATA CONSISTENCY, DATA STORAGE

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A standardized method along with standardized sampling forms implies the use of standardized data input methods and error checks in respect to a world-wide consistent data structure, being crucial for the comparability of all collected data.

The GLORIA coordination provides a data input tool (GDIT – the GLORIA Data Input Tool) – now as Microsoft ACCESS application, in future also as an online browser-based application. Prior to any data input, a consistency check of your species list will be accomplished by the GLORIA coordination.

The input tool reflects the field sheets to the highest degree possible, to avoid errors during data entry.

The procedure of data input strictly complies with the following steps:

- ◆ When planning to establish a GLORIA site (*target region*), first a unique site code has to be obtained from the GLORIA coordination (CC-TTT; CC, 2-digit country code; TTT 3-digit *target region* code). This code will already be needed for fieldwork, e.g. for all *photo documentations* and is the primary key of the database.
- ◆ Fieldwork is finalized.
- ◆ A complete species list has to be sent to the GLORIA coordination for checking the species names and nomenclature (see chapter 6.1).
- ◆ Upon approval of this species list by the GLORIA coordination, a personalized data input tool for that distinct site will be created and sent to the respective field team.
- ◆ Data will be entered by the respective field team.
- ◆ Data consistency checks are applied by algorithms included in the data input tool (see below for details).
- ◆ Once all errors are eliminated, data can be uploaded and is ready for your analyses.

Once all data is entered and before it can be uploaded or exported for personal use, the data has to be checked for consistency. Found errors have to be eliminated.

The following error types will be detected by the tool:

- ◆ One or more mandatory fields in any forms of your dataset were left empty.
  - ◆ One or more species in any forms of your dataset lack a cover or abundance value.
  - ◆ One or more species are missing in the respective *summit area section* but occur in one or more of the  $1\text{-m}^2$  quadrats of the respective *cardinal direction*.
- Note:** The following points are only relevant if the supplementary *subplot-frequency counting* was applied.
- ◆ One or more species are missing in the respective  $1\text{-m}^2$  quadrat, but occur in the corresponding frequency quadrat.
  - ◆ One or more species are missing in the respective frequency quadrat but occur in the corresponding  $1\text{-m}^2$  quadrat.
  - ◆ One or more species have a frequency of 0 (100 counts of 0).

Errors can result from fieldwork, as well as from data input. The tool produces a list of errors and gives you hints on how to solve them.

It is important to know about error sources to anticipate and prevent errors already during fieldwork.

Considerations on data consistency already to be taken in the field:

- ◆ The species list of each *quadrat* is a subset of the species list of the corresponding *summit area section*. All species from a *quadrat* MUST also be in the list of the corresponding section.
- ◆ If you applied the *subplot-frequency* method (chapter 5.1.2), the resulting species list MUST be congruent with the species list of the visual cover estimation in the  $1\text{-m}^2$  quadrats.
- ◆ Depending on the method used in *summit area sections* (abundance or also cover), each species MUST have a value for the *abundance categories*, assigned either r!, r, s, c, d or both *abundance category* and a cover value.
- ◆ All fields on the forms have to be filled in during fieldwork. Reconstruction of missing entries during data input is tedious and error prone. This applies especially to commonly neglected entries like researcher names, start/end times, and the measurement protocol.

The data input tool is designed for the input of data collected along the accepted standard recording methods (STAM) as well as along the supplementary recording methods (SUPM). The input of data collected with deviating methods in the frame of additional GLORIA activities (as described in chapter 7) have to be handled



by the particular *target region* team or by the coordinating group of a particular additional activity. A central data storage at the GLORIA coordination, however, is planned to be offered for additional activities.

The GLORIA coordination maintains the *central GLORIA Database (CGDB)* to the state of the art of data storage standards. Apart from that, each site team has to take care of their data storage by their own. In addition, archive your original and scanned field sheets.

Over the longer term, personal turnover in groups will occur and some *target regions* may get orphaned. Notwithstanding this, the value of permanent plots and data will increase by years, as long as the full datasets (including the necessary photos for plot reassignment) are properly stored and accessible for future generations of researchers. Besides the double storage of data in the central CGDB as well as at each team's institution, publishing of the complete *target region* data would be a worthwhile effort.

## 6.3 HANDLING OF THE PHOTO DOCUMENTATION

The original *photo documentation* materials should be stored in your office\* together with your original field forms for further *monitoring*. But photos must as well be delivered digitally with standardised file names (see [Box 6.1](#)) to the GLORIA coordination so that they can be directly included in the *central GLORIA Database (CGDB)*.

\*Past experience has shown that depositing photos and other documentation in institution libraries may be a more robust archiving strategy as staff leave, where records may be lost.

Use the high-resolution images as you have taken in the field. All digital photo files have to be renamed according to the GLORIA-unique *coding* system. Please see [Box 6.1](#) and Annex III as well as the GLORIA web site for more information on how to do this and to deliver the materials to the GLORIA coordination.

### BOX 6.1 GLORIA-UNIQUE CODES FOR VARIOUS ITEMS IN FORMS AND PHOTOGRAPHS

Various items in the GLORIA dataset must have a GLORIA-wide specific *coding*, which is used in forms, on photographs, for *temperature loggers*, as well as in the database.

◆ **Country codes:** The two-digit ISO 3166 codes are used. Examples: AT for Austria, CA for Canada, CL for Chile, GE for Georgia, NZ for New Zealand, RU for Russia.

◆ **Target region codes:** These three-digit alphanumeric codes are created **solely** by the GLORIA coordination to avoid code conflicts; please contact us to obtain a *target region* code. Examples: SNE is Sierra Nevada/Spain, GNP is Glacier National Park, Montana/USA, MJW is Ma-Ji-Wa, Hengduan Shan, Yunnan/China.

◆ **Summit codes:** Three-digit character codes (avoid numbers). Each researcher who is responsible for a *target region* shall select such codes for his/her summits, avoiding *coding* conflicts within the TR. Examples: BAR is Mount Barcroft, GHK is Ghacktkogel, MPO is Maly Pourkeu, PFO is Piz Foraz.

» These three code elements must be indicated in the header of any field protocol form.

◆ **All measurement points.** Their codes are indicated in [Fig. 3.2](#).

◆ **All sampling areas.** Their codes are indicated in [Fig. 3.2](#). Special care

should be devoted to the *coding* of *1-m<sup>2</sup> quadrats*, as indicated in [Fig. 4.1](#). For example, if you stand below the lower boundary of a southern *3m × 3m quadrat cluster*, and look towards the summit, then the left lower *1-m<sup>2</sup> quadrat* is coded S11 (the first column and first row of the cluster), whereas the right lower *quadrat* is coded S31 (the third column and first row). The other *quadrats* are coded in a similar way according to their column-row-position in the cluster, S13, S33, and S22 for the middle quadrat where loggers are positioned. This *coding* is similar to what is used in many geographic maps and GIS applications.

◆ **Full-length-codes:** These are used for items that may be used or recorded separately from sampling protocols *Forms 0, 1–4, 5-S, 6-S*. Such items should be coded with full-length-codes, which are a combination of the country-, *target region*-, and summit-code followed by other specific code elements.

They are used, e.g. for:

◆ **Temperature data loggers:** For each logger, indicate the logger position and installation year on the logger **and** in the protocol as:

CC\_TTT\_SSS\_QQQ\_YYYY with CC: countrycode, TTT: *target region* code, SSS: summit code, QQQ: *quadrat* code (see [Fig. 4.1](#)), YYYY: (year) of installation of the logger in the field.

Example for logger position and installation year:

❖ ES\_SNE\_TCA\_W22\_2002 for a *temperature logger* in Spain, Sierra Nevada, Pico del Tosal Cartujo, western *3m × 3m quadrat cluster - quadrat 22*, installed in 2002.

◆ **Photographs:** A blackboard with indications must be included in the photo view (see chapter 4.4). Whenever a distinct GLORIA item is photographed, such as *measurement points*, plots, *temperature data loggers*, indicate the relevant code elements in the correct sequence. As separator of the code elements you may use a point (.) to save space on the blackboard.

On any photo, do not forget to indicate the date on the blackboard in the sequence YYYY-MM-DD.

Examples for photo codes are:

❖ AT\_HSW\_GHK\_N33\_20010817 for a photograph of a *1-m<sup>2</sup> quadrat* in Austria, Hochschwab, Ghacktkogel, *1-m<sup>2</sup> quadrat N33*, on 17th August 2001.

❖ ES\_SNE\_TCA\_p10m-S\_20080703 for a photograph of: Spain, Sierra Nevada, Pico del Tosal Cartujo, southern *summit area* corner point at the *10-m level*, on 3rd July 2008.

On photos of data loggers, also write the prefix LOG- in front of the plot code onto the blackboard (e.g. ES\_SNE\_TCA\_LOG-W22).



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## 6.4 DATA PROPERTY RIGHTS AND DATA SHARING

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For all data which are included in the central GLORIA Database (CGDB; such as on species, habitat and site properties, soil temperature, and photo data) the following rules apply:

- ◆ Every contributor of field data retains the exclusive ownership of the data.
- ◆ Only persons and teams who have contributed data to the central GLORIA Database are eligible to be part of data sharing. This, however, should not restrict cooperation between GLORIA members (data providers) and external persons for analysis and publication of their GLORIA data.
- ◆ The use of a site dataset or of parts of it by eligible members of the GLORIA network requires the data provider's permission.
- ◆ The authorship of intended publications must be negotiated between the data requester and the data owner(s).

These rules require the following procedure:

- ◆ Eligible data requesters, who wish to use data from other sites, must submit a request to the GLORIA coordination ([office@gloria.ac.at](mailto:office@gloria.ac.at)), which contains:
  - ❖ A description of the intended data analysis including hypothesis, methods and expected results.
  - ❖ A detailed description which data are needed: sites (target regions), monitoring cycle(s), plot types, habitat and site properties, soil temperature, photo data, species presence/absence, species cover, species subplot-frequency, or on particular species groups.
  - ❖ A suggestion for lead and co-authorships.
- ◆ The GLORIA coordination will discuss the proposal (i) regarding other planned activities in the GLORIA consortium; (ii) with the requester; and (iii) with the data owners.
- ◆ Upon consent, the GLORIA coordination will send the negotiated dataset to the requester.
- ◆ The data requester guarantees that the data are only used for the negotiated purpose.

Any further analysis on this dataset requires a new request.

Re-use, redistribution and the production of derivatives are usually based on published data and therefore underlie the policies of the respective journal or publisher. The re-use of unpublished material requires permission of the data provider.

Selection of sites and data sets for data analysis: For analyses of GLORIA data including large-scale analyses, no specific regulation or selection criteria on which sites or data sets are included can be given. This of course depends on the respective research question and the completeness of required data sets, which e.g. may focus on selected biomes, on particular bedrock types, on sites with at least one or with multiple resurvey data sets or even on sites with data sets from a particular time period.

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## 7 EXTRA APPROACHES IN GLORIA (EXAP)

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This chapter shows that the GLORIA programme has grown well beyond its standard *Multi-Summit Approach* after its first decade of operation. Apart from standard and supplementary methods for GLORIA *summit sites*, several additional activities have started as further components of the GLORIA network. These **extra approaches** are directly related to a GLORIA *target region*, but are usually not confined to the *summit sites*, and partly have an interdisciplinary focus. This chapter describes an array of further *monitoring* and data collection activities which are directly related to GLORIA *target regions*. These activities focus either on extended spatial designs and/or on topics other than summit vegetation, such as on other organism groups, ecosystem components or on socio-economic and cultural aspects. They were already presented at the international GLORIA conference, held in Perth, Scotland, in September 2010. All approaches have been initiated, developed and applied in the field by various GLORIA teams on different continents.

The first subchapter 7.1 deals with plant species *monitoring* along downslope belt transects of GLORIA summits to the upper forest belt. Its principal target is to identify the regional lower and upper range limits of species distributions.

The following three subchapters focus on various animal organism groups in different sampling approaches in GLORIA *target regions*: 7.2 on *pitfall trapping* of invertebrates, 7.3 on other methods of invertebrate sampling and 7.4 on *herpetological monitoring* around and downslope from the GLORIA *summit sites*. Further we refer here to a recent comprehensive account on faunistic (mostly arthropod) monitoring at GLORIA summit habitats in the Alps (ÖKOTEAM 2014).

Subchapter 7.5 contains approaches to survey the *soil variability* around GLORIA *summit sites*. The final two subchapters deal with socio-economic and cultural aspects in GLORIA *target regions*. In 7.6 the recognition of past and current anthropogenic factors concerning land use practices and socio-economic implications are attempted. Chapter 7.7 focuses on *ethnobotany* in the context of local people's perception of adaptations to and mitigations of climate change.

Descriptions of these thematic subchapters differ in the level of development and standardisation. Further method elaboration and testing and subsequent step-by-step descriptions of working procedures are still required for some of these extra approaches.

On the other hand, further GLORIA-related activities were recently emerging in the following fields, which should be mentioned here in brief:

Focus on *plant functional traits* (PFTs): This can considerably build on extensive previous research (e.g. Halloy & Mark 1996, Cornelissen et al. 2003, Pohl et al. 2011, Venn et al. 2011) and is to a large part a matter of collateral data which may be obtained from existing literature and data bases (see, e.g., Cornelissen et al. 2003, Landolt et al. 2010). The identification and use of suitable *plant functional traits* holds an outstanding potential for GLORIA in comparing vegetation of different biomes with little or no floristically overlapping species composition. Especially, this information may prove useful in developing predictive models of responses of plants with particular traits to changes in abiotic factors, and in the overall view, to climate change. Researchers within the GLORIA programme are in the process of collecting field, lab, and collated data on plant functional traits of the species at their respective GLORIA sites, such as initiated through an INTERACT project at the Cairngorms GLORIA site, Scotland, and a recent North American/European collaboration (contact MARTHA APPLE, Montana Tech) or have compared functional leaf traits with summit species data at the Snowy Mountains GLORIA site, Australia (Venn et al. 2014).

Focus on experimental warming: Experimental studies using open-top-chambers (Molau & Mølgaard 1996) and eco-physiological measurements were recently started at tropical and subtropical GLORIA sites in Ecuador and N-Argentina. These new experimental sites, being of course established well outside of the GLORIA summit sites, would provide valuable links and possibilities of comparison with long-established networks such as the International Tundra Project (ITEX, <http://www.geog.ubc.ca/itex/>). Contact: FRANCISCO CUESTA, PRISCILLA MURIEL, CONDESAN, Catholic University Quito, respectively.

Focus on ecosystem services: An assessment of ecosystem services in GLORIA *target regions* / catchment areas, using a new rapid assessment method developed for the LTER-Europe network (Dick et al. 2014) may be applied in a wider GLORIA context and could also contribute to the further development of GLORIA activities described in the subchapters 7.6 and 7.7. Contact: JAN DICK, CEH Scotland.

The key responsibilities for the further elaboration, wider application and supervision of any of the extra approaches and activities mentioned and described in this chapter lie with the particular expert groups. Their status and progress, however, is planned to be also displayed on the GLORIA website including eventual future activities which are not yet mentioned in this manual.

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## 7.1 GLORIA DOWNSLOPE PLANT SURVEY

ANN DENNIS<sup>1</sup> & JIM BISHOP<sup>2</sup>

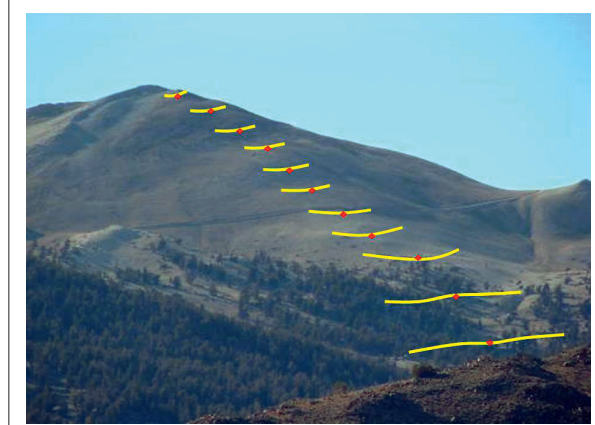
1 | THE CALFLORA DATABASE, Albany, California, USA;  
2 | OROVILLE, California, USA

Standard GLORIA summit methods could be much strengthened, if for each species recorded in summit sampling, the upper and lower limits of continuous distribution and the center 'optimum' within the *target region* were known. This information is central to interpretation of GLORIA *monitoring* data with respect to key hypotheses about the response of different species groups to climate change (compare chapter 1.2). In many cases, casual observation and published literature are too generalized and imprecise to supply elevational distribution data that are adequate for these purposes.

The *Downslope Plant Survey* provides the required elevational distribution information in a quantitative manner that reflects the specific characteristics of the *target region*.

This method also serves as a supplement to the GLORIA summit methodology, providing an additional set of quantitative measurements for *monitoring* changes in elevational distribution of species.

A *Downslope Plant Survey* comprises a set of horizontal transects (belt transects) at regular elevation intervals (commonly 25-metre) from the highest elevation in the *target region* to some distance below *treeline*, selected to be as consistent as possible in aspect and topographic situation (Fig. 7.1). Several series like the one illustrated in Fig. 7.1 will usually be needed to cover the full elevational range of a particular *target region*. Like the 10m×10m square procedure used as a supplementary method in the GLORIA summit methodology (compare chapter 5.3), sampling is based on defined plots of 100m<sup>2</sup>. However, the *Downslope Plant Survey* plot is laid out as a 1m×100m belt along a *contour line* (Fig. 7.2). For survey purposes, we prefer the elongated layout because it generally includes

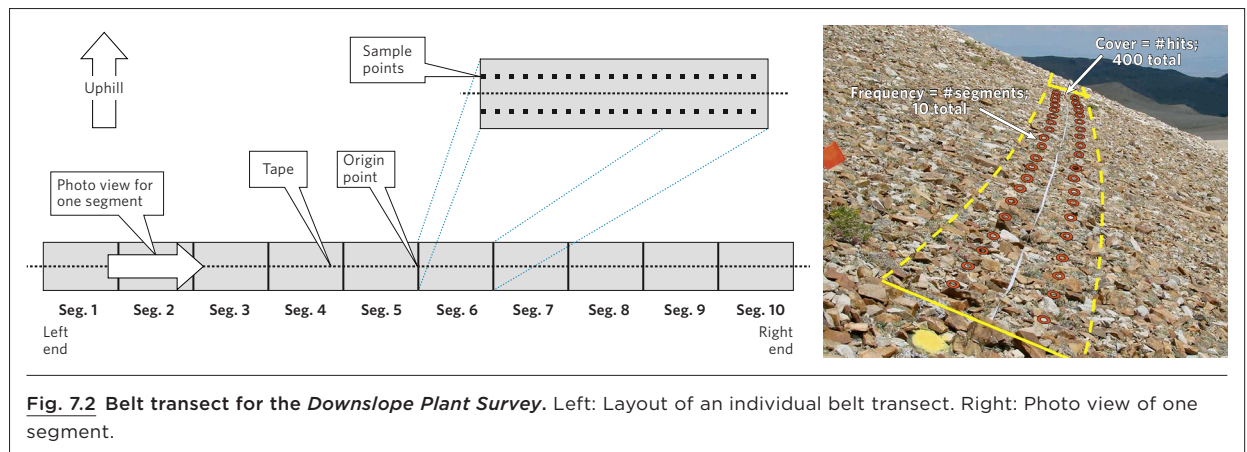


**Fig. 7.1 Downslope Plant Survey.** Placement of a series of belt transects at regular elevation intervals from just below a GLORIA summit to below *treeline*.

more species than a square layout of the same area. We recommend using a combination of *point-line intercept* cover estimation and species inventory in each of the ten segments per transect. These two methods used together provide measures sensitive to differences in abundance appropriate both for species that form substantial fractions of *top cover* as well as species that are too small and sparse to form more than trace amounts of cover. In sparsely vegetated areas, the latter often comprise the large majority of species present.

### METHODS

Before going to the field, use map resources to select a series of transect locations at regular elevation intervals (e.g. 25m), consistent in aspect and avoiding ravines and steep slopes. Where possible, downslope belt transects may be established in each *cardinal direction*. At each location, produce a species inventory for each of the 10 segments of a horizontal belt of 1m×100m, *point-line intercept* (*line-pointing*) cover estimates for species, and *top cover* classes consistent with the GLORIA summit methodology (compare chapter 5.3). Fig. 7.3 shows a sample datasheet.



**Fig. 7.2 Belt transect for the Downslope Plant Survey.** Left: Layout of an individual belt transect. Right: Photo view of one segment.

Use the following procedure:

## SAMPLING PROCEDURE

- ◆ Go to the first preselected location. Using GPS, record exact coordinates. Always place a permanent marker at this original point of each transect.
- ◆ Fasten the end of a 50m tape at this point and run horizontally along a level *contour line* to your left (facing uphill). The crew member stationed at the origin should help the person with the tape to stay on a level course, using a clinometer or a level. Place a pin flag at each 10m interval along the tape, identifying five segments of 10m length. Each segment consists of a belt of 1-m width, 50cm below and 50cm above the tape which is the mid-line.
- ◆ Line-pointing for cover estimation: This method is similar to the *pointing with a grid frame* and *line-pointing* described in chapters 4.1.2 and 5.3, respectively. For each segment, use a prepared pointer tool such as the one shown in Fig. 7.4 to tally species cover (or *top cover of surface types* where no vascular plant occurs). The instrument should have two *sampling pins* that are 50cm apart (use e.g. knitting needles with a diameter of 2mm). Move this instrument along the tape with the needles perpendicular to it. Start 25cm inward of the left segment edge of segment 1 (Fig. 7.2). Here you record the species that are hit by the *sampling pins* (i.e. on each side one species that is 25cm away from the tape) by noting the species name and making a stroke on the left side of the respective segment column (Fig. 7.3). In case of several vegetation layers, record every plant species that is hit by the needle at this point or make a stroke for the encountered *surface type* in the case that no vascular plant was hit. Repeat recording every 50cm along the tape until you reach the right edge of segment 5. This yields in total 200 points for the half of the transect (50m tape, recording interval 0.5m, upper and lower side). This provides the same point spacing and density as in the GLORIA *10m×10m squares* (chapter 5.3) and therefore can be converted into species cover. It is advisable to do *line-pointing* before the species inventory (described below) because here the most common species are then first written on the sampling sheet.
- ◆ Species inventory: Record all vascular plant species encountered in each 1-m belt moving along the tape. Start at the far end (segment 1, left side of the transect). Use a 1m long stick marked at mid-point as a guide (positioned just above

and parallel to the surface and in right angle to the tape) and travel along the tape. Each species occurring within this segment (1m×10m) must be recorded. Note the species name (when not yet listed) and place a check mark on the right side in the 'Segment 1' column on the datasheet (Fig. 7.3). This results in a species presence/absence dataset of the segment. Repeat for the remaining four segments (segments 2-5), marking your recordings in the appropriate segment-columns.

- ◆ Take photos: While tape is in place, photograph each 10m segment in order, beginning with Segment 1 and viewing toward the higher segment number. The view should include the near end and the far end of the segment, marked by pin flags or the sample stick. Also, take one or more photos of the permanently marked transect origin and of the endpoint (50m away) to be used for finding it in the future. In each photo, include a blackboard with date, *target region*, series name, elevation, segment number, and photographed object.

- ◆ Rewind the tape.

- ◆ Repeat the above steps, but this time towards the right from the permanently marked origin. This time, start to record at the permanently marked origin and work your way towards the right far edge of segment 10 (segments should end up numbered sequentially from left to right facing uphill, just as the columns are arranged on the datasheet).

- ◆ Count all check marks in the species-inventory-columns for each species and place the total number in the 'SegCount' column (Fig. 7.3). The filled 'SegCount' column contains frequency scores (values between 1 and 10) for each species encountered in the transect. For the more common species (and *surface types*) which were captured by the pointer tool, add up tally marks of all segments and place total in the 'Total Hits' column for each *top cover of surface type* and plant species. Later, cover estimates can be calculated by dividing total hits by 400 (total points) sampled per transect, e.g. 15 hits/400 pts = 0.0375 or 3.75 percent cover.

- ◆ Repeat for remaining transect locations.

### Note on additional sampling in 10m×10m squares

(chapter 5.3): When doing the *Downslope Plant Survey*, it would be recommendable to extend also the sampling procedure in the *10m×10m squares* in the *summit area* in order to obtain consistent data sets: Record the occurrence of each species in each 1m×10m strip, regardless of



Country \_\_\_\_\_ Target Region \_\_\_\_\_ Series Name \_\_\_\_\_ Transect # \_\_\_\_\_  
 Latitude \_\_\_\_\_ Longitude \_\_\_\_\_ Aspect \_\_\_\_\_ Elevation \_\_\_\_\_  
 Date \_\_\_\_\_ Time: from \_\_\_\_\_ to \_\_\_\_\_ Observers \_\_\_\_\_

[illegible][illegible]

Comments:

7 - EXTRA APPROACHES IN GLORIA (EXAP)



at the *treeline ecotone* and the *alpine-nival ecotone*. Frequency scores (number of segments out of 10) provide a basis for interpretations of lower and upper margins and center (optimum) zone (cf. Gottfried et al. 2012) for all individual species, most of which are too sparse to show up in point intercept sampling. The example in [Table 7.1](#) only shows a subset of species representing the different types of elevational distribution ranges. The example data reflect the previously used 100-point methodology, which has been updated to the 400-point method described herein.

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## 7.2 INVERTEBRATE MONITORING ON GLORIA SUMMITS

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### OBJECTIVES AND AIMS

Non-sessile organism groups should also be considered as biosensors with respect to climate change impacts. Insect herbivores, for example, appear to be more sensitive to climate change than their host plants (Hodkinson & Bird 1998). This approach, however, focuses on flightless, mainly ground-dwelling and therefore rather stationary arthropods.

Being flightless, which is typical for many alpine insects, and thus those present at GLORIA summits, they move on the ground surface, as well as do spiders, harvestmen and millipedes. In order to capture the whole variety of crawling and running invertebrates and estimate their species richness and relative abundances, *pitfall trapping* is routinely used. Pitfall traps consist of containers (usually plastic cups) that are buried in the soil until ground-level (Fig. 7.5). They are filled with a low-volatile liquid as fixative to hinder invertebrates, mainly ants and spiders, from escaping and prevent damage or predation by other animals.

Pitfall traps are usually either established in line at equal distances or put in places with higher chances of capture. Within the context of GLORIA's *Multi-Summit Approach* (see chapter 3), the so-called "cross-pattern" of pitfall traps is proposed (Mikhailov 2009). By now it has been tested at three *target regions* in the Urals (RU-SUR, RU-NUR, RU-PUR) in the seasons 2008 and 2011 with satisfactory results.

Even though this *invertebrate monitoring* approach operates within the *summit area*, it is considered here as an additional GLORIA activity because of the largely deviating methodological approach, as opposed to the sessile plant organism groups, and the highly specialised expertise needed to identify invertebrate species.

### SAMPLING DESIGN AND METHODS

#### MATERIALS

To establish the "cross-pattern" of traps (Fig. 7.5) you will need:

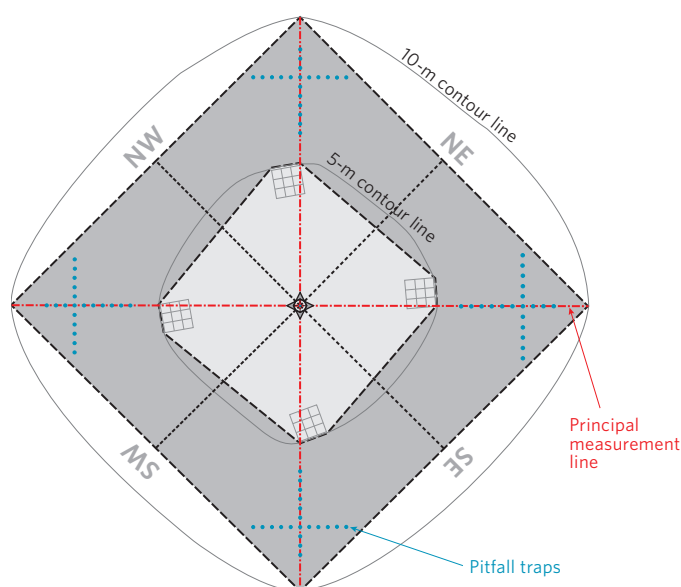
- ◆ Standard plastic cups: approx. 100 for every summit (the size of cups may vary, but it is best to use cups of 200 ml volume and an opening of Ø 75 mm);
- ◆ Scoop (made from high quality steel and it is better to have two);
- ◆ Acetic acid (CH<sub>3</sub>-COOH) as fixative: 0.5 liter of 70% acid or more if the concentration is less. Acetic acid as fixative is recommended. It is the most environmentally friendly, easiest available for purchasing and can be dissolved to 3% using water from natural water sources nearby.
- ◆ Two plastic bottles (1.5-2.0 liters) for making a 3-5% solution of fixative.

#### POSITIONING OF TRAPS

- ◆ Pitfall traps are established in each *cardinal direction* (N, E, S, W): ten traps are positioned along the *principal measurement line* and another ten traps form a line crossing the seventh trap (seen from the *highest summit point*) at right angle (Fig. 7.5).

**Fig. 7.5 Cross-pattern design of pitfall traps on a GLORIA summit.**

Left, the "ideal" arrangement with 20 pitfall traps in each *cardinal direction*, upper right, pitfall traps along the *principal measurement* of a cardinal direction, bottom right, pitfall trap positioned in the soil.



◆ Each “cross pattern” of traps is usually established between the standard corner points *p5m* and *p10m* (Fig. 7.5).

◆ The regular “cross-pattern” is designed for an “ideal summit”. Landscape complexity and situation of rocks and stones on a particular summit, however, may cause constraints. Where substrate is not suitable, it is possible to move the traps slightly in any direction from the two defined lines, but deviations should be kept as small as possible. Further, the actual setting of traps must be accurately documented (mapped) for each summit.

## SEASON

There are two optima for alpine insects in the temperate to southern boreal mountains of Eurasia: ‘early summer optimum’ (second half of June to early July) and ‘late summer optimum’ (last week of July to first week of August). In sub-Arctic mountains (e.g. Polar Ural) only the second optimum exists due to the shorter vegetation season. Do the invertebrate investigations of all summits of one *target region* during the same optimum period. Dividing summits among both optima may cause biased results being difficult to compare.

## PROCESSING OF THE COLLECTED MATERIAL

After a period of three days to one week, the traps are removed and the invertebrates from each trap are recorded separately in a field data sheet. The most common and/or abundant species may be determined to species level at once, others at least to genus or family level with indicating specific features (colour, size, sculpture). Adult insects should be collected in containers with ethyl acetate, insect larvae and other invertebrates in vials of 70% ethanol, both containers and vials must be accurately labelled. The exact determination of collected specimens follows later on by comparing with reference collections or by specific expertise.

Any flying insects (sawflies, bumblebees and moths) captured by pitfall traps are excluded from the following data processing due to the occasional character of these findings.

## DATA PROCESSING

For field sampling, modified versions of the data sheets **Form 3** and of the form for *subplot-frequency counts* (**Form 5-S**) may be used for each *summit area section*. **Form 5-S** is used for the species composition in each trap. In **Form 3** every species is entered, followed by indication of class, order and family, number of collected specimens, dynamic density (see below), dominance and abundance.

The time of trapping and number of traps may vary, so **dynamic density** is better for the purpose of comparison. It shows the number of collected specimens of a species per time and trapping unit (I used 10 trap-days as unit). For example, when 60 specimens were captured after three days of trapping by 20 traps (i.e. two trapping units), the dynamic density is  $60/3/2=10$ .

The percentage of the recorded specimens of a particular species divided by the total number of all collected specimens enables to use Renkonen’s index of dominance (5% and more: **dominant**, 2 to 4,9%: **subdominant**, and less than 2%: **rare**; Renkonen 1938).

Pesenko’s index (Pesenko 1982), on the other hand, helps to evaluate the role of species in the biotope. If *N* is the total number of all trapped specimens, then 1-3 specimens of one species indicate **single**,  $4 - N^{0,4}$  **rare**,  $N^{0,4}+1 - N^{0,6}$  **abundant**,  $N^{0,6}+1 - N^{0,8}$  **mass species**. The groups dominant and subdominant are a subject for further analysis. The difference between dominance and the role of the species in the biotope is a subject of comparison of both between *summit area sections* at one summit and between summits in space and time.

Data on **geographic distribution** (ranging from Holarctic, Palaearctic, Euro-Siberian to regional and local endemics) and *zonobiome* / *altibiome* preference or **altitudinal rank** (polyzonal, arctic-alpine, boreo-montane, alpine, etc.) gives useful information for resurvey comparisons. The ratio between endemic and widespread species as well as between alpine specialists and generalists is a good indicator of climate change influence on each summit. The actual trends found between higher and lower summits of one *target region* may indicate possible scenarios of climate change driven trends (Mikhailov 2009).

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## 7.3 GLORIA-ASSOCIATED ARTHROPOD MONITORING

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Although GLORIA is explicitly focused on vegetation, we have added arthropods as response variables to the portfolio of satellite studies associated with the core GLORIA effort at our WMRC *master site* (White Mountains, California). Arthropods represent much of the total abundance, diversity, and trophic complexity in these mountains; we have recorded 103 families of terrestrial arthropods, and 35 species of butterflies, via rapid assessment sampling of seven White Mountain sites over seven years. We have thus been able to capture a significant component of overall assemblage complexity quickly and efficiently.

### METHODS

We suggest three complementary methods for *monitoring* arthropods at co-located sites:

- ① A species-level census for butterflies;
- ② Standard sweeps for extensive sampling of epigeal and volant arthropods at family level;
- ③ A vacuum-quadrat method for small scale, intensive sampling of both substrate- and canopy-associated arthropods at family level.

Sites are selected along an elevation transect (parallel to the *Downslope Plant Survey* transects below the GLORIA summits; cf. chapter 7.1). You should choose areas with a mixture of flat open ground and vegetation cover whenever possible, where insect sampling is most productive. In our example, seven sites are chosen near a road or good trail

(Fig. 7.6), so that each site can be sampled for 45 minutes to an hour, leaving time for travel by car or foot between sites. Each site should be censused once annually during the summer season (e.g. the last week of July in the White Mountains).

① Butterflies are sampled with a mix of netting and direct visual identification (Fig. 7.6) per protocols established for the North American Butterfly Association's (NABA) "4<sup>th</sup> of July" butterfly count ([http://www.naba.org/butter\\_counts.html](http://www.naba.org/butter_counts.html)). The goal of this protocol is to count and identify each individual butterfly seen at each of the seven predetermined sites. If visual identification is uncertain, voucher specimens should be collected for verification by specialists. The numbers of butterflies of each species observed at each site is recorded in the spreadsheet. When the sampling takes place in North America, the spreadsheet should be sent to NABA for publication in their annual count report.

② Each sweep sample consists of 50 standard net sweeps (New 1998, Southwood & Henderson 2000, Holmquist et al. 2010, Holmquist et al. 2011a), covering a total of 400m<sup>2</sup>. The net has a 30.5cm diameter aperture and a mesh size of 0.5mm×0.75mm (e.g. BioQuip #7112CP). Sweep samples should be collected prior to further disturbing the sites, and samples are put on ice after sampling. Canopy height is then measured at four equidistant points within the sampling area.

③ Vacuums with nets inserted in the intake tube are effective for intensive sampling of fauna (e.g. Dietrick et al. 1960, Arnold et al. 1973, Macleod et al. 1994, Buffington & Redak 1998, Holmquist

**Fig. 7.6** Confering over a butterfly identification near White Mountain Peak, California.





**Fig. 7.7 Vacuum method in conjunction with a netted quadrat for arthropod sampling.** Left: Tossing the netted quadrat, right: Vacuuming fauna from vegetation through the elasticized aperture in the net (photos by Lance Iversen, San Francisco Chronicle).

et al. 2011b). In order to capture motile fauna and sample a known area of habitat, we recommend the construction of a 0.5 m<sup>2</sup> steel quadrat with a conical mesh covering (Fig. 7.7). The mesh cone has an elasticized hole at the apex through which a vacuum intake tube is inserted. This quadrat is thrown toward the target area from a distance and staked in place with tent stakes in order to form a seal with the substrate. Canopy height is then measured at all four quadrat corners after the quadrat has been staked, but before vacuuming. The vacuum intake is then inserted through the mesh aperture for sampling (Fig. 7.7). This technique is efficient and particularly effective at capturing motile taxa, albeit on a small scale (Holmquist & Schmidt-Gengenbach 2006). We used a Craftsman 320 km/h gasoline vacuum modified with a nylon “no-see-um” mesh (0.25 mm) collecting chamber inserted in the intake tube in conjunction with the netted quadrat (Fig. 7.7). After staking the thrown quadrat, we make multiple passes through the vegetation with the vacuum intake from all four orientations over a four-minute period. The intake is then removed from the quadrat, the integral mesh collecting bag is removed from the intake tube, and the fauna and litter are transferred to a re-sealable plastic bag and placed on ice or frozen as soon as possible. Fauna are separated from litter in the laboratory.

Average wind speed and air temperature are measured at each location with a handheld weather meter (e.g. Kestrel 3000). Measurements are taken in the center of the sampling area. Wind speed is averaged over a one-minute period, and air temperature is recorded after stabilization.

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## 7.4 HERPETOLOGICAL MONITORING ON GLORIA SUMMITS

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GLORIA *target regions* typically support assemblages of several vertebrate taxonomic groups. This presents opportunities to monitor such species in contexts of long-term *monitoring* of climate and ecological change performed under conventional GLORIA *monitoring* protocols in these rarified environments. Adding vertebrate *monitoring* modules also builds critically needed data series that can improve understanding of both species ecology as well as change processes of global importance.

In GLORIA *target regions*, herpetological work is concerned with censusing amphibian and reptile species for diversity, abundance and disease prevalence at a range of sites in the general vicinity of the GLORIA summits (Seimon et al. 2007), along line transects at the summits themselves, and along transects downslope from the summits. Here we present an approach developed for *herpetological monitoring* in the Cordillera Vilcanota of the Peruvian Andes, and performed by herpetological survey work conducted in other South American GLORIA *target regions* including Sajama and Apolobamba (Bolivia), and Famatina (Argentina).

### OBJECTIVES/AIMS

This module complements other GLORIA methods, and is therefore structured to fit to the methodology used for plants, invertebrates, and other vertebrates such that surveys can be conducted by teams working concurrently. We restrict our discussion here to systematic line transect surveys performed on GLORIA summits; however, more general surveying can be conducted elsewhere around the *target region* (see e.g. methods in Seimon et al. 2007). The module is split into two parts and will allow the researcher to perform the following two objectives:

- ◆ Assessment of species diversity and *monitoring* the population of amphibians and reptiles; and
- ◆ assessment of the amphibian chytrid fungus *Batrachochytrium dendrobatidis* (Bd) in amphibians at the survey site.

Bd is an emerging infectious disease considered to be a leading conservation threat, causing declines and extinctions in numerous species worldwide (Collins & Crump 2009, Fisher et al. 2012). These two methods do not have to be conducted concurrently, and the researcher has the flexibility to choose the methods that are most

appropriate for the survey site and the resources available. Utilization of both methods will allow the long-term evaluation of the response of amphibians and reptiles in habitats undergoing environmental changes, and will allow the generation of baseline data and simultaneous *monitoring* of the impact of disease in a context of climatic change.

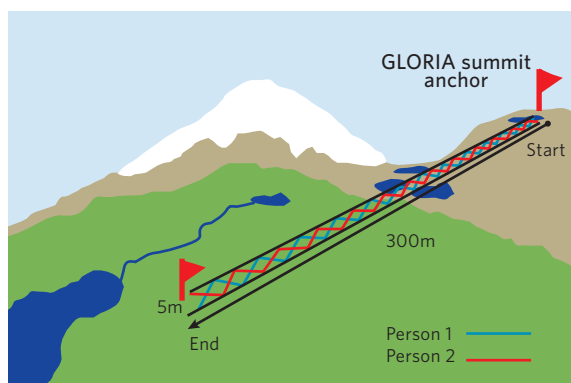
### PRE-SURVEY ACTIVITIES:

- ◆ Conduct literature reviews on the types of species and environmental characteristics of the *target region*.
- ◆ Establish contact with a herpetologist expert in the taxonomy of species in the region who can ensure proper species identification and interpretation of results.
- ◆ Seek out necessary information about collection and import/export permits from national wildlife management authorities well ahead of time (six months or more may be necessary) to ensure permissions can be arranged before you head into the field.
- ◆ Identify and contact a laboratory to perform molecular testing for amphibian pathogens to help ensure that samples will be tested in a timely and cost-effective manner.

### OBJECTIVE 1. ASSESSMENT OF SPECIES DIVERSITY AND MONITORING POPULATIONS OF AMPHIBIANS AND REPTILES

- ◆ **Materials for quantitative transect:** GPS, pH strips, ruler and tape measure, 300m of string or flags, thermometer, notebooks, camera, ziploc bags, permanent marker pens, soft hand nets, spring scales, 70% ethanol and spray bottle for cleansing equipment and boots.
- ◆ **Sampling Design** for developing an elevational transect and performing a visual encounter survey: The main objective of this module is to assess the amphibian and reptile diversity. The abundance and the spread of Bd in relation to anuran range extension can be monitored as a second activity.
- ◆ **Setting the transect corridors:** For herpetological surveys, all elevational transects on GLORIA summits originate at the *highest summit point (HSP)* and extend for 300m (surface distance) in a corridor 5m wide (Fig. 7.8 and Fig. 7.9). The surveyor sets the transect corridor by walking from the *HSP* maintaining the chosen *compass bearing* (see below) while marking the centerline by planting flags every 15 meters (string could also be used). The endpoint is set 300m from





**Fig. 7.8** Scheme of a transect for herpetological monitoring used to perform visual encounter survey from a GLORIA highest summit point.

the HSP and should be marked with a stone cairn or similar indicator to facilitate future resurveys. For reptiles, transects may be developed crosswise from the HSP in the four cardinal directions: this method facilitates consistency and comparison with invertebrate and plant sampling protocols. For amphibians, a single transect of 5m x 300m is set from the HSP on a bearing aimed at intersecting the most favourable habitat such as watercourses, ponds, spring sources, etc. (Fig. 7.9). It is up to the surveyor to establish the optimal direction, and this and other metadata must be carefully recorded in notes to enable replication in future surveys (e.g. record distance and compass bearing from HSP, GPS points, and photos). Be careful when walking in the summit area, especially at the 3m x 3m quadrat clusters, to avoid trampling impacts.

◆ **Visual Encounter Survey:** After transect corridors are set, two to three surveyors will perform a visual encounter survey starting at the HSP. They will walk through accessible terrain in a crisscross pattern extending 2.5m on either side of the centerline marked by the flags. To locate specimens that may be hidden from view, they will overturn rocks, probe and separate bunchgrass and other vegetation, and sift through ponds using nets (Fig. 7.8 and Fig. 7.9). Take care to minimize disturbance to the natural habitat by returning all rocks and vegetation disturbed during the survey to its previous state (Fig. 7.10).

◆ **Biosecurity considerations:** The amphibian chytrid fungus (Bd) is transmitted by a form of the fungus called a “zoospore” and causes chytridiomycosis, a disease fatal to many amphibian species. Zoospores require moisture and cool temperatures and can persist in moist environments



**Fig. 7.9** The lower terminus of a herpetological survey transect looking northeast from the GPS unit at the lower endpoint towards the origin at a GLORIA highest summit point. The distance is 300m along a line of small flags marked with highly visible green tape. The red dashed line highlights the centerline axis in the figure.



**Fig. 7.10** Visual Encounter Survey methods include removing and then carefully replacing rocks to locate vertebrates that might be otherwise hidden from view.

for several months. Therefore, Bd zoospores spread from place to place in water, moist or wet materials (including soil or scientific equipment) or on the skin of infected amphibians. Researchers working in the field must be aware of two main risks they pose that can imperil amphibians and other taxa:



- ❖ spread of disease within a population;
- ❖ spread of disease between sites.

A site is defined as a location or place within which the proximity of individual amphibians is close enough that it is likely to transmit pathogens to each other. Its size is dependent on the particular pathogen and physical characteristics of the location. For amphibian researchers working within river systems, separate transects should be regarded as separate sites, requiring biosecurity protocols to be applied. For isolated water bodies such as lakes, ponds and dams, separate water bodies should likewise be regarded as separate sites. To minimize disease risk a 'Fieldwork Code of Practice' has been developed by the Declining Amphibian Task Force (see <http://www.fws.gov/ventura/docs/species/protocols/DAFTA.pdf>):

- ❖ Treat everything an amphibian touches as a biosecurity risk and minimize risks where possible.
- ❖ To minimize disease risk frogs should only be handled when necessary and with fresh clean gloves. Gloves should be changed between each animal.
- ❖ A 'one bag - one frog or tadpole' approach should be used for frog handling. Never keep animals co-housed in catching bags.
- ❖ Bags should not be re-used unless completely disinfected between uses. Note that if skin swab samples are going to be taken to test for Bd using quantitative PCR, bags should never be re-used. Remember that PCR is very sensitive and the current methods can detect less than one zoospore of Bd contamination leading to potential false positive results.
- ❖ Clean every piece of measuring equipment and containers between specimens.
- ❖ Scrub and clean muddy boots and equipment before decontamination.
- ❖ Fully decontaminate equipment between sites (including boots and nets).
- ❖ Use diluted bleach, sodium hypochlorite (4%) or ethanol (70%) to disinfect equipment, boots and clothing.

◆ **Data collection:** During the survey, collect for each animal encountered data on GPS location, elevation, water temperature, air temperature, pH and weather conditions. Photograph the individual and the habitat, measure the snout-ventral length of the animal, and record its weight using a digital or spring scale. Note the overall health of the

animal (i.e. if the animal appears active, jumps/runs normally and is generally active, or if the animal seems lethargic and fails to jump or run on contact). If you have specialists on the survey team who are able to identify species with certainty, amphibians and reptiles may be released after recording. If not, it will be necessary to take high-quality close-up photographs in sharp focus and eventually collect a voucher specimen for identification by an experienced taxonomist.

## OBJECTIVE 2. ASSESSMENT OF THE AMPHIBIAN CHYTRID FUNGUS BD IN AMPHIBIANS FOUND WITHIN THE SURVEY SITE

- ◆ Materials for monitoring health status: GPS, notebooks, camera, box of nitrile gloves, small and large re-sealable bags (e.g. ziploc bags), scissors, water-proof marker pen, nets, brush for cleaning mud off boots before disinfecting, 70% ethanol and spray bottle for cleaning equipment and boots between sites, and sterile fine tip swabs such as Rayon swabs cat# MW113 from Advantage Bundling/Medical Wire Company. Avoid swabs with stems made of wood or metal.
- ◆ Sampling procedure for the collection of swabs for Bd analysis: This protocol was developed to allow field biologists to non-destructively sample amphibians in the field for the presence of Bd (Brem et al. 2007).
  - ❖ Prior to swabbing, label tubes (one per animal) with the ID number, GPS coordinates and name of location, species or common name, approximate age, and date.
  - ❖ Gently, capture amphibians by hand. If you are using a dip net, be aware that Bd zoospores could be caught on the net and transferred between individuals or provide false positive results, therefore, use different nets whenever possible, or disinfect the net as often as you can (there is no perfect solution to this problem).
  - ❖ Swab the underside of the hind feet, thighs, abdomen, and forefeet, each four to five times. Remember you are in effect scraping small amounts of tissue from the skin. Some pressure must be applied but be gentle.
  - ❖ Place the swab back in the tube and cap it.
  - ❖ If sampling more than one amphibian, change gloves and repeat process. When removing gloves, the best way to prevent contamination is to pull the gloves off by inverting them into each other. To reduce risk

of contamination, it is useful for one person to perform the swabbing and a second person to handle the amphibians.

❖ Samples need to be stored dry and can be kept at room temperature prior to shipment for testing. If the environment is humid it is best to place tubes in a sealable box with desiccant. Avoid extreme high temperature and direct sunlight. Freezing at -20°C is recommended for long-term storage. The samples should be sent to a laboratory that performs chytrid diagnostics. There, the DNA from the swabs will be extracted and tested by real-time quantitative Polymerase Chain Reaction (PCR) for the amplification of Bd using established methods (Boyle et al. 2004).

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## 7.5 SOIL VARIABILITY AT GLORIA SITES

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Soil is a three dimensional body with properties reflecting the impact of factors such as climate, parent material, topography, vegetation, soil organisms (including bacteria and invertebrates), and time span. Soils are continuously changing, they are dynamic, and soil taken at different depths reflects the age and differentiation of the soil material.

### OBJECTIVES AND AIMS

The main objective of this additional activity within GLORIA is to provide baseline information on soil parameters related to key ecological processes, such as soil carbon and nitrogen dynamics, for long-term *monitoring* of soil ecological processes under global change scenarios.

### SOIL SAMPLING

As a general rule, soil samples are to be collected during the mid-growing season. On each summit four locations that correspond to the *cardinal directions* north, east, south and west are selected. Two types of soil samples, taken outside the lower *summit areas* (Fig. 7.11) in each *cardinal direction* are recommended:

#### SAMPLE TYPE 1

Four soil samples (S1) per *summit site* (16 per *target region*) are taken outside below the 10-m *summit area* section in each *cardinal direction*. (Fig. 7.11). Always be very careful when taking soil samples in order to minimize soil and site disturbance.

One soil core of approximately 5 cm × 5 cm and 20 cm depth is taken (approximately 500g of soil, wet weight).

The soil core is divided into two fractions: 0-10 cm depth and 10-20 cm depth. At shallow soils the depth interval can be adjusted to 0-5 cm, 5-10 cm, or 0-2.5 cm, 2.5-5 cm, respectively, dependent on the site conditions. Upper and lower parts of the core are put in separate labeled plastic bags for transportation.

Back in the lab, soil samples are gently crumbled manually while fresh to break the soil aggregates, and then the crumbled soil is air-dried for several days and sieved at ≤ 2 mm for the subsequent analysis.

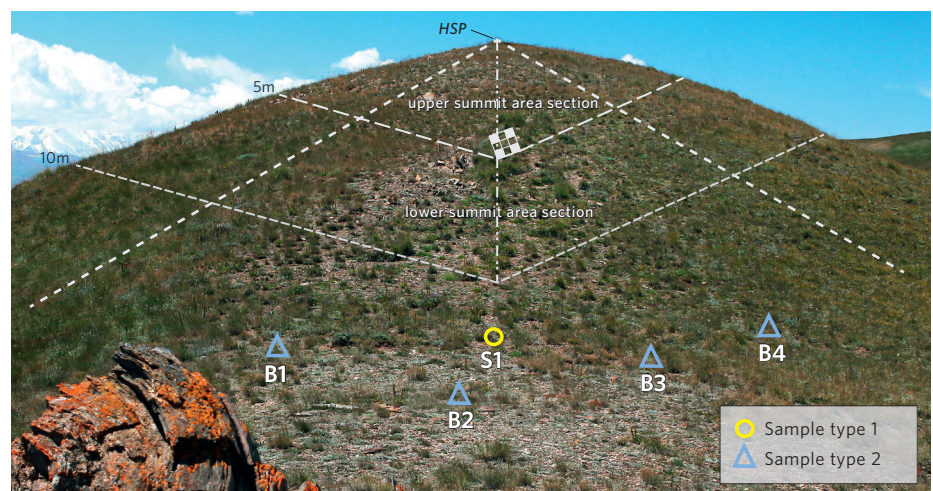
#### Basic variables recommended to be analyzed in sample type 1:

- ◆ Soil pH (soil diluted in H<sub>2</sub>O and CaCl<sub>2</sub>);
- ◆ Particle size fractionation: percentage of sand, silt and clay components,
- ◆ Soil texture,
- ◆ Total C (organic and inorganic),
- ◆ N and P contents.

The **C:N** and **N:P** ratios are important indicators of ecosystem functioning (Wardle et al. 2004), and the use of physical fractionation methods allows disentangling the factors involved in the associations between soil mineralogy and soil organic carbon (SOC) as they differ in composition, structure and function (Christensen 2001). These methods expose the organic matter (OM) that is physically protected in soil aggregates. Few data exist on SOC concentrations and particle-size fractions in soils collected from alpine environments, or the age of carbon fixed in the mineral part. Concentrations of C and N in each particle-size soil fraction are determined with the dry combustion method.

**Elemental concentrations of nutrients** (Ca, Mg, Na, K, and P) are measured with inductively coupled plasma (ICP)-AES equipment after acid digestion of soil samples.

**Fig. 7.11** Soil sampling locations for sample type 1 and 2.



## SAMPLE TYPE 2 (FOUR SUBSAMPLES)

In each *cardinal direction* four soil subsamples (B1, B2, B3, B4; each of approx. 60g wet weight from approx. 0 to 10 cm soil depth) are taken outside below the 10-m *summit area section* (Fig. 7.11; 16 sub samples per *summit site*; 64 per *target region*). Every sub-sample should be put in a separate, labeled plastic bag and stored in portable ice coolers while being in the field and afterwards at 4°C in the lab to halt further soil mineralization processes. These samples will be used for assessment of soil mineral nitrogen content, i.e., ammonium (NH<sub>4</sub><sup>+</sup>) and nitrate (NO<sub>3</sub><sup>-</sup>) concentrations, which are a direct measure of N availability for plants, and soil incubation experiments.

NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub><sup>-</sup> concentrations are analyzed in three replicates for each of the four subsamples collected and values averaged for each aspect (i.e. 12 per aspect). The procedure is as follows: 4g of fresh soil are mechanically shaken for 30 minutes with 40 ml of 1M KCL solution to extract mineral N. Later, the suspensions are filtered and filtrates are stored at -15°C until a standard colorimetric method is applied to determine NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub><sup>-</sup> concentrations. For the incubation experiment the soil is kept moist in dark at controlled temperature and NO<sub>3</sub><sup>-</sup> measurements are taken at day 0 and day 21 to estimate soil nitrification process. Only small amounts of soil are required to prepare the extracts for this analysis.

### Further recommended soil analyses for GLORIA sites include:

- ◆ SOC (soil organic carbon) stabilization: The methods used for characterizing SOC stabilization are not suitable for charcoal or black carbon (BC) estimation. Alternative methods, however, have shown that the oxidation with sodium persulfate is suitable to isolate a stable fraction from soils where charcoal/BC is a significant contributor to SOM (soil organic matter). Fresh roots should be removed before air-drying.
- ◆ Soil incubation for CO<sub>2</sub> flux measurements in incubators at different temperature (T) regimes, e.g. mean winter and summer T recorded by the standard data loggers. Since some of the necessary equipment and tools to assess CO<sub>2</sub> fluxes in field conditions are constrained by the harsh environmental conditions of alpine habitats, soil incubation methods are recommended.
- ◆ Determination of soil microbial biomass (labile C) with the chloroform fumigation-extraction technique (FE) on fresh samples (Coleman et al. 2004).
- ◆ Microbial community analysis. Two methods are suggested:
  - ❖ Determination of CLPP (Community-Level Physiological Profiles) to measure the

C substrate utilisation patterns of microbial communities (Muñiz et al. 2014).

- ❖ Phospholipid-derived fatty acids (PLFA) analysis is used as a marker to differentiate bacteria and fungi groups based on the fatty acid signatures of the membrane of the micro-organism. The fungal/bacterial ratio is then calculated from the amounts of PLFAs specific to fungi and bacteria, respectively (Frostegård & Bååth 1996).

- ◆ Invertebrate biogenic structures. Although difficult for some areas it would be desirable to collect biogenic structures (BS) produced by invertebrates, i.e. earthworms and ants. Standard analyses apply for these types of samples, and we also recommend the use of NIRS (Near Infrared Spectroscopy) signatures (Joffre et al. 2001) to characterize the molecular composition of organic matter for assessment of both BS and bulk soil to assess the influence of soil animal activity on C and N dynamics (Hedde et al. 2005).

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## 7.6 SOCIO-ECONOMIC AND CULTURAL ASPECTS IN GLORIA REGIONS

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### INTRODUCTION

The GLORIA methodology asks that researchers select sites and establish *target regions* in areas that are minimally influenced by humans. However, in some areas, fulfilling this ideal criterion can be challenging to near impossible. Multiple research sites in the Andes, for example, have been established in remote areas, but the influence and activities of humans, from pastoral production to tourism, are often still present and impact the vegetation cover and land cover change in a *target region*. Andean landscapes, including seemingly isolated mountain peaks, are the product of several millennia of the interactions of mountain climate and hydrological systems, physical and bio-geographic variables, and *anthropogenic activities* (Thomas & Winterhalder 1976, Browman 1989, Baied & Wheeler 1993, Gade 1999, Denevan 2001). Recognizing the myth of finding a “pristine landscape” in the Andes (Denevan 1992), GLORIA teams working in South America have worked to incorporate socio-economic and cultural aspects in site establishment and *monitoring*.

It is important to recognize that landscapes are cultural products that are continuously shaped by humans interacting with and impacting natural systems (Sauer 1929, Crumley et al. 1994). While *target regions* across the globe may have a varying amount of human impacts and different socio-economic factors to consider, our GLORIA research in South America encountered multiple, yet common, human activities in relation to site establishment, and provide here baseline considerations for site implementation and *monitoring*.

In the overall GLORIA context, we can subsume that

- ◆ GLORIA standard summit sites are reference points. As for meteorological stations, they are invaluable to researchers, whether it be in social or biological sciences, to anchor their investigations in the environmental context of change.
- ◆ Human-mediated impacts are prevalent. If we do not acknowledge and record them, they may be masked as the ‘noise’ of random fluctuations. Incorporating human impacts explicitly allow for them to be understood, and their trends and tendencies evaluated. Also, they can then be identified among the multiple drivers of change to

determine those parts of change due to humans, to climate, or to other causes.

### OBJECTIVE

The primary objective of this module is to provide a framework for recognizing and documenting anthropogenic factors in GLORIA site establishment and *monitoring*. GLORIA sites are often considered the nexus of interdisciplinary studies, and this may also include socio-economic and cultural aspects that influence the vegetation of sites both in the present and future.

Considering human activities also provides a broader multi-scale context to GLORIA sites, heightening their value and interest for surrounding populations and decision-makers.

### GUIDELINES FOR DOCUMENTING ANTHROPOGENIC ACTIVITIES

Upon selection of a *target region*, it is important to document the breadth and degree of human impacts in the area that may influence site characteristics. The guidelines of this module include consideration of the following:

- ◆ *anthropogenic activities*,
- ◆ temporal and spatial dimensions,
- ◆ additional documentation, and
- ◆ establishing *local partnerships*.

#### ◆ *Anthropogenic activities*

Drawing upon our GLORIA experiences in the Andes of Peru (Vilcanota) and Bolivia (Sajama, Tuní, and Apolobamba), [Table 7.2](#) provides a baseline reference of the dominant *anthropogenic activities* that may influence site characteristics. All of the listed factors have been found in relation to GLORIA sites in the Andes and many researched further (Halloy et al. 2010). Each *target region* is different, but human presence is often unavoidable and therefore must be accounted for.

**Table 7.2** Anthropogenic factors that may impact GLORIA sites and require documentation

<b>A</b>	<b>Land use</b>
◆	pastoralism
◆	agriculture
◆	mining
◆	tourism
◆	hunting
◆	plant gathering for medicinal or traditional use
◆	ceremonial or sacred sites
◆	fire/burning practices
<b>B</b>	<b>Land tenure/management</b>
◆	private, communal, national, or institutional
◆	formal and informal arrangements in land access, protection and management



Some anthropogenic factors may require further investigation in order to properly assess the amount of impact they may have in a *target region* or on site characteristics. For example, pastoralism is particularly common in the Andes, and both domesticated and wild grazing animals can influence species richness and cover in a *target region* (Yager et al. 2008a, Patty et al. 2010). Often evidence of animal grazers is documented at GLORIA sites during site establishment and survey, including presence of animal dung/droppings or clipping (i.e. grazing) of vegetation. If there is abundant evidence of animals disturbing the site, it may be of interest to conduct a more thorough study of the number of animals accessing the site, and to further investigate local pasture management or rotation practices. Pasture management may often include intentional or non-intentional burning or fire practices that will certainly influence vegetation succession. These activities may require interviews with locals and field *monitoring* (including camera installation or on-going surveys).

Also prevalent in the Andes is the use of a *target region* by locals and visitors for tourism, plant gathering, and ceremonial practices. Therefore, the amount of foot traffic in a region may vary throughout the year and over time. Some may come infrequently or seasonally, accessing the area as a corridor for photography, trekking, or exploration, while others may come regularly to gather rare plants for medicinal purposes, or to visit high mountain areas for ceremonial purposes. Below are photographs that show some of the common human activities (Fig. 7.12) as occurring in the GLORIA *target region* of Sajama National Park, Bolivia.

#### ◆ Temporal and spatial dimensions

It is important to also recognize the temporal and spatial dimensions of human impacts. In particular, one must consider the past, present, and potential impacts of humans while documenting and *monitoring* sites. Even if human presence is not highly visible or noted during site establishment, it does not guarantee that sites may not be subject to the impacts of social changes in the future. Sites

might have been impacted in the past in ways which are not necessarily obvious to the uninformed researcher. For example, past large-scale extraction of yareta (*Azorella compacta*) cushions and queñua (*Polylepis tarapacana*) trees for fuel used in mines and railroads has left whole landscapes devoid of these plants, which were originally part of the local alpine vegetation.

While mountain and alpine areas, from the Alps to the Andes, are recognized and even valued for their isolation, thus making them ideal “natural laboratories” for the study of natural systems and minimally influenced vegetation (Barry 1994, Grabherr et al. 2000, Körner 2003); it is also recognized that humans have inhabited and influenced alpine ecological systems for generations (Ellenberg 1979, Netting 1981, 1990, Gade 1999), alongside climate change in recent years (Grabherr et al. 1994, Erschbamer et al. 2006, Gottfried et al. 2012, Pauli et al. 2012), and that both climate change and humans are expected to have an even greater impact on alpine regions in the future (Beniston 1994, Vuille et al. 2008, Seimon et al. 2009). In the Andes, even the “protected areas” have many indigenous communities that continue to live in the park and utilize the resources, including alpine vegetation. Thus, the human factor must be considered along with the climate change factor over space and time.

Climate change and ongoing social changes (from population growth to competition over land or resources) may further influence future access and the movement of people and animals into a region. Production zones of a particular ecological tier may become overcrowded or unproductive due to climate or social change, and cause the displacement or upward movement of peoples and animals to access, occupy, and utilize the resources at higher elevations in mountain regions. Thus, it is important to consider and document the varying levels of production and people in a particular *target region*. Drawing again on the example of GLORIA in Sajama, the primary production zones in a *target region* were documented, including the elevational tiers of production and dominant species (Yager 2009, Beck et al. 2010a). Interdisciplinary studies



**Fig. 7.12** Photographs of *anthropogenic activities* in a GLORIA *target region*, Sajama, Bolivia.  
(Left: Burning, Center: Pathways, Right: Cultural Site)



**Fig. 7.13** Photographs of local workshops and community work on GLORIA and climate change themes, Sajama, Bolivia.

of GLORIA in Vilcanota have also examined species movement and human dimensions (Halloy et al. 2006, Seimon et al. 2007, Seimon et al. 2009). Once documented, it can provide reference for changes or encroachments occurring in the future, due to both climatic and human changes. With adequate documentation, one can both tease apart the influence of different drivers, as well as investigate their synergies.

#### ◆ Additional documentation

Other factors that may merit further investigation and possibly mapping include documentation of population settlements, paths or roads, and community or private infrastructure (canals, dams, structures, business, etc.). Satellite imagery and aerial photography often provides a reference for site selection and also documentation of human presence and potential influences on GLORIA sites. In some cases, we conducted mapping exercises directly with community members (Yager 2009, Meneses et al. 2010). In this way, areas of intensive land cover changes or threats to GLORIA sites could be more easily identified. Other resources that may provide important quantitative information on socio-economic activities and cultural infrastructure include municipal plans, protected area management plans, and interviews with key informants that regularly access or live in the GLORIA *target region*.

#### ◆ Establishing local partnerships

One of the most important aspects of our projects in South America is to establish personal and engaging relationships with local populations and communities in the GLORIA *target region*. In order to facilitate the awareness and objectives of GLORIA, and also to engage locals in participating in plant identification or site selection, we have conducted various workshops, interviews, and field exercises with local communities (Fig. 7.13). The purpose is to create a mutually beneficial relationship where objectives, visions, experiences, and lessons are shared and respected. In this way, both the scientists that come into an area to investigate, and the

locals inhabiting a region, share an interest in the project's success and benefit from the results and engagement.

A great deal of local community work has been conducted at the GLORIA sites Sajama and Apolobamba, with positive results (Ulloa & Yager 2007, Yager et al. 2008b, Beck et al. 2010b, Hoffmann & Yager 2010, Meneses et al. 2010). Park guards and community members have assisted in the installation and *monitoring* of sites, as well as sharing in identifying the impacts of climate change from both a scientific and experiential perspective. Many local indigenous communities in the Andes maintain traditional livelihood practices, such as pastoralism as a primary economic activity, and thus depend on a healthy and abundant alpine vegetation. Therefore, these communities directly benefit from engaging in a discussion and participating in GLORIA research to assist in generating a more holistic understanding of climate changes impacts on vegetation and local livelihoods. In areas where human populations are actively present in *target regions*, establishing interdisciplinary GLORIA teams and *local partnerships* is essential to understanding the full range of climate change impacts, and is also mutually beneficial in continued site *monitoring*.

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## 7.7 ETHNOBOTANY INTEGRATED WITHIN GLORIA

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In many parts of the world, especially in less developed regions and on indigenous peoples' lands, alpine vegetation is tightly linked to livelihoods and ecosystem services (see, for example, Salick & Byg 2007, Salick 2012). Also in the European Alps, however, many ethnobotanically important alpine plants were recorded (Grabherr 2009, Lamprecht 2012). To put our GLORIA and climate change data in context, it is valuable to record alpine plant uses, as well as local peoples' perceptions of, adaptations to, and mitigations of climate change. Why is GLORIA important to local people? Why do people care about changing alpine plant distributions and populations with climate change? How will these affect their lives and livelihoods? How are people adapting to these changes? What traditional mitigation strategies are being practiced (perhaps unwittingly) and could be supported? Depending on time and monetary constraints, these questions can be easily and directly answered within the GLORIA framework or more elaborately and significantly addressed with extra time devoted in alpine communities.

Most directly, uses of all plants inventoried in GLORIA sampling can be recorded. Uses can be determined by directly interviewing traditional doctors (Fig. 7.14), local inhabitants and/or by referring to the literature. These use data are best recorded in comparable formats by all participating GLORIA teams, so that we can analyze relative importance of alpine vegetation among various peoples around the world.



**Fig. 7.14 An ethnobotany interview.** Himalayan GLORIA researchers Dr. Suresh Ghimire (Nepal, left) and Sangay Dema, MSc (Bhutan, right) interview Jigme, traditional medicine expert (center), at the Institute of Traditional Medicine Services, Bhutan. Photo by Ben Staver.

It is not crucial that everyone uses exactly the same database, but comparability is useful. The Missouri Botanical Garden (MBG) has developed a relatively simple specimen based *Ethnobotany* database that I use as an example, but other institutions have their own systems as well (Cook 1995). At MBG the *Ethnobotany* database is embedded within the general herbarium database (TROPICOS, [www.tropicos.org](http://www.tropicos.org)) so that basic herbarium and *Ethnobotany* data for each voucher specimen include:

- ◆ Scientific taxon name
- ◆ Collectors and number
- ◆ Date
- ◆ Local expert, name, age
- ◆ Language (see Ethnologue [www.ethnologue.com/](http://www.ethnologue.com/))
- ◆ Ethnic Group/Cultural affiliation
- ◆ Country (see [http://www.iso.org/iso/country\\_codes.htm](http://www.iso.org/iso/country_codes.htm))
- ◆ Locality
- ◆ Geographic coordinates (latitude/longitude) of origin
- ◆ Use categories, see Table 7.3
- ◆ Plant part(s) used
- ◆ Vernacular name
- ◆ Production or processing
- ◆ Additional ethnographic information
- ◆ Image
- ◆ Collection permits/agreements
- ◆ Notes

The MBG associated *Ethnobotany* database includes simple general and subdivided fields to enter different kinds of usages (Table 7.3). Each use is associated with a plant part: leaf, stem, flower, seed, fruit, bark, wood, root, tuber, whole plant, or above ground plant. Additionally, notes on the preparation of the plant part and descriptions of use can be added to each use. These plant use data will allow us to compare the importance and ecosystem services of alpine flora around the world.

If GLORIA teams have the time and interest, further local community participation can illuminate the impacts of alpine climate change on people, their livelihoods and the ecosystem services provided by alpine environments. For example, we have done extensive interviews (for methodology see Kutsche 1998) and used GIS (Clarke 2003, Bolstad 2005, DeMers 2005, Longley et al. 2005, Chang 2006) and participatory techniques (Chambers 1994a, b) to understand various aspects of peoples' responses to climate change in our GLORIA areas including:

- ◆ Traditional people and climate change (Salick & Byg 2007, Salick & Ross 2009)



<b>Table 7.3 Use categories of Missouri Botanical Garden <i>Ethnobotany</i> database</b> (under TROPICOS, <a href="http://www.tropicos.org">www.tropicos.org</a> )		
<b>A Food – human</b>	◆ Infections, parasites, fungi	<b>G Cultural Uses</b>
◆ Beverages	◆ Inflammation and pain	◆ Handicrafts (non-fiber)
◆ Condiments, herbs, spices	◆ Poisons and antidotes	◆ Recreation, games, sports, toys
◆ Fruits and vegetables	◆ Zoopharmacognosy	◆ Religion
◆ Legumes and pulses	◆ "Humors"	◆ Accessories, cosmetics, jewelry
◆ Grains and rice	◆ Belief systems	◆ Musical instruments, art
◆ Root and tuber carbohydrates	◆ General, non-specific symptoms	◆ Psychoactive drugs
◆ Nuts	◆ Other/NA	◆ Other/NA
◆ Additives		
◆ Other/NA	<b>D Chemicals</b>	<b>H Constructions/Structural materials</b>
	◆ Latex, rubber	◆ Timber
<b>B Food – animal</b>	◆ Resins, non-edible gums	◆ Furniture
◆ Fodder, forage, graze, silage	◆ Oils (non-edible), waxes, soaps	◆ Building materials
◆ Browse	◆ Dyes, paints, colors	◆ Tools, utensils
◆ Invertebrate food	◆ Tannins, flavonoids	◆ Transportation
◆ Fruits	◆ Aromatics	◆ Other/NA
◆ Other/NA	◆ Solvents	
	◆ Adhesives	<b>I Environmental</b>
<b>C Medicines – human &amp; veterinary</b>	◆ Other/NA	◆ Barriers, boundaries
◆ Blood and circulatory system		◆ Erosion control
◆ Dental	<b>E Fuels</b>	◆ Fertilizers, soil improvement
◆ Digestive system	◆ Firewood, charcoal	◆ Ornamentals
◆ Endocrine system (hormones)	◆ Oils, alcohols, resins, waxes	◆ Pollution control
◆ Female and male reproductive systems	◆ Other/NA	◆ Pest control
◆ Urinary system		◆ Other/NA
◆ Immune system	<b>F Fibers</b>	
◆ Metabolic system, fevers, nutrition	◆ Cloth, clothing, apparel, thread	<b>J Other</b>
◆ Muscular-skeletal systems	◆ Paper	◆ Research
◆ Nervous system and mental health	◆ Baskets, fiber, containers, fiber	◆ Genetic resources
◆ Respiratory system	household goods, fiber handicrafts	
◆ Sensory systems	◆ Rope, string, netting	<b>K Notes: detail on use(s)</b>
◆ Skin and related tissue	◆ Other/NA	

- ◆ Tibetans' perceptions of climate change (Byg & Salick 2009, Salick et al. 2012)
- ◆ Traditional agro-pastoral land use and change (Salick et al. 2005, Salick & Moseley 2012)
- ◆ Tibetan sacred sites conserve alpine biodiversity (Anderson et al. 2005, Salick et al. 2007)
- ◆ Tibetan doctors and villagers collect medicinal plants in high alpine meadows (Salick et al. 2004, Law & Salick 2005, Salick et al. 2006, Law & Salick 2007, Salick et al. 2009, Byg et al. 2010, Salick et al. 2012)
- ◆ Tibetan cosmology of climate change (Salick & Moseley 2012)
- ◆ Climate change affects Tibetan culture, land use, health, medicine, agriculture, and forestry (Salick 2012, Salick et al. 2012)
- ◆ Using traditional knowledge, Tibetans creatively adapt to climate change (Salick et al. 2012)

Added to GLORIA's intensive ecological *monitoring*, these cultural data provide a powerful platform from which to analyze the dynamics of coupled natural and human systems in response to global climate change. Additionally, GLORIA data are given meaning and relevance to local people with whom many of us work.

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# GLOSSARY OF TERMS USED IN THE MANUAL

» All terms listed in this glossary are written in *italics* throughout this manual.

**1-m<sup>2</sup> quadrat:** Permanent 1m×1m quadrats for detailed vegetation recording positioned at the four corner positions within the 3m×3m quadrat clusters.

**3m×3m quadrat cluster:** A 3m×3m square positioned in each of the four main geographic directions referring to the highest summit point (HSP) with its lower side at the 5-m level below the HSP.

**3m×3m grid:** Grids constructed of flexible measuring tapes with 3×3 subdivisions (i.e. nine 1-m<sup>2</sup> quadrats); see Fig. Al.1 in Annex I.

**5-m level:** The elevation level at the 5-m contour line below the highest summit point (HSP).

**5-m summit area:** The upper summit area, divided into four summit area sections for recording. This area reaches the 5-m level at the two lower corner points (p5m-...) of each 3m×3m quadrat cluster. Between the quadrat clusters, this area usually lies above the 5-m level because the corner points are connected by the shortest straight lines possible. The 5-m summit area also includes the quadrats of the 3m×3m quadrat clusters.

**10-m level:** The elevation level at the 10-m contour line below the highest summit point (HSP).

**10-m summit area:** The lower summit area, divided into four summit area sections for sampling. The lower boundary of this area is delimited by four corner points (p10m-) at the 10-m level in each of the four cardinal directions, which are connected by the shortest straight lines possible. The 10-m summit area lies between this line and the lower limit of the 5-m summit area.

**10m×10m squares:** A supplementary design and recording procedure within the summit area. 10m×10m squares are established in each cardinal direction with their mid-, upper and lower points on the intersection line of the respective cardinal direction, where the

mid-point is one of the lower corners of the 3m×3m quadrat cluster. In each square a total of 400 points are sampled by applying the *line-pointing* method along 20 parallel strings. Finally, the remaining rarer species not recorded during *line-pointing* are inventoried.

**16-quadrat area:** The sum of all 1-m<sup>2</sup> quadrats of a summit; these are 16 in number (four per quadrat cluster in four clusters, one in each cardinal direction).

**Abundance categories:** Abundance classes along an ordinal scale used for the estimation of species abundance in SASs. Five abundance categories are distinguished: r! (very rare), r (rare), s (scattered), c (common), d (dominant). See chapter 4.2 for definitions.

**Alpine life zone:** The mountain terrain starting at the low-temperature determined treeline ecotone and extending upwards. It comprises the area where any low-stature vegetation or scattered plant individuals between the climatic treeline ecotone and the highest mountain tops occur. The term is also applied to the entirety of high mountain biomes world-wide (compare Körner 2003).

**Alpine-nival ecotone (or subnival zone):** The transition between the alpine zone and the nival zone; it may coincide with the lower permafrost limit.

**Alpine zone:** The zone between the treeline and the upper limit of closed vegetation. Here, the vegetation is a significant part of the landscape and its physiognomy and plant cover is usually >20–40%. In some mountain regions it is subdivided into a lower alpine zone dominated by dwarf-shrub communities, and an upper alpine zone dominated by grassland communities (Nagy & Grabherr 2009).

**Altitudinal index:** Indicates the average vertical distribution of a plant species across a set of four summit areas of a GLORIA target region in a specific year of observation. It is computed by first defining the relative altitude of each summit in metres above the altitude of the lowest summit and second, by weighting these relative altitudes by the species' frequencies on the respective summits (i.e. the presence/

absence of the species in the eight summit area sections per summit). Finally the altitudinal index of a species is calculated as the weighted average altitude of the species' distribution across the four summit sites (Pauli et al. 2012).

**Altitudinal species profile:** Describes the vertical distribution of a plant species across vegetation belts by its lower (AL) and upper (AU) distribution margin, as well as its distribution centre (AC) (Gottfried et al. 2012). An AL-AC-AU profile is expressed as vegetation belts: montane (mo), treeline ecotone (tl), alpine (al), nival (ni), indifferent (id). E.g. mo-tl-al stands for a species which is centred at the treeline ecotone but extends into both the montane and the alpine belt, tl-id-al would mean the species is equally distributed from the treeline ecotone to the alpine belt. Extreme outposts at lower elevations should not be considered.

**Altitudinal species rank:** The vertical distribution of plant species defined by Gottfried et al. (2012) as six rank classes. Each rank class comprises a set of similar altitudinal species profiles, following the classical central European concept of vegetation belts. The ranks are defined as: (1) species with a nival distribution centre, (2) alpine to nival species that do not descend to the treeline, (3) alpine centred species which do not descend to the montane belt, (4) alpine centred species that descend to the montane belt and species indifferently distributed from the treeline to the alpine belt, (5) species centred in the treeline ecotone or indifferently distributed from the montane to the alpine belt, (6) species with a montane-centred distribution or indifferent from the montane belt to the treeline.

**Anthropogenic activities:** Impacts of human activities such as land use through, e.g., pastoralism, agriculture, mining, tourism, burning practices, or through land tenure may alter alpine vegetation and biodiversity patterns. Therefore, type, spatial dimension as well as temporal dimensions (impacts may change over time due to socio-economic constraints) are documented as an extra approach in some GLORIA target regions (chapter 7.6).

**Area cover:** The actual surface area a species covers in exact square measures. This is relevant in a supplementary approach for recording the cover of rare species in the SASS (chapter 5.2.2). For example, a rare species' total area cover may be determined by adding up area cover of individuals or groups of individuals, e.g. 5 cm × 5 cm × 3 individuals or 2 cm × 3 cm × 12 individuals, etc. The total area cover of species can later on be converted into percentage cover once the area of a SAS is calculated.

**Arthropod monitoring:** Several extra approaches are in use to monitor arthropod diversity in GLORIA target regions (chapter 7.3): (1) species-level census of butterflies, (2) standard sweeps for epigeal and volant arthropods at the family level, and (3) vacuum-quadrat method for small-scale sampling of substrate- and canopy-associated arthropods at the family level. Further pitfall trapping is used for ground-dwelling invertebrates monitoring on GLORIA summits (chapter 7.2).

**Bare ground:** Surface type used for top cover estimations: open soil (organic or mineral), i.e. earthy or sandy surface which is not covered by plants.

**Bryophytes on soil:** Surface type used for top cover estimations in 1-m<sup>2</sup> quadrats (Form 2): Bryophytes growing on soil without being covered by vascular plants, i.e. there are no multiple vegetation layers.

**Cardinal directions:** The main geographic directions north, east, south, and west (N, E, S, W).

**Central GLORIA Database:** This database (CGDB) is maintained at the GLORIA server in Vienna and contains all GLORIA data (such as on species, habitat and site properties, soil temperature, and photo data) recorded until now (see [www.gloria.ac.at](http://www.gloria.ac.at)). See also data property rights and data sharing.

**CGDB:** Central GLORIA Database.

**Clinometer:** An instrument to measure slope angle. A clinometer is needed for determining the 5-m level and 10-m level, where the clinometer indicates exact horizontal views when measuring downhill from the HSP. It also can be used for measuring slope within the 1-m<sup>2</sup> quadrats. For example, the Suunto

PM-5/360PC is a recommendable device.

**Coding:** Various items must have a GLORIA-wide standardised code, which is used in sampling forms, photographs, temperature data loggers, and in the data base. These codes define the country (two digits), the target region (three digits), the summit (three digits), the plot (three digits), the corner points of plots, and the date of recording (see Box 6.1 & Annex III for coding used in the photo documentation).

**Cold-adapted plant species:** Subsumes plant species which are capable to grow, reproduce and persist under low-temperature conditions. These usually low-stature plants are able to survive severe winter frost through frost-hardening and/or have special plant functional traits enabling them to cope with cold spells (rapid chilling) which can occur also in the growing season. In extra-tropical regions they are able to deal with short growing seasons. The term *cryophilic species* ("cold-loving") is sometimes used synonymously.

**Compass:** Use a hand-bearing compass with high accuracy; the Suunto KB-14/360 is a recommendable instrument for GLORIA measurements.

**Compass direction:** Determined at the HSP by using the 360° scale. Be careful, the magnetic compass direction usually deviates from the geographic direction by the magnetic declination. Both compass direction and magnetic declination must be known to point out any geographic direction such as the geographic cardinal directions (N, E, S, W) and those of second order (NE, SE, SW, NW).

**Contour lines:** Isolines which connect points of equal altitude; the contour line at the 5-m level as well as those at the 10-m level have to be determined in order to establishing the plots. Contour lines and the elevation levels refer here to the highest summit point.

**Crosshair points:** The intercept or intersection points of the strings of a pointing frame. For the standard Multi-Summit Approach, hundred points are used for recording in 1-m<sup>2</sup> quadrats by pointing with a grid frame.

**Cryophilic species:** "cold-loving" plants; sometimes used synonymously for cold-adapted plant species.

**Data property rights and data sharing:** Each contributor retains the exclusive ownership of the data. Therefore, the use of the data by others requires the data provider's permission (chapter 6.4).

**Downslope Plant Survey:** An extra approach for obtaining data on the regional vertical distribution range of vascular plant species. Horizontal transects of 100 m length are established at regular elevation intervals of 25 m from the highest standard summit site to some distance below the treeline. Line-pointing with 400 points per transect yield data on species cover and species inventories are made in each of the ten segments of 10 m × 1 m per transect (see chapter 7.1).

**E-5m-SA:** The upper summit area section on the east slope (see Fig. 3.2), delimited by the corner points: HSP, pSE-5 (at the intersection line), p5m-E11, p5m-E31, and pNE-5 (at the intersection line).

**E-10m-SA:** The lower summit area section on the east slope (see Fig. 3.2), delimited by the corner points: p5m-E11, pSE-5 and pSE-10 (at the intersection line), p10m-E, pNE-10 and pNE-5 (at the intersection line), and p5m-E31.

**Ecotone:** Used here as the transition zone between elevation belts, e.g. the treeline ecotone, the alpine-nival ecotone.

**Electronic spirit level:** Might be used alternatively instead of a clinometer for determining the 5-m and the 10-m level and for measuring slope angles (e.g. 'Swiss Level', with a display showing the degrees of angle and with a beep signal when positioned horizontally or vertically), however, a clinometer (Suunto PM-5/360PC) may be more accurate and easier to handle in the field.

**Ethnobotany:** In order to put GLORIA data in context of human plant use, in some GLORIA target regions ethnobotanical data of vascular plant species found on the monitoring summits are collected along a standardised protocol developed for the Missouri Botanical Garden Ethnobotany database (chapter 7.7).

**EXAP:** Extra approaches performed in a GLORIA target region.

**Extra approaches (EXAP):** This category was introduced to distinguish additional recording activities performed within a GLORIA *target region* from those which are spatially and methodically strictly confined to the *summit areas* (STAM and SUPM, described in chapters 3-5). EXAPs deal with animal organism groups, *Downslope Plant Surveys*, *soil variability*, and socio-economic and cultural aspects (see chapter 7).

**Flat summit:** Flat or plateau-like high mountain landscapes are common in some mountain systems. Wherever possible, *flat summit* situations should be avoided. Only in absence of alternatives, such summits may exceptionally be used. A slight modification of the sampling design, however, is needed in these cases in order to keep the sampling area at a reasonable size: If the *5-m level* is not reached within 50m surface distance from the HSP, establish the “lower” side of the *3m×3m grid* at this 50m distance point. Similarly, if the *10-m level* is not reached within 100m, put the “10-m point” at 100m distance from the HSP (see also [Box 3.4](#)).

**Flexible measuring tapes:** Rolls of tape measure with a centimetre scale which can be wound up. 50-m tapes are best for measuring the HSP-corner point distances, short tapes (usually 2 m, or 3 m) for measuring data logger distances from the nearest *measurement points* and for measuring the exact vertical distances at the *5-m* and *10-m levels*.

**Form 0:** Protocol sheet for general information of the *target region* (in Annex II).

**Form 1:** Measurement protocol for the summit setup (in Annex II).

**Form 2:** Standard sampling sheet for *1-m<sup>2</sup> quadrats* (in Annex II).

**Form 3:** Standard sampling sheet for *summit area sections* (in Annex II).

**Form 4:** Protocol sheet for codes, positions and start/end dates of *temperature data loggers* (in Annex II).

**Form 5-S:** Sampling sheet for *subplot-frequency counts* in *1-m<sup>2</sup> quadrats* (in Annex II).

**Form 6-S:** Sampling sheet for *10m×10m squares* (in Annex II).

**Forestline (or timberline):** The line where closed (montane) forests end.

**Frequency counts:** See *subplot-frequency counts*.

**Frequency grid frame:** Wooden (or aluminium) frame with an inner width of 1m×1m with cell divisions of 0.1m×0.1m (see [Fig. 5.1](#)) used for *subplot-frequency counts*. The frame differs from the *pointing frame* by the number and arrangement of strings which are here only nine in each direction and the outer strings are positioned 10cm from the margin.

**GDIT:** GLORIA data input tool.

**Geographic direction:** The directions relative to the geographic North Pole; main (or cardinal) *geographic directions*: north, east, south, west (N, E, S, W), to be used for fixing the *principal measurement lines*; *geographic directions* of second order: northeast, southeast, southwest, northwest (NE, SE, SW, NW), to be used for fixing the *intersection lines*. Note that these directions are different from *compass directions* in most cases due to *magnetic declination*.

**GLORIA:** Global Observation Research Initiative in Alpine Environments ([www.gloria.ac.at](http://www.gloria.ac.at)).

**GLORIA data input tool (GDIT):** Electronic tools for data input provided by the GLORIA coordination, where all species found on all four *summit sites* of a particular *target region* are incorporated. Currently it runs as a Microsoft ACCESS application, in future also as online browser-based web application (chapter 6.1).

**GLORIA-Europe:** The first international GLORIA project, conducted under the European Union's 5th RESEARCH TECHNOLOGY AND DEVELOPMENT FRAMEWORK PROGRAMME (project number EVK2-CT-2000-0056) from 2001 to 2003. The project consortium consisted of 23 partner groups and included 18 *target regions* distributed across Europe.

**GMBA:** Global Mountain Biodiversity Assessment, a network launched by the international umbrella programme DIVERSITAS (<http://www.diversitas-international.org/>) to actively explore and explain the biological richness of the mountains of the world (<http://gmba.unibas.ch/>).

**Grazing impact:** Disturbance caused by grazing mammals (human livestock as well as wild-living mammals) may mask climate-induced changes. Therefore, obvious features indicating grazing, i.e. faeces/dropping, browsing damage, and trampling, are to be noted under “comments on *grazing impacts*” on the sampling for the *summit area section* (*Form 3*) and will be recorded through the supplementary *subplot-frequency counts* in *1-m<sup>2</sup> quadrats*.

**Grid frame:** A usually wooden frame of 1m×1m inner width, used for either *pointing with a grid frame* or for *subplot-frequency counts*, different arrangements of strings are used, dependent on the method. For either method different versions of the *grid frame* are used.

**Herpetological monitoring:** Censuses of amphibians and reptiles are so far only conducted in tropical GLORIA *target regions* as *extra approaches*. For reptiles, transects may be developed crosswise from the HSP in the four *cardinal directions*; for amphibians, a single transect of 300m×5m is set from the HSP in a direction where the most favourable habitats are intersected. For amphibians, also the health status concerning chytridiomycosis is determined (chapter 7.4).

**High mountain biomes:** see *alpine life zone*.

**High mountain environment:** Generally corresponds to the *alpine life zone*. According to Troll (1966), high mountain areas are determined by (1) their position above the natural low-temperature *treeline*, (2) a landscape shaped by glaciers, which were present at least in the Pleistocene, and (3) frost as an important factor for pedogenesis and substrate structure. Further, a common feature of mountains is steepness or ruggedness, which causes the forces of gravity to shape and create habitat types and which makes exposure an important factor of life (Körner et al. 2011).

**Highest summit point (HSP):** The culmination point of a summit, used as the *principal measurement point*. At *moderately shaped summits*, it lies more or less in the middle of the *summit area*. Rocky outcrops, which may occur elsewhere in the *summit area* and may exceed the altitude of the central culmination point should not be used as the *principal measurement point*.



**HSP:** The highest summit point.

**In situ:** To examine a phenomenon exactly in place where it occurs, e.g. *in situ monitoring* of vegetation in its natural habitat.

**Intersection lines:** Four straight lines from the HSP to the boundary lines of the 5-m summit area and 10-m summit area, positioned in the exact geographic directions of second order (NE, SE, SW, NW). The measurement points pNE-5, pNE-10, pSE-5, etc. are positioned at the crossing points of these lines with the boundary lines of the summit areas.

**Invertebrate monitoring on GLORIA summits:** An extra approach for recording ground-dwelling arthropods using pitfall trapping. Pitfall traps are arranged in a 'cross pattern' in each cardinal direction within the summit area (chapter 7.2, Mikhailov 2009).

**Lichens on soil:** Surface type used for top cover estimations in 1-m<sup>2</sup> quadrats (**Form 2**): lichens growing on soil without being covered by vascular plants, i.e. there are no multiple vegetation layers.

**Life zone:** A major unit of the planet's geo-biosphere, defined by mean annual bio-temperature, annual precipitation, and the ratio of annual potential evapotranspiration to mean total annual precipitation (Holdridge 1947). Life zones largely overlap with the *zonobiomes* of Walter's system (Walter 1985). The *alpine life zone*, as the world-wide entirety of high-mountain biomes, is considered as a special-case of low-temperature biomes because of its scattered distribution across the planet (Körner 2003).

**Line-pointing:** A point-line intercept method for recording species cover and top cover of surface types along a straight line. In the GLORIA context, line-pointing is used for supplementary recording of species cover in the SASs, where usually 100 points are sampled per SAS (see chapter 5.2.2), for supplementary 10 m × 10 m squares in each cardinal direction of the summit area, where 400 points are used per square (chapter 5.3), and for the *Downslope Plant Survey*, where also 400 points are sampled in each 100-m belt transect (chapter 7.1). The sampling pins should have a diameter of 2 mm.

**Litter:** Surface type used for top cover estimations: dead plant material.

**Local partnerships:** The establishment of personal and engaging relationships with local populations and communities is an important aspect in the context of the documentation of *anthropogenic activities* in GLORIA target regions, aiming at mutual benefits between researchers and people living in the area (chapter 7.6).

**Magnetic declination:** Angle between the direction of the magnetic north (compass north) and the geographic North Pole (true north). Its magnitude is location-specific and changes over time. For the current magnetic declination of any place world-wide see: <http://www.ngdc.noaa.gov/geomag-web/>

**Master site:** Well-equipped research stations to carry out scientific investigations which cannot be performed at GLORIA summit sites or within standard GLORIA target regions. Such high-mountain master sites are based on existing research capacities and infrastructures. The research activities may include methodological test trials for STAM, SUPM or EXAP activities, studies on snow, permafrost and vegetation patterns, plant phenology, experimental and modelling approaches with alpine plants. Targeted studies on, e.g. primary productivity, microbial activity in soils, plant propagation, precipitation changes, nitrogen deposition, grazing impacts may further be of interest for the interpretation of changes in biodiversity and vegetation patterns. Research at GLORIA master sites, however, is not subject of this field manual.

**Measurement lines:** Straight lines between the HSP and the measurement points. The lengths of these lines and the compass direction from the HSP have to be measured (i.e. the principal measurement lines, the lines from the HSP to all corner points of the 3 m × 3 m quadrat clusters, and the intersection lines).

**Measurement points:** All points within the summit area used as delimitation points (corner points) of permanent plots (see Fig. 3.2).

**Moderately shaped summit:** Summits which (1) are not too steep, so that measurement and sampling work can be done without using climbing equipment; (2) have a clear culmination point, where the distance to the 5-m levels in all main geographical directions

is less than 50 m, and the distance to the 10-m levels is less than 100 m.

**Monitoring:** Is used here in the context of long-term monitoring at resurvey intervals of five to ten years, but without incorporated management objectives and without a fixed end-date (see also surveillance, Elzinga et al. 1998, Legg & Nagy 2006).

**Monitoring cycle:** The repetition of the standard recording procedure on GLORIA summit sites. Such resurveys are usually performed at intervals of five to ten years (see chapter 4.5).

**Multi-Summit Approach:** The basic approach of GLORIA for the comparison of climate-induced changes of high mountain biota along the vertical and horizontal climatic gradients. Summit sites arranged in different altitudes in a target region will be used as reference units. Such target regions should be distributed over all major biomes (*zonobiomes*) on Earth. The standardised sampling design, as described in this manual, should be applied on each summit.

**N-5m-SA:** The upper summit area section on the north slope (see Fig. 3.2), delimited by the corner points: HSP, pNE-5 (at the intersection line), p5m-N11, p5m-N31, and pNW-5 (at the intersection line).

**N-10m-SA:** The lower summit area section on the north slope (see Fig. 3.2), delimited by the corner points: p5m-N11, pNE-5, pNE-10 (at the intersection line), p10m-N, pNW-10 and pNW-5 (at the intersection line), and p5m-N31.

**Nival zone:** The zone of open vegetation above the alpine zone, where vegetation is not a significant part of the landscape.

**p (-N13, -N33, -E13, -E33, -S13, -S33, -W13, W33):** The upper corner points of the 3 m × 3 m quadrat clusters (they usually lie above the 5-m level, see Fig. 3.2).

**p5m (-N11, -N31, -E11, -E31, -S11, -S31, -W11, W31):** The lower corner points of the 3 m × 3 m quadrat clusters. They lie at the 5-m level in each main geographic direction; one of these points per main geographic direction also lies on the principal measurement line. The p5m-... points also delimit the 5-m summit area (see Fig. 3.2).

**p10m (-N, -E, -S, -W):** The lower corner points of the 10-m summit area. They lie at the 10-m level in each of the main directions at the lower end points of the *principal measurement lines* (see Fig. 3.2).

**PAF:** see *Point and Flexible Area sampling method*.

**Percentage cover:** The percentage cover of a species (*species cover*) or of a *surface type* as related to the area size of a plot.

**Photo documentation:** Essential for the fast and accurate reassignment of sampling plots for reinvestigations. The position of each 3m × 3m *quadrat cluster*, 1-m<sup>2</sup> *quadrat*, corner points of the *summit area sections*, and the *HSP* have to be carefully documented with photos – in addition, photos of the *temperature data logger* position and a view of the entire summit should be taken (see chapter 4.4 and Annex III for coding).

**Pitfall trapping:** A standard method for sampling ground-dwelling invertebrate diversity. Pitfall traps are usually plastic cups (ca. 200 ml) filled with acetic acid as fixative (see chapter 7.2).

**Plant functional traits:** Features (morphological, physiological, phenological) that represent ecological strategies and determine how plants respond to environmental factors, affect other trophic levels and influence ecosystem properties (Pérez-Harguindeguy et al. 2013).

**Point and Flexible Area sampling method:** A combined species cover method with *line-pointing* and *area cover estimation* for rare species (Halloy et al. 2011). The method can be used in a modified version for supplementary species cover sampling in the *SASs* (chapter 5.2.2).

**Pointing frame:** This is a usually wooden *grid frame* with an inner width of 1m × 1m. The frame has ten tightened strings in each direction, resulting in 100 *crosshair points* distributed regularly over the 1m<sup>2</sup> area. Strings are positioned at 5 cm from the inner margin and 10 cm from each other parallel string (see Fig. 4.2).

**Pointing with a grid frame:** A point intercept method (point-framing) with a *pointing frame* of 1m × 1m inner width and 100 *crosshair points*. Using a *sampling pin* at each *crosshair point*, it measures *species cover* and *top cover* of *surface*

*types* (e.g. a species hit at 34 points corresponds to 34% cover). Species with low cover, however, are not or only occasionally hit by the *sampling pin*.

**Point-line intercept method:** Recording at intercept points in regular intervals along straight lines to obtain cover data of species or of *surface types*; see *line-pointing* for GLORIA-relevant applications.

**Principal measurement line:** The straight lines from the *HSP* through one of the *p5m-...* points to the *p10m-...* points in each of the main *geographic directions*. Deviations of these lines from the exact *geographic direction* should be avoided, but may be necessary if habitat or terrain in the exact direction is not appropriate for the 3m × 3m *quadrat cluster*.

**Quadrat:** Used here for permanent 1-m<sup>2</sup> *quadrats* for detailed vegetation recording.

**Quadrat cluster:** Used here for 3m × 3m *quadrat clusters* positioned in the four main *geographic directions* of a summit.

**S-5m-SA:** The upper *summit area section* on the south slope (see Fig. 3.2), delimited by the corner points: *HSP*, *pSW-5* (at the *intersection line*), *p5m-S11*, *p5m-S31*, and *pSE-5* (at the *intersection line*).

**S-10m-SA:** The lower *summit area section* on the south slope (see Fig. 3.2), delimited by the corner points: *p5m-S11*, *pSW-5* and *pSW-10* (at the *intersection line*), *p10m-S*, *pSE-10* and *pSE-5* (at the *intersection line*), and *p5m-S31*.

**Sampling pin:** A pin of 2 mm diameter used for various pointing methods such as for *pointing with a grid frame* in 1-m<sup>2</sup> *quadrats*, in supplementary *point-line intercept* recording of the *PAF* method in *SASs*, 10m × 10m *squares*, and in transects of the *Downslope Plant Survey*. For example, a thin knitting needle may be used.

**SAS:** *Summit area section*.

**Scree:** *Surface type* used for *top cover estimations*: debris material – this includes unstable or stable scree fields, as well as single stones of various size, lying on the surface or being more or less fixed in the soil substrate; the grain size is bigger than the sand fraction (as opposed to *bare ground*).

**Soil variability:** This extra activity aims at collecting information on soil properties such as soil pH, C:N and N:P ratios, soil organic carbon (SOC), which are related to key ecological processes (chapter 7.5).

**Solid rock:** *Surface type* used for *top cover estimations*: rock outcrops – rock which is fixed in the ground and does not move even slightly (e.g. when pushing with a boot).

**Species cover:** Percentage cover of each species in the 1-m<sup>2</sup> *quadrat* recorded by visual estimation (e.g. 0.01m<sup>2</sup> surface cover of a species corresponds with 1%, irrespective of relief or slope angle). In dense vegetation, cover of all species together can exceed 100% because of overlapping layers. Intra-specific overlaps are ignored. All vascular plant species will be recorded (bryophytes and lichens on the species level are optional). A supplementary method recommends *species cover* recording also in the *summit area sections* by applying different approaches, dependent on the abundance of species (*PAF*; for details see chapter 5.2.2).

**STAM:** *Standard recording methods of GLORIA's Multi-Summit Approach*.

**Standard recording methods (STAM):** Describes the basic recording procedure of the *Multi-Summit Approach* that is required in all GLORIA *target regions* in order to build the fundamental globally comparative dataset on vascular plants and soil temperature (see chapters 3 and 4).

**Subplot-frequency counts:** Presence/absence records of plant species (vascular plant species, cryptogam species where time and experts are available) and of *grazing impacts* in the sixteen 1-m<sup>2</sup> *quadrats* by using a *frequency grid frame* of 1m × 1m inner width. In each of the 100 subplots of 10 cm × 10 cm, species presences and signs of *grazing impacts* are to be sampled (see chapter 5.1.2). The method was originally considered as an obligatory standard method, but was shifted to the optional level because very much time is needed in dense and species-rich vegetation.

**Subtypes for top cover estimation:** To estimate the percentage cover of bryophytes and lichens growing below the *surface type vascular plants*, or on the *surface types solid rock*, and *scree*

(only used in *1-m<sup>2</sup> quadrats*, **Form 2**). Cover percentages of these subtypes refer to the area covered by the relevant *surface type*.

**Summit site:** Culmination points in a mountain system used for biodiversity monitoring in GLORIA. This can be even a small hump in a ridge which projects at least 20 elevation metres above the surrounding land features. *Moderately shaped summits* should be selected for GLORIA sites, whereas steep summits should be avoided for safety reasons and because of limited space for plant growth due to rockiness. The latter accounts also for summits composed of boulder fields. *Flat summits* may exceptionally be used in the absence of alternatives, however, with a slight modification of the sampling design.

**Summit area:** The entire sampling area of a *summit site*: i.e. *5-m summit area* (which includes the *16-quadrat area*), and *10-m summit area*.

**Summit area section:** The four subdivisions of the *5-m summit area* and the four subdivisions of the *10-m summit area* (eight sections per summit). These sections are used as sampling units to estimate the *top cover* of *surface types*, and to capture all vascular plant species and their abundance within each *summit area section*.

**Summit selection (criteria):** The evaluation of a GLORIA summit is made by six criteria: (1) volcanism – must be absent, (2) climate – must be consistent among all summits of a *target region*, (3) geomorphological summit shape – should be a *moderately shaped summits*, (4) habitat situation – should be typical for the respective elevation zone of the region, potential sites for plants to establish must be available, (5) bedrock material – must be consistent among all summits of a *target region*, (6) land use/land use history – pristine areas preferred, areas with remarkable changes in human land use practices in recent times must be avoided.

**SUPM:** *Supplementary sampling designs and recording methods* as optional/additional procedures of plant recording on GLORIA summits.

**Supplementary sampling designs and recording methods (SUPM):** This category was introduced to distinguish supplementary plant recording procedures on GLORIA summits which

may be performed on an optional basis as opposed to the required standard methods (STAM, described in chapters 3-4). *SUPMs* may deal with cryptogam species, additional plot designs, additional recording methods in the standard plots (e.g. species cover in *summit area sections*, species frequency in *1-m<sup>2</sup> quadrats*) and/or *supplementary 1-m<sup>2</sup> quadrats* within the *10-m summit area* (see chapter 5).

**Supplementary 1-m<sup>2</sup> quadrats:** In order to enhance statistical power for detecting small changes on a GLORIA summit, the number of *1-m<sup>2</sup> quadrats* may be doubled on an optional basis. Such additional *1-m<sup>2</sup> plots* are also arranged in *3m × 3m quadrat clusters*, which are positioned near the *10-m level* in each *cardinal direction* (see chapter 5.1.3 and Fig. 5.3).

**Surface types:** Sampling features for *top cover* estimations in the *16-quadrat area*. These are: *vascular plants*, *solid rock*, *scree*, *bare ground*, *bryophytes on soil*, *lichens on soil* (both if not covered by vascular plants), and *litter*. The same types will be used in the *summit area sections*.

**Surveillance:** Often used interchangeably with *monitoring*, but *surveillance* concerns measuring change in the absence of a directly incorporated management context (Elzinga et al. 1998), such as long-term ecological and biodiversity *monitoring*. Others distinguish *surveillance* as recording information at a point which is being repeated subsequently as *monitoring* (Bunce et al. 2011).

**Target region:** The mountain area in which four *summit sites*, representing the regional elevation gradient, are located. The general climatic situation within this area should not show fundamental differences along a horizontal gradient.

**Taxa input sheet:** Information for each taxon found in a *target region*, such as name, authors, nomenclatorial reference, synonyms, information on herbarium specimen, etc. to be entered into the central GLORIA database (see Table 6.1).

**Temperature data loggers (T-loggers):** Small instruments used for continuous temperature measurements on the summits at 10 cm below soil surface (measuring interval of one hour). Two types, “Geo-Precision MLog 5W”

(www.geoprecision.com) and “Onset TidBit v2” (www.onsetcomp.com) are currently in use. The aim is to compare temperature regimes and to detect the length of the snow cover period along the elevation gradient.

**Thermic vegetation indicator:** Characterizes the thermal status, i.e. the collective vascular plant species preferences, of a patch of vegetation (e.g. within *1m<sup>2</sup>*) along an elevation gradient, which resembles a thermal gradient (Gottfried et al. 2012). The *thermic vegetation indicator* (*S*) is calculated as a composite score (a weighted average) of a vegetation plot:  $S = (\sum \text{rank}(\text{species}_i) \times \text{cover}(\text{species}_i)) / \sum \text{cover}(\text{species}_i)$ , where rank is the *altitudinal species rank*, and cover the percentage *species cover* (Gottfried et al. 2012).

**Thermophilic plants:** Plant species which are warm-demanding concerning any temperature-related factor for plant life including the length of a thermally suitable growing season. It is used here in relative terms, e.g. a species of alpine grassland is more thermophilic as a species centered in the *nival zone*.

**Thermophilisation:** The transformation of the species composition and species' abundances in plant communities towards a more thermophilic assemblage. In the context of alpine vegetation, this term was introduced by Gottfried et al. (2012) and refers to the vegetation in a particular study plot or set of plots on a summit, *target region*, or larger geographical levels. It is defined by the *thermophilisation indicator* (*D*), as an immigration or a cover increase of species which predominantly occur at lower elevations (i.e. these species are more thermophilous relative to the average of the vegetation at the given site) and/or as a decrease in cover or disappearance of species which predominantly occur at higher elevations (i.e. these species are relatively more cryophilic/cold-adapted).

**Thermophilisation indicator (D):** Quantifies the change of the thermal status of a species assemblage within the same vegetation plot over time. It is defined as difference of the *thermic vegetation indicator* (*S*) between the recent and the baseline observation:  $D = S_{\text{recent year}} - S_{\text{baseline year}}$  (Gottfried et al. 2012).

**Top cover:** The vertical projections of each *surface type* in percent within the  $1\text{-m}^2$  *quadrat* (in a view perpendicular to the slope angle). *Top cover* of all *surface types* present within a *quadrat* adds up to 100%.

**Treeline:** Is the line where trees or groups of trees taller than 3m end.

**Treeline ecotone:** Is the zone between the *forestline* and the *tree species line*.

**Tree species line:** Is the line beyond which no adult individuals of tree species (including prostrate ones or scrub) occur.

**T-loggers:** see *temperature data loggers*.

**Vascular plants:** (1) target organism group of the *Multi-Summit Approach* (see chapter 1.5 for consideration about using *vascular plants*); (2) *surface type* used for *top cover* estimations: the *top cover* of all vascular plants together.

**W-5m-SA:** The upper *summit area section* on the west slope (see Fig. 3.2), delimited by the corner points: *HSP*, *pNW-5* (at the *intersection line*), *p5m-W11*, *p5m-W31*, and *pSW-5* (at the *intersection line*).

**W-10m-SA:** The lower *summit area section* on the west slope (see Fig. 3.2), delimited by the corner points: *p5m-W11*, *pNW-5*, *pNW-10* (at the *intersection line*), *p10m-W*, *pSW-10* and *pSW-5* (at the *intersection line*), and *p5m-W31*.

**Zonobiome:** The major subdivisions of the geo-biosphere according to Walter's ecological system (Walter & Breckle 2002), determined by the prevailing climate as the primary independent factor in the environment. Biomes of similar climate, supporting similar plant formations are aggregated to *zonobiomes*. Globally, nine *zonobiomes* are distinguished. Mountain systems are treated as *orobiomes*, which may occur within a single biome or may stretch across two or several *zonobiomes*.

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# THE GLORIA FIELD MANUAL

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## ANNEX I: MATERIALS FOR PLOT SETUP AND RECORDING

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# CHECKLIST FOR MATERIALS AND EQUIPMENT

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## For measuring the position of plots and of the corner points of the *summit area*

- ◆ a *compass* (recommended: Suunto KB-14/360)
- ◆ check the magnetic declination before starting fieldwork
- ◆ a *clinometer* (recommended: Suunto PM-5/360PC)
- ◆ two rolls *flexible measuring tapes* with 50m length
- ◆ two *flexible measuring tapes* with 3m length

## Optional (in addition):

- ◆ altimeter
- ◆ Differential GPS with sub-metre accuracy
- ◆ for the supplementary *10m×10m squares* you need additional *flexible measuring tapes*: one roll of 50m (for delimitation) and one of at least 10m (for *line-pointing*)

## For delimiting the *1-m<sup>2</sup> quadrats*

- ◆ four sampling grids of 3m×3m with 1m×1m cell size (per *target region*; see Fig. A1.1 in Annex I).
- ◆ about hundred pieces of ordinary 100 mm nails
- ◆ thin wire
- ◆ adhesive tapes (for repairing grids)

## For delimiting the *summit area sections*

- ◆ two rolls of thin string, each with about 500m length; can be shorter for steeper summits
- ◆ four rolls of the same type of string, about 100m each; can be shorter for steeper summits (the colour of strings should contrast with the surface; e.g. yellow or white; check if strings are on an easy-to-handle spool)

## For permanent marking

- ◆ about 80 short aluminium tubes per summit (0.8 to 1cm in diameter, in various lengths between 10 and 25cm) or other appropriate material
- ◆ durable white or yellow paint (as an alternative to the aluminium tubes)
- ◆ a small chisel (or cold cutter)

## For photo documentation

- ◆ a high-resolution digital camera with wide-angle to normal focal length
- ◆ Memory cards (e.g. SD cards)
- ◆ a small blackboard (e.g. 15×20cm)
- ◆ chalk and a small sponge or something else to clean the blackboard
- ◆ a signal stick or rod (1.5 - 2m) to mark the SAS corner points while taking photographs

## For the recording procedures

- ◆ sampling forms in a sufficient number of copies (see Annex II). The minimum needed for a *target region* field campaign: 1× **Form 0**, 4× **Form 1**, 64× **Form 2**, 32× **Form 3**, 4× **Form 4** (if optional methods are applied: 64× **Form 5-S**, 16× **Form 6-S**); bring spare forms.
- ◆ writing material (including pencil for rainy conditions)
- ◆ *compass* (as above)
- ◆ *clinometer* (as above)
- ◆ transparent templates for cover estimations (see Fig. A1.3a & b in Annex I)
- ◆ wooden (or aluminium) *pointing frame* of 1m×1m inner width (see Fig. A1.2 in Annex I) for *pointing with a grid frame*; if optional methods are applied: a *frequency grid frame* (Fig. 5.1) for *subplot-frequency counts*
- ◆ *sampling pin* of 2mm diameter for pointing methods (e.g. a thin knitting needle)

## For temperature measurements

- ◆ Sixteen miniature *temperature data loggers* (preferably GeoPrecision Mlog-5W), i.e. four for each summit (see chapter 4.3.2), watch, gardening trowel, for data readout: laptop, dongle (wireless interface).

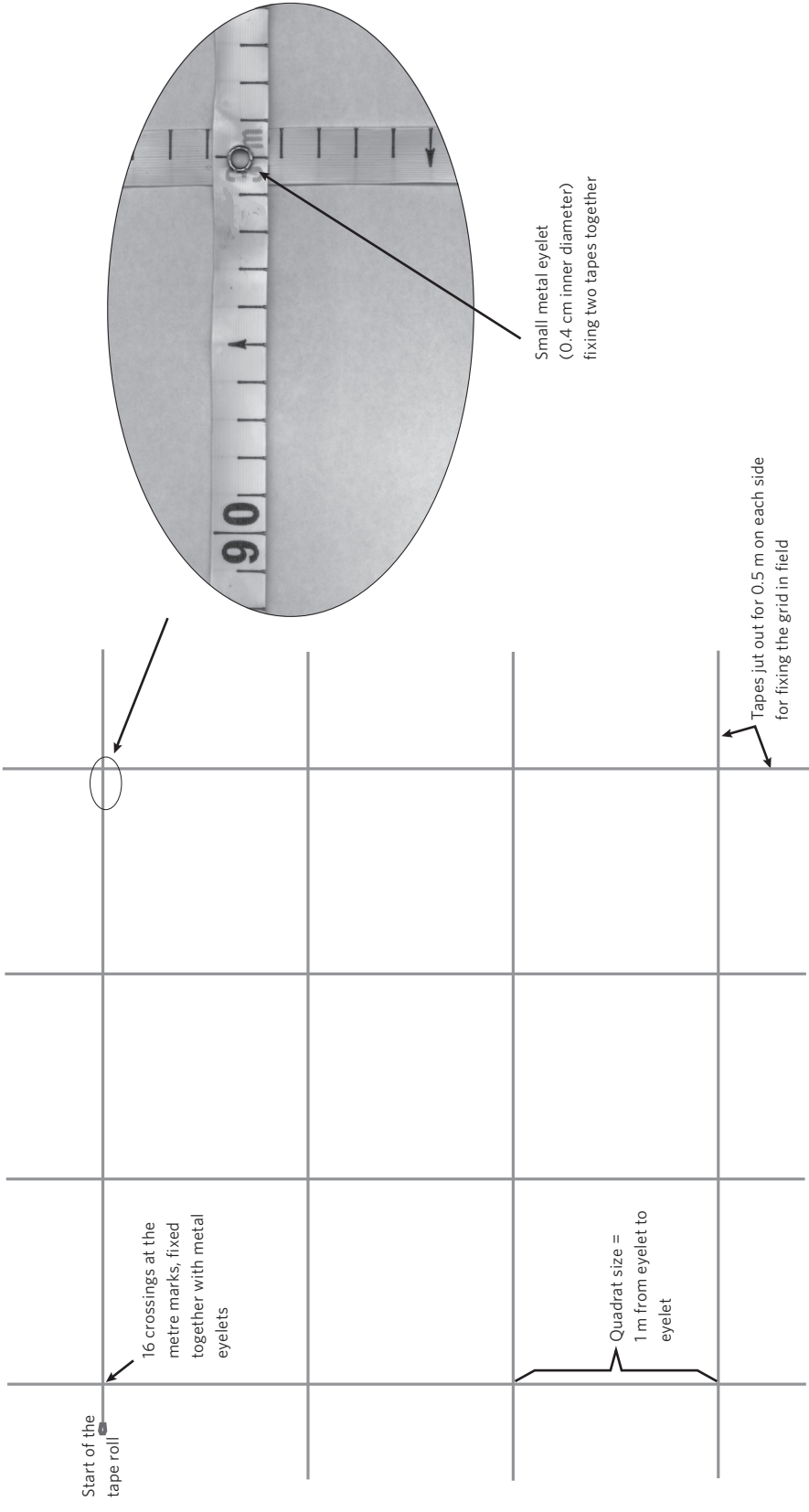
**Step 1.** Preparation of 8 pieces of flexible measuring tapes of 4 m length: These pieces are cut off from e.g. a 50-m tape measure roll (the first at the 3.5 m mark, the second at the 7.5 m mark, and so on).

**Step 2.** At each metre mark of all 8 tapes, a round hole of 0.4 cm diameter is punched in the middle of the tape (= 4 holes per tape).

**Step 3.** The 8 tapes are arranged into a 3 m x 3 m grid: column tapes and row tapes are fixed together with small metal blanks (i. e. eyelets of 0.4 cm diameter). Eyelets are put through the 2 holes at each crossing point and riveted with special pliers which are usually sold with the eyelets. The result is a 3 m x 3 m grid with 1 m x 1 m subdivisions. Note that each subdivision is

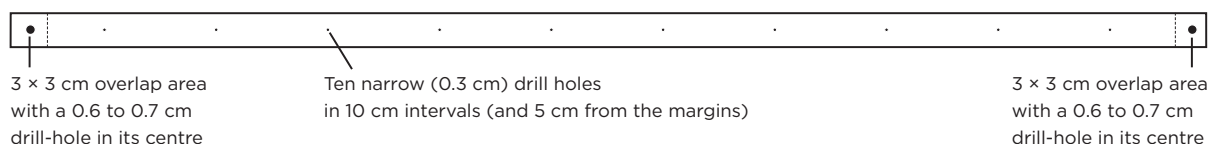
slightly smaller than 1 m<sup>2</sup>, because of the width of the tape. This minor reduction of each quadrat area is accepted because of two advantages:  
 (1) the construction of the tape is less complicated because the inner width of the quadrat need not be measured before punching the holes;  
 (2) the scale at the delimitations of the sampling quadrat ranges exactly from one to the next metre mark - this is helpful for cover estimation. Each tape juts out from the 3 x 3 m grid area for 0.5 m on each side. This is helpful for fixing the grid in the field.

Four such grids are to be constructed (one for each 3 m x 3 m plot cluster). Grids are to be removed after field work at a summit site is finalised. Therefore, one set of 4 grids is sufficient for one target region.

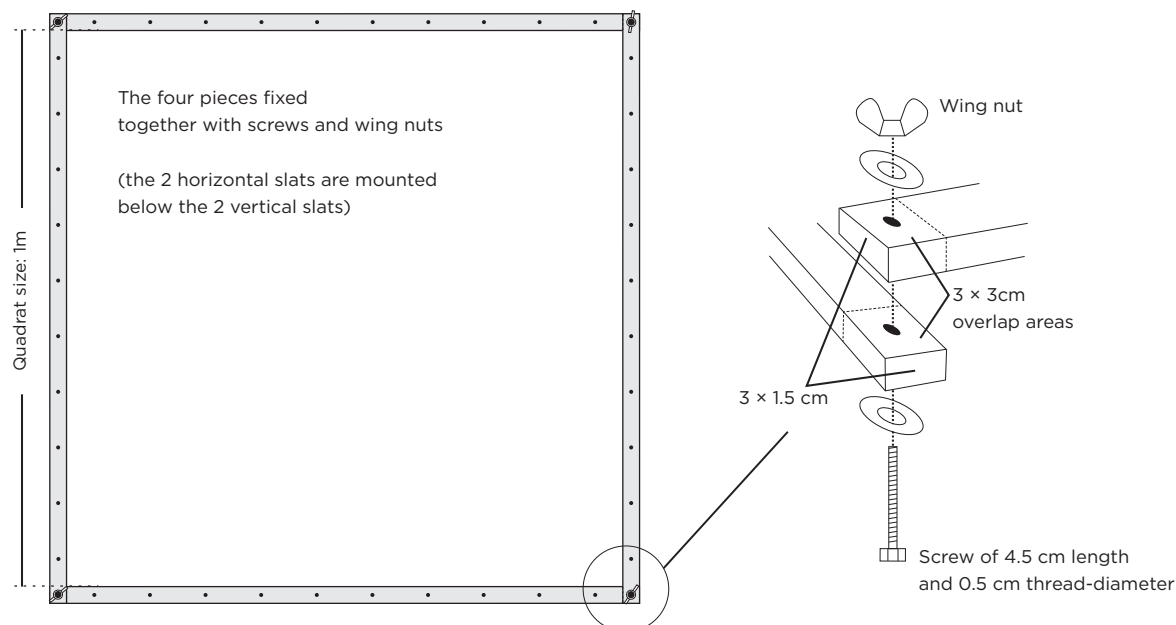


**Fig. AI.1** Construction of the 3m x 3m grids.

**Step 1. Construction of 4 equal pieces of small wooden slats (3 cm × 1.5 cm and 106 cm length):**



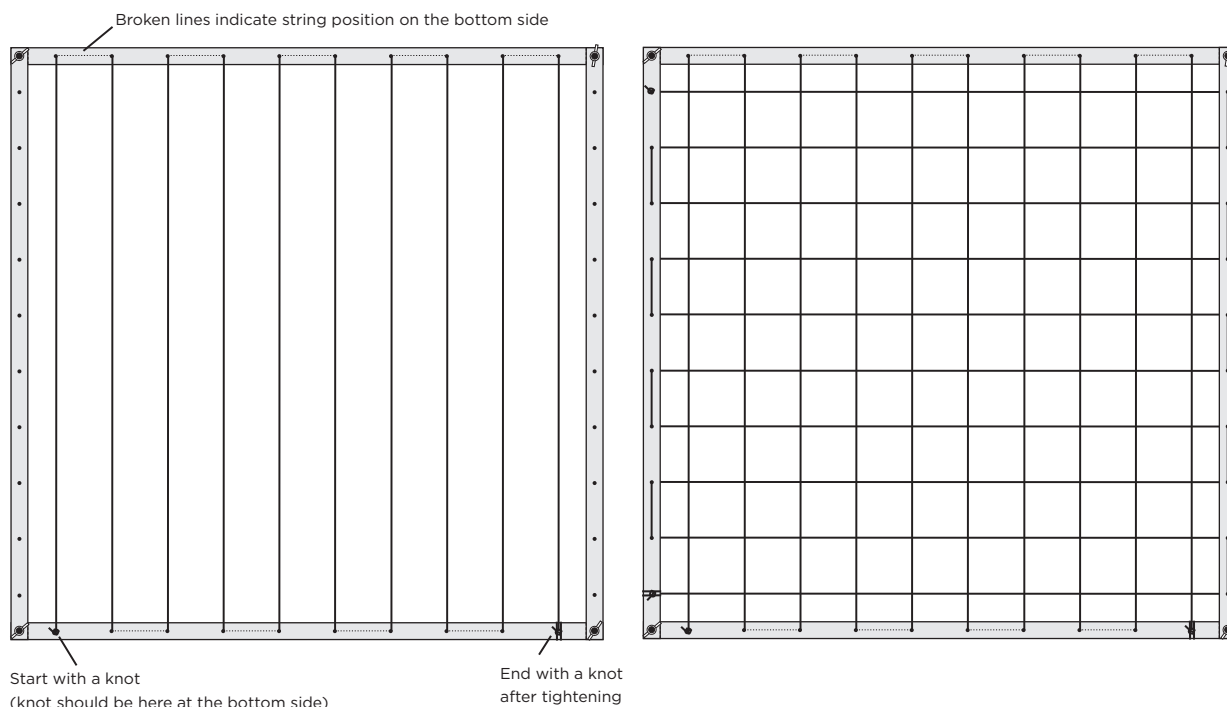
**Step 2. Fixing the 4 pieces together:**



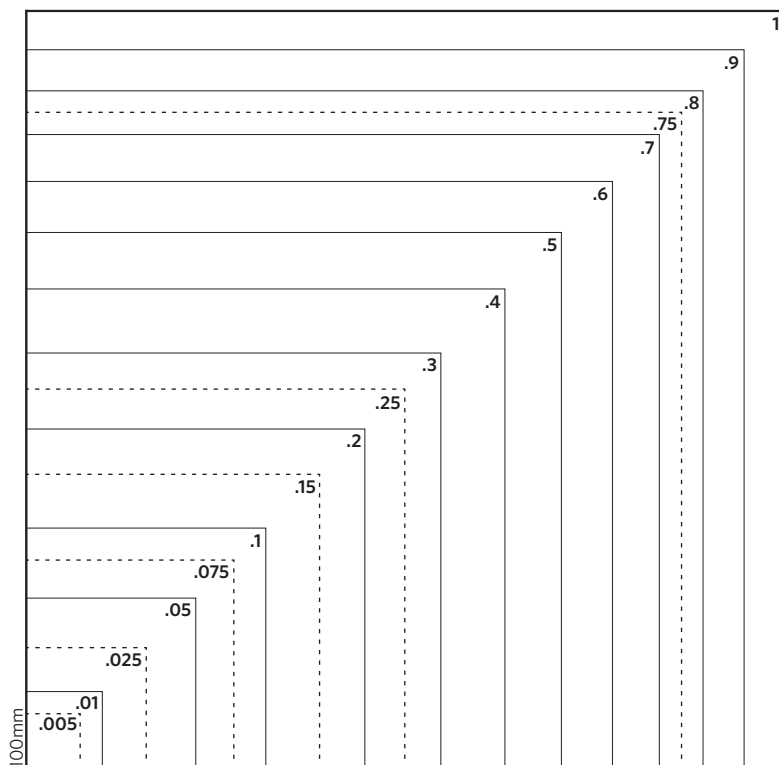
**Step 3. Threading and tightening of the strings:**

a) String for the columns is aligned at the upper side of the wooden slats

b) String for the rows is aligned at the bottom side of the wooden slats, interwoven with the column string



**Fig. AI.2 Construction of the 1m×1m grid frame for pointing with 100 crosshair points.**



**Fig. AI.3a Templates for percentage cover estimations: rectangular shapes.** These templates may be copied to a transparency and prepared for the field work. Make sure that the original size is maintained (i.e. when photocopying).

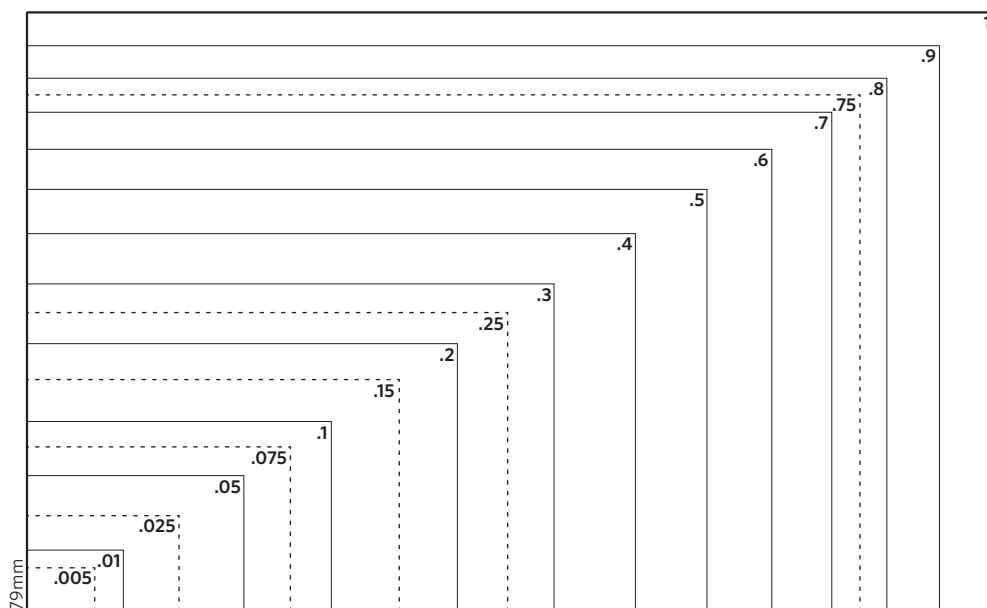
#### Rectangular shapes I

Templates for percentage estimations

Numbers indicate % values of a 1m x 1m quadrat

GLORIA 2001

170mm



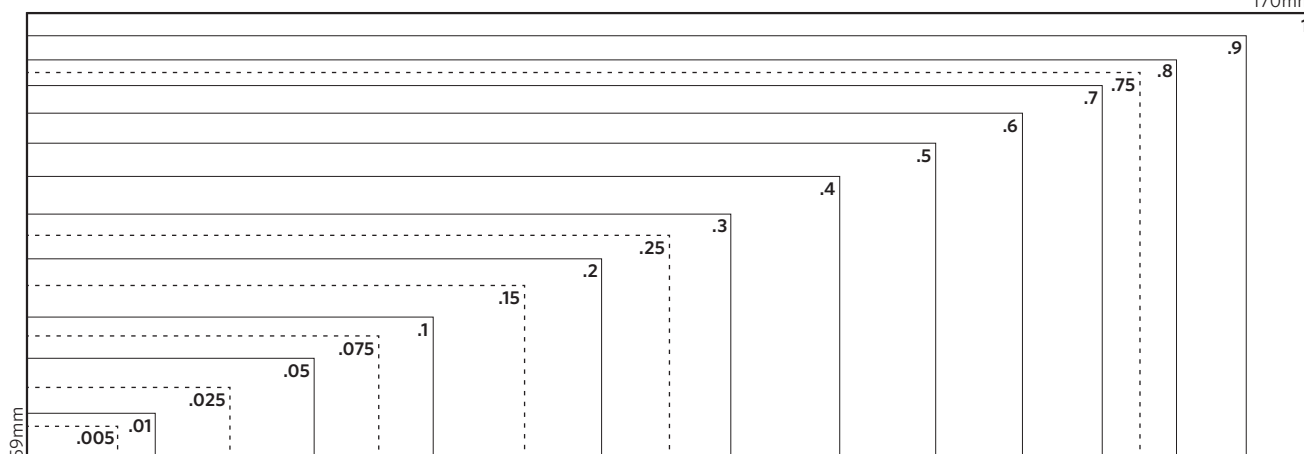
#### Rectangular shapes II

Templates for percentage estimations

Numbers indicate % values of a 1m x 1m quadrat

GLORIA 2001

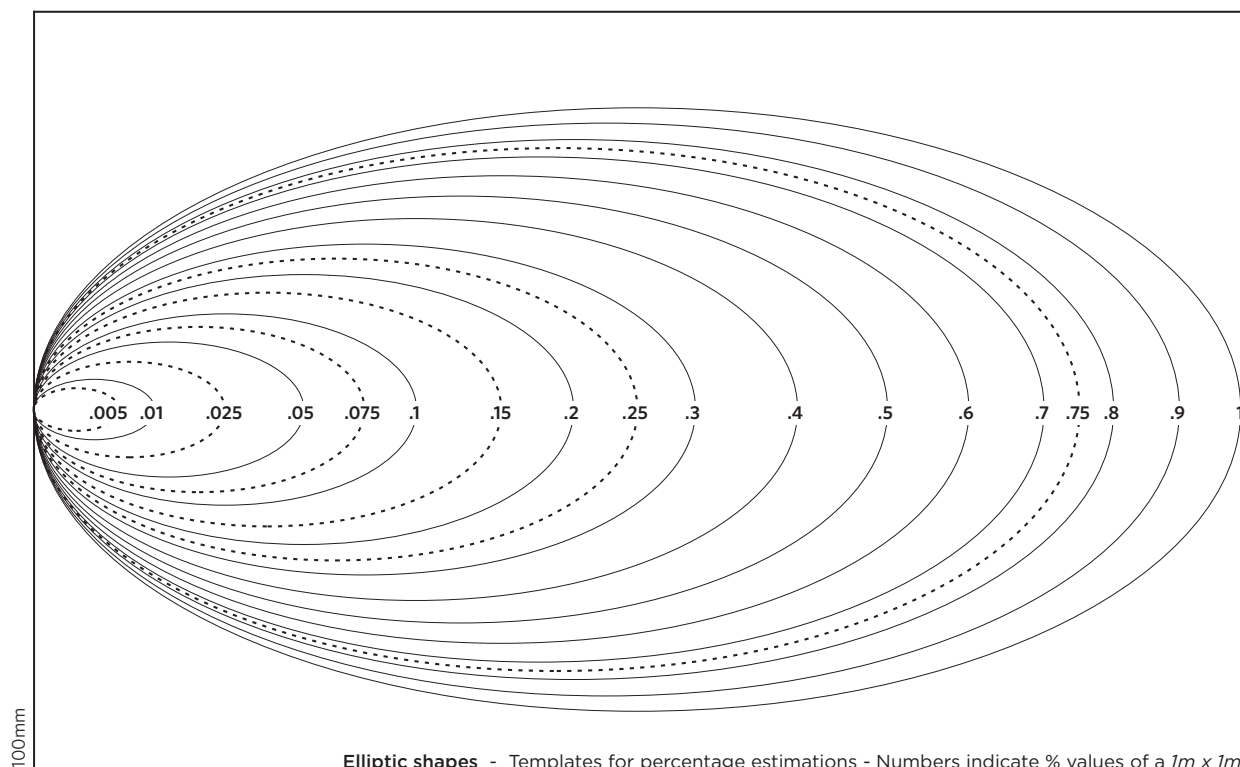
170mm



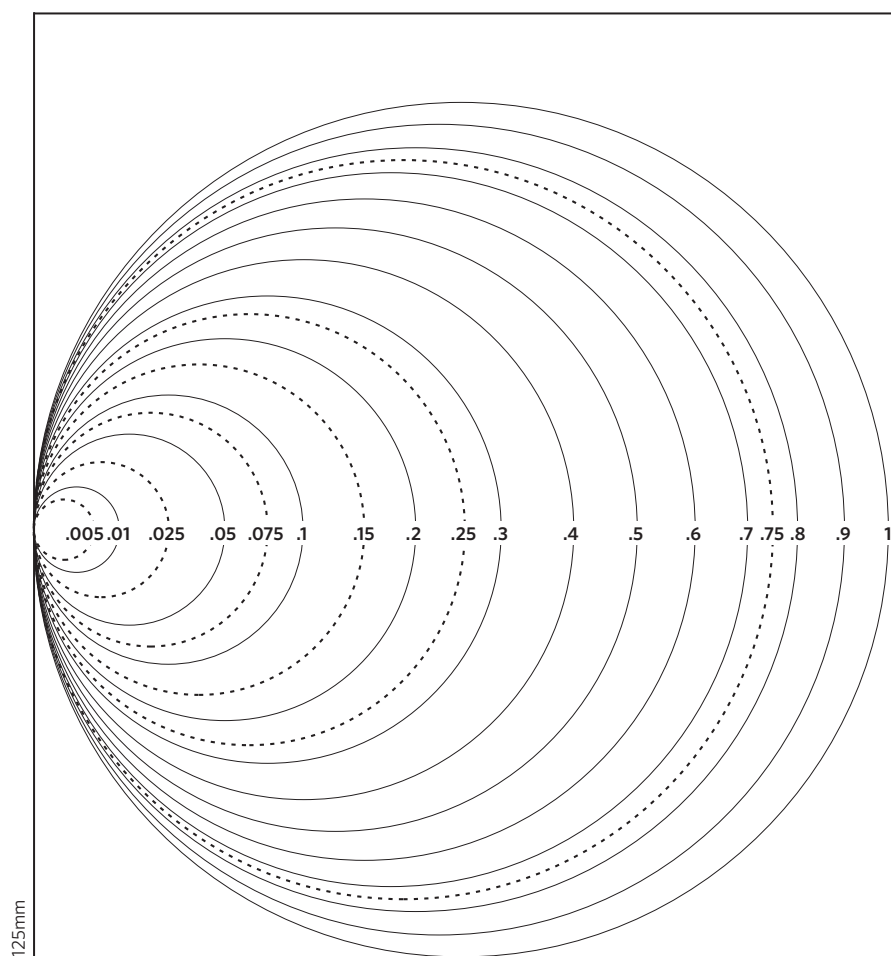
**Rectangular shapes III** - Templates for percentage estimations - Numbers indicate % values of a 1m x 1m quadrat

GLORIA 2001





**Elliptic shapes** - Templates for percentage estimations - Numbers indicate % values of a *1m x 1m quadrat*  
GLORIA 2001



**Fig. AI.3b** Templates for percentage cover estimations: circular and elliptic shapes.

These templates may be copied to a transparency and prepared for the field work. Make sure that the original size is maintained (i.e. when photocopying).

#### **Circular shapes**

Templates for percentage estimations

Numbers indicate % values of a *1m x 1m quadrat*

GLORIA 2001

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# THE GLORIA FIELD MANUAL

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## ANNEX II: DATA SAMPLING FORMS

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### PART 1: SAMPLING FORMS

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#### STANDARD SAMPLING FORMS

**Form 0** Target region **114**

**Form 1** Measurement protocol **115**

**Form 2** 1-m<sup>2</sup> quadrat (with notes on a separate page\*) **116**

**Form 3** Summit area section (with notes on a separate page\*) **118**

**Form 4** Temperature loggers **120**

#### SUPPLEMENTARY SAMPLING FORMS

**Form 5-S** Subplot-frequency counts in the 1-m<sup>2</sup> quadrat **121**

**Form 6-S** 10 m × 10 m square (with notes on a separate page\*) **122**

\* For fieldwork, notes should be printed on the backside of the form.

Form 0

Target region

Country code <sup>1)</sup>	Date	Researcher(s)	
Target region code <sup>1)</sup>			

Altitude of major vegetation boundary lines (in metres)

Potential natural forestline <sup>2)</sup>	Potential natural treeline <sup>2)</sup>	Alpine-nival ecotone <sup>2)</sup>
Current forestline <sup>2)</sup>	Current treeline <sup>2)</sup>	

Predominant bedrock material and approximate soil pH at the summit sites of the target region<sup>4)</sup>

Short description of the target region, particularly regarding land use history and the current land use situation<sup>5)</sup>

Comments on vegetation boundary lines<sup>3)</sup>

SUMMIT	Summit code <sup>1)</sup>	Summit name	Altitude (m a.s.l.)	Vegetation zone or ecotone <sup>6)</sup>	Comments on the summit situation <sup>7)</sup>
Altitude	LOW				
	HIGH				

**Notes**  
1) See Box 6.1 for coding. 2) Enter the approximate metres above sea level (m a.s.l.) for each vegetation boundary line which indicates its average altitude in the *target region*; the forestline (or timberline) is defined as the line where closed forests end; the treeline is defined as the line where groups of trees taller than 3m end; the alpine-nival ecotone is the transition zone between the upper alpine belt and the nival belt - make an estimation of the altitude of the upper boundary line of the alpine zone, where closed vegetation ends (this line may coincide with the permafrost limit in many mountain regions). 3) Where required make comments on the indicated altitudinal positions of boundary lines; e.g. deviations from the average altitude; mention if a boundary line does not exist in the *target region* and comment on the reasons for its absence. 4) Bedrock material of the summit sites of the target region, which should be consistent throughout the four summits (consistent regarding the influence of the bedrock on the species composition); in addition, make a rough estimate on the average soil pH (e.g. acid: <4.5, intermediate: 4.5-6.5, neutral/alkaline: >6.5). 5) If the situation is not pristine or natural, indicate what kind of land use have or had an impact on the present vegetation. 6) Only the following entries are possible: treeline ecotone, lower alpine, lower/upper alpine ecotone, upper alpine, alpine-nival ecotone, nival. 7) Make comments on the situation of the particular summit if vegetation zone or ecotone is not properly applicable and describe the deviations. Further comment on any other pronounced deviation from an 'ideal' standard summit situation (compare chapter 2.2 in the field manual).  
Use extra blank sheets, if necessary - indicate the number of extra sheets in this box (e.g. 1 of 2, 2 of 2 etc...)

# Form 1 Measurement protocol

Country code <sup>1)</sup>	Date	Highest summit point (HSP) <sup>3)</sup> Photo check <sup>8)</sup>	Altitude (m)	Geographic co-ordinates (deg/min/sec)	
Target region code <sup>1)</sup>	Researcher(s)			long.	lat.
Summit code <sup>1)</sup>					
Summit name <sup>2)</sup>		Magnetic declination (°) for compass measurements <sup>4)</sup>			

## QUADRAT CLUSTERS & 10-m POINTS

	Point number <sup>5)</sup>	Distance (m) <sup>6)</sup>	Compass direction (°) <sup>7)</sup>	Photo check <sup>8)</sup>
NORTH	p5m-N11	<input type="checkbox"/>		<input type="checkbox"/> 3mx3m grid cluster overview
	p5m-N31	<input type="checkbox"/>		<input type="checkbox"/> 3mx3m grid cluster overview
	p-N33			<input type="checkbox"/> 3mx3m grid cluster overview
	p-N13			<input type="checkbox"/> 3mx3m grid cluster overview
	p10m-N			<input type="checkbox"/> 10-m-point
EAST	p5m-E11	<input type="checkbox"/>		<input type="checkbox"/> 3mx3m grid cluster overview
	p5m-E31	<input type="checkbox"/>		<input type="checkbox"/> 3mx3m grid cluster overview
	p-E33			<input type="checkbox"/> 3mx3m grid cluster overview
	p-E13			<input type="checkbox"/> 3mx3m grid cluster overview
	p10m-E			<input type="checkbox"/> 10-m-point
SOUTH	p5m-S11	<input type="checkbox"/>		<input type="checkbox"/> 3mx3m grid cluster overview
	p5m-S31	<input type="checkbox"/>		<input type="checkbox"/> 3mx3m grid cluster overview
	p-S33			<input type="checkbox"/> 3mx3m grid cluster overview
	p-S13			<input type="checkbox"/> 3mx3m grid cluster overview
	p10m-S			<input type="checkbox"/> 10-m-point
WEST	p5m-W11	<input type="checkbox"/>		<input type="checkbox"/> 3mx3m grid cluster overview
	p5m-W31	<input type="checkbox"/>		<input type="checkbox"/> 3mx3m grid cluster overview
	p-W33			<input type="checkbox"/> 3mx3m grid cluster overview
	p-W13			<input type="checkbox"/> 3mx3m grid cluster overview
	p10m-W			<input type="checkbox"/> 10-m-point

## INTERSECTION LINES

Point num.	Dist. (m) <sup>6)</sup>	Comp. dir. (°) <sup>7)</sup>	Photo check <sup>8)</sup>	Point num.	Dist. (m) <sup>6)</sup>	Comp. dir. (°) <sup>7)</sup>	Photo check <sup>8)</sup>
pNE-5			<input type="checkbox"/>	pSW-5			<input type="checkbox"/>
pNE-10			<input type="checkbox"/>	pSW-10			<input type="checkbox"/>
pSE-5			<input type="checkbox"/>	pNW-5			<input type="checkbox"/>
pSE-10			<input type="checkbox"/>	pNW-10			<input type="checkbox"/>

## COMMENTS

<p>Use extra blank sheets for further remarks, if necessary.</p> <p>Indicate the number of extra sheets in this box</p>	Entire summit
	Photo check <sup>8)</sup>

## Notes

- See Box 6.1 for coding.
- Full name of the summit (from topographic maps or a working name where no official name is available).
- The highest summit point is the culmination point +/- in the middle of the summit area (rocky outcrops which may be higher but are not centred in the summit area should be ignored).
- The angle (with its correct sign) between the direction of the geographic North Pole and of the magnetic North Pole (e.g. -6 for a magnetic declination of 6° W; +10 for 10° E; see Box 3.1).
- Mark those checkbox where the respective point lies on the principal measurement line (e.g. p5m-N11 or p5m-N31, both are not possible; compare Fig. 3.2).
- The length of a straight surface line between the HSP and the measurement point (in metres, with two decimal places); keep the measurement tape tightened for all distance measurements (see Box 3.3).
- The compass direction from the HSP to the measurement point in degrees (360° scale; see Box 3.1). Please note: always write the magnetic compass directions (i.e. degrees as indicated on the compass).
- Photo check: check the box after photos are taken to make sure that the photo documentation is complete (see under 4.4 for details).

## Form 2 1-m<sup>2</sup> quadrat

Country code <sup>1)</sup>		Date	Aspect <sup>2)</sup>
Target region code <sup>1)</sup>		Recording time from to	
Summit code <sup>1)</sup>		Researcher(s)	Slope (°) <sup>3)</sup>
Quadrat code <sup>1)</sup>			

### Top cover of surface types (%)<sup>4)</sup>

		Pointing hits <sup>9)</sup>	Total hits <sup>10)</sup>
Vascular plants			
Solid rock			
Scree			
Lichens on soil not covered by vascular plants			
Bryophytes on soil not covered by vascular plants			
Bare ground			
Litter			
	100%		

### Subtypes in % of the top cover type<sup>5)</sup>

Lichens below vasc. pl.		Bryoph. below vasc. pl.	
Lichens on solid rock		Bryophytes on solid rock	
Lichens on scree		Bryophytes on scree	

General comments on the quadrat

### Plant species cover (%)<sup>6)</sup>

	Species	cf. <sup>7)</sup>	%-cover <sup>6)</sup>	Pointing hits <sup>9)</sup>	Total hits <sup>10)</sup>
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					

	Cover sum <sup>8)</sup>
Total number of vascular plant species	

If you have used extra sheets, indicate their number (e.g. 1 of 2, 2 of 2 etc...)

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See back page for footnotes



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## NOTES: FORM 2      1-m<sup>2</sup> QUADRAT

---

- 1 See [Box 6.1](#) for coding.
- 2 Average aspect of the quadrat surface (N, NE, E, SE, S, SW, W, or NW).
- 3 Average slope angle of the quadrat surface (in degrees, 360° scale).
- 4 The vertical projection of cover (perpendicular to the slope angle), all types together add up to 100% (for definitions of surface types see under 4.1.1). Top cover of surface types is surveyed by visual estimation as well as through pointing.
- 5 The top cover of subtypes is estimated as percentage of the respective top cover surface type (see under 4.1.1).
- 6 Percentage cover of each species, surveyed by visual estimation (see chapter 4.1.1); avoid indications such as less than (<) or more than (>); all vascular plants must be recorded; lichens and bryophyte species are optional (see [Box 4.2](#)); indicate species either by using species names or by (provisional) codes.
- 7 Use the cf. column if the identification of the taxon is doubtful (use **g** if this is the case for the genus level, **s** for the species level, **t** for a lower taxonomic level); make a specifying comment in such cases.
- 8 Check the cover sum (the cover of all species together) against the top cover surface type "vascular plants": the cover sum of all vascular plant species can be higher but not lower than the top cover of vascular plants surface type - the cover sum can be more than 100% in dense vegetation due to overlapping layers (see under 4.1.1).
- 9 Use a grid frame of 1m×1m inner width with 100 crosshair points (see [Fig. 4.2](#)) and a pin/knitting needle of 2mm diameter for point recording at 100 points. Always conduct pointing after you have completed visual cover estimation.

Where you hit with your pin a surface without vascular plants, make a stroke at the respective surface type. Where you hit vascular plants, make a stroke at the respective species - record all vascular plant species that you hit at a point, i.e. also species at the lower vegetation layers are considered (but do not make a stroke for a surface type that lies below a vascular plant).

- 10 Enter the sum of all strokes of the tally.

## Form 3 Summit area section (SAS)

### Codes of<sup>1)</sup>

Country	
Target region	
Summit	
SAS	
Date	
Time from	to

Researcher(s)
Comments on grazing impacts <sup>3)</sup>

### Top cover of surface types (%)<sup>2)</sup>

Vascular plants	
Solid rock	
Scree	
Lichens (excl. epilithic)	
Bryophytes	
Bare ground	
Litter	
SUM	100%

	Species <sup>4)</sup>	cf. <sup>5)</sup>	Abundance <sup>6)</sup>	%-Cover <sup>7)</sup> (optional)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				

	Species <sup>4)</sup>	cf. <sup>5)</sup>	Abundance <sup>6)</sup>	%-Cover <sup>7)</sup> (optional)
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				
41				
42				
43				
44				
45				
46				
47				
48				
49				
50				
51				
52				
53				
54				
55				
56				
57				
58				
59				
60				

Comments on species recording

Total number of vascular plant species  
in this *summit area section*

See back page for footnotes

If you have used extrasheets, indicate their  
number (e.g. 1 of 3, 2 of 3, etc.)

- 1 See Box 6.1 for coding; for *summit area sections* (SAS), e.g. N05, N10, E05.
- 2 Visual cover estimation of the surface types (top cover) within the *summit area section*, indicated as percentage value; see chapter 4.2.
- 3 Comment on impacts of grazing such as faeces, browsing damage, trampling; see Box 4.6.
- 4 Entering all vascular plant species is **obligatory**; lichens and bryophyte species are **optional** (see Box 4.2); indicate species either by using species names or by (provisional) codes.
- 5 Use the cf. column if the identification of the taxon is doubtful (use **g** if this is the case for the genus level, **s** for the species level, **t** for a lower taxonomic level); make a specifying comment in such cases.
- 6 Indicate the abundance of species in five qualitative *abundance categories* (obligatory):
  - r!** (**very rare**): one or a few small individuals.
  - r** (**rare**): some individuals at several locations, can hardly be overlooked in a careful observation.
  - s** (**scattered**): widespread within the section; the species cannot be overlooked but its presence is not obvious at first glance (not necessarily an evenly dispersed distribution over the entire summit area section).
  - c** (**common**): occurring frequently and widespread within the section – presence is obvious at first glance (cover is less than 50%).
  - d** (**dominant**): very abundant, making up a high portion of the phytomass, often forming more or less patchy or dense vegetation layers; species covers more than 50% of the area of the SAS (this is the only abundance class which is entirely related to cover).
- 7 Only optional (as an additional record): Percentage cover estimation for each species; avoid indications such as: less than (<) or more than (>). Percentage cover may either be surveyed by direct visual cover estimation or by *point-line intercepts* (for the more common species) and recording of *area cover* (i.e. the exact area size, such as m<sup>2</sup>, dm<sup>2</sup>, etc.; for the rarer species) which can be converted into percentage cover later on (*PAF* method; see chapter 5.2.2).

## Form 4 Temperature loggers

Country code <sup>1)</sup>	Summit code <sup>1)</sup>
Target region code <sup>1)</sup>	Full summit name

### First installation

Quadrat code <sup>1)</sup>	Logger serial <sup>2)</sup>	Logger type <sup>3)</sup>	Start date	Start time <sup>4)</sup> (local time)	UTC diff. <sup>5)</sup>	Dist-11 <sup>6)</sup>	Dist-31 <sup>7)</sup>	Photo check open <sup>8)</sup>	Photo check closed <sup>8)</sup>	Researcher(s)	Comments
								<input type="checkbox"/>	<input type="checkbox"/>		
								<input type="checkbox"/>	<input type="checkbox"/>		
								<input type="checkbox"/>	<input type="checkbox"/>		
								<input type="checkbox"/>	<input type="checkbox"/>		
								<input type="checkbox"/>	<input type="checkbox"/>		

### Data read-out

#### De-installation needed<sup>11)</sup>

Quadrat code <sup>1)</sup>	Logger serial <sup>2)</sup>	Logger type <sup>3)</sup>	Stop date	Stop time <sup>9)</sup> (local time)	Researcher(s)	Comments <sup>10)</sup>	New logger serial <sup>12)</sup>	Logger type <sup>3)</sup>	Start date	Start time <sup>4)</sup> (local time)	Photo check open <sup>8)</sup>	Photo check closed <sup>8)</sup>
											<input type="checkbox"/>	<input type="checkbox"/>
											<input type="checkbox"/>	<input type="checkbox"/>
											<input type="checkbox"/>	<input type="checkbox"/>
											<input type="checkbox"/>	<input type="checkbox"/>
											<input type="checkbox"/>	<input type="checkbox"/>

1) See Box 6.1 for coding. 2) The logger serial number is usually indicated somewhere on the logger and is the reference number for identifying a logger when launching and reading out the data. 3) Indicate the logger type, e.g. GeoPrecision, TidBit or TinyTag. 4) Indicate the time after finishing the installation of each logger in the field (use your local time). 5) Indicate the time difference, i.e. the number of hours to be added or subtracted from your local time to the UTC/GCT (Coordinated Universal Time/Greenwich Mean Time); for example, if the local time is 14:00 and UTC 12:00, the value to be entered is -2. 6) Distance (in m with two decimal places) from the logger to the left lower cluster corner (e.g. p5m-S11; see Fig. 4.5). 7) Distance (in m with two decimal places) from the logger to the right lower cluster corner (e.g. p5m-S31; see Fig. 4.5). 8) Photo check: Check the box after photos are taken to be sure that the photo documentation is complete (documentation of the logger position with the hole open and documentation after the hole is closed with substrate material; see Fig. 4.5). 9) Indicate the time of data read-out (use your local time). In cases where de-installation is necessary indicate the time before digging out the logger. 10) Comment on logger failure and de-installations; in any case when you de-install the logger, indicate **DR** for data read-out (e.g. in the case of TidBit loggers), **BC** for battery change, or **LC** for logger change. 11) Only to be filled out when you de-install the logger. 12) Indicate the new logger serial number. In cases of installing the same logger (battery change or TidBit data read-out), indicate "ident" for identic logger.

### Form 5-S Subplot-frequency counts in the 1-m<sup>2</sup> quadrat

[illegible]

If you have used extra sheets, indicate its number (e.g. 1 of 2, 2 of 2 etc...)	
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**1)** See box 6.1 for coding. **2)** Each cell in this form represents a 0.1 m x 0.1 m cell of the grid frame (see Fig. 5.1) = 100 possible cells for each species where the presence of the species will be indicated with an X. **3)** Grazing impact: frequency of impacts caused by livestock grazing (impacts caused by wild-living mammals are also included, because the latter may hardly be distinguishable from livestock impacts). **4)** Species (all vascular plants, bryophytes and lichens are optional): indicate species names or by (provisional) codes. A species is considered as present when showing plant parts within the boundary strings of a 0.1 m x 0.1 m grid cell (always in view perpendicular to the grid frame plane). **5)** Use the "cf." column if the identification of the taxon is doubtful (see **g** if this is the case for the genus level, **s** for the species level, **t** for a lower taxonomic level). **6)** Use the "cf." column if the identification of where it is rooted. **7)** Use the "cf." column if the identification of the taxon is doubtful (see **g** if this is the case for the genus level, **s** for the species level, **t** for a lower taxonomic level).





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## NOTES: FORM 6-S GLORIA 10m × 10m SQUARE

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- 1 See Box 6.1 for coding.
- 2 Enter the cardinal direction (N, E, S, or W).
- 3 Indicate starting line position with a check mark at one of the four options.
- 4 The same *surface types* as used in the *summit area sections*, but without the *surface type* "vascular plants" (compare chapter 5.3.1). Surface types are only tallied where no vascular plants were hit.
- 5 Twenty parallel lines for *line-pointing* (column 1-20); twenty points along each line (compare chapter 5.3.1).
- 6 Enter the sum of all strokes of the tally.
- 7 Enter all vascular plant species which you hit with the sampling pin. When you hit more than one vascular plant species on one point, tally all of them. After you have completed line pointing, add (below or on a continuation sheet) all additional vascular plant species that occur within the *10m × 10m square*.

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# THE GLORIA FIELD MANUAL

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## ANNEX II: DATA SAMPLING FORMS

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### PART 2: EXAMPLE SHEETS

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Examples of standard sampling *forms 0, 1-4* **125**

and of supplementary *forms 5-S, 6-S* **132**

Example of the GLORIA *target region Taxa input sheet* **135**

# Form 0 Target region

## EXAMPLE

Country code <sup>1)</sup>	AT	Date	05. August 2010	Researcher(s)	Maria Montalto, Yuri Serov
Target region code <sup>1)</sup>	HSW				

### Altitude of major vegetation boundary lines (in metres)

Potential natural forestline <sup>2)</sup>	1700m	Potential natural treeline <sup>2)</sup>	1900m	Alpine-nival ecotone <sup>2)</sup>	2800m
Current forestline <sup>2)</sup>	1600m	Current treeline <sup>2)</sup>	1820m		

Predominant bedrock material and approximate soil pH at the summit sites of the target region<sup>4)</sup>  
Limestone  
pH +/- neutral

Short description of the target region, particularly regarding land use history and the current land use situation<sup>5)</sup>

No significant human land use; mountain pasturing has never been important within the alpine zone of the target region.

In some areas timber logging at the forest line and livestock grazing in the lower treeline ecotone - but only before around 1920; none of the summits show obvious impacts caused by these activities; pasturing is restricted now, because area is protected as a fresh water reserve.

Comments on vegetation boundary lines<sup>3)</sup>

Forestline and treeline were slightly lowered due to historic land use (pasturing, logging);

### SUMMITS

	Summit code <sup>1)</sup>	Summit name	Altitude (m a.s.l.)	Vegetation zone or ecotone <sup>6)</sup>	Comments on the summit situation <sup>7)</sup>
LOW	BER	Bergerl	1823m	treeline ecotone	The eastern part of the summit is rather flat, but 5m and 10m points can be setup within 50m/100m distances
	PEB	Peak Beauty	2201m	lower alpine	
	MEX	Monte Exemplario	2537m	lower - upper alpine	
HIGH	MSC	Mount Schwabi	2819m	alpine - nival	unstable scree slopes on the N and NW slopes - be careful with fieldwork

### Notes

1) See Box 6.1 for coding. 2) Enter the approximate metres above sea level (m a.s.l.) for each vegetation boundary line which indicates its average altitude in the target region; the forestline (or timberline) is defined as the line where closed forests end; the treeline is defined as the line where groups of trees taller than 3m end; the alpine-nival ecotone is the transition zone between the upper alpine belt and the nival belt - make an estimation of the altitude of the upper boundary line of the alpine zone, where closed vegetation ends (this line may coincide with the permafrost limit in many mountain regions). 3) Where required make comments on the indicated altitudinal positions of boundary lines; e.g. deviations from the average altitude; mention if a boundary line does not exist in the target region and comment on the reasons for its absence. 4) Bedrock material of the summit sites of the target region, which should be consistent throughout the four summits (consistent regarding the influence of the bedrock on the species composition); in addition, make a rough estimate on the average soil pH (e.g. acid: <4.5, intermediate: 4.5-6.5, neutral/alkaline: >6.5). 5) If the situation is not pristine or natural, indicate what kind of land use have or had an impact on the present vegetation. 6) Only the following entries are possible: treeline ecotone, lower alpine, lower/upper alpine ecotone, upper alpine, alpine-nival ecotone, nival. 7) Make comments on the situation of the particular summit if vegetation zone or ecotone is not properly applicable and describe the deviations. Further comment on any other pronounced deviation from an 'ideal' standard summit situation (compare chapter 2.2 in the field manual).

Use extra blank sheets, if necessary - indicate the number of extra sheets in this box (e.g. 1 of 2, 2 of 2 etc...)

1 of 1

# Form 1 Measurement protocol

## EXAMPLE

Country code <sup>1)</sup>	AT	Date	07. August 2010	Highest summit point (HSP) <sup>3)</sup>	Altitude (m)	Geographic co-ordinates (deg/min/sec)	
Target region code <sup>1)</sup>	HSW	Researcher(s)	Yuri Serov	Photo check <sup>6)</sup>	2537	long.	15° 08' 01" E
Summit code <sup>1)</sup>	MEX		Maria Montalto			lat.	47° 36' 53" N
Summit name <sup>2)</sup>	Monte Exemplario	Magnetic declination (°) for compass measurements <sup>4)</sup>					
						+2	

### QUADRAT CLUSTERS & 10-m POINTS

Point number <sup>5)</sup>		Distance (m) <sup>6)</sup>	Compass direction (°) <sup>7)</sup>	Photo check <sup>8)</sup>	
NORTH	p5m-N11	32	358	<input checked="" type="checkbox"/> quadrat N11	<input checked="" type="checkbox"/> 3mx3m grid cluster overview
	p5m-N31	30.54	354	<input checked="" type="checkbox"/> quadrat N31	
	p-N33	27.91	355	<input checked="" type="checkbox"/> quadrat N33	
	p-N13	29.53	359	<input checked="" type="checkbox"/> quadrat N13	
	p10m-N	44.47	358	<input checked="" type="checkbox"/> 10-m-point	
EAST	p5m-E11	18.17	94	<input checked="" type="checkbox"/> quadrat E11	<input checked="" type="checkbox"/> 3mx3m grid cluster overview
	p5m-E31	17.75	88	<input checked="" type="checkbox"/> quadrat E31	
	p-E33	14.78	87	<input checked="" type="checkbox"/> quadrat E33	
	p-E13	15.26	92	<input checked="" type="checkbox"/> quadrat E13	
	p10m-E	27.55	88	<input checked="" type="checkbox"/> 10-m-point	
SOUTH	p5m-S11	24.33	172	<input checked="" type="checkbox"/> quadrat S11	<input checked="" type="checkbox"/> 3mx3m grid cluster overview
	p5m-S31	24.08	167	<input checked="" type="checkbox"/> quadrat S31	
	p-S33	21.1	168	<input checked="" type="checkbox"/> quadrat S33	
	p-S13	21.4	170	<input checked="" type="checkbox"/> quadrat S13	
	p10m-S	40.85	172	<input checked="" type="checkbox"/> 10-m-point	
WEST	p5m-W11	23.04	268	<input checked="" type="checkbox"/> quadrat W11	<input checked="" type="checkbox"/> 3mx3m grid cluster overview
	p5m-W31	23.17	265	<input checked="" type="checkbox"/> quadrat W31	
	p-W33	20.2	265	<input checked="" type="checkbox"/> quadrat W33	
	p-W13	20.07	267	<input checked="" type="checkbox"/> quadrat W13	
	p10m-W	39.5	268	<input checked="" type="checkbox"/> 10-m-point	

### INTERSECTION LINES

Point num.	Dist. (m) <sup>6)</sup>	Comp. dir. (°) <sup>7)</sup>	Photo check <sup>8)</sup>	Point num.	Dist. (m) <sup>6)</sup>	Comp. dir. (°) <sup>7)</sup>	Photo check <sup>8)</sup>
pNE-5	20.35	43	<input checked="" type="checkbox"/>	pSW-5	14.35	223	<input checked="" type="checkbox"/>
pNE-10	29.24	43	<input checked="" type="checkbox"/>	pSW-10	26.5	223	<input checked="" type="checkbox"/>
pSE-5	16.5	133	<input checked="" type="checkbox"/>	pNW-5	21.35	313	<input checked="" type="checkbox"/>
pSE-10	29.2	133	<input checked="" type="checkbox"/>	pNW-10	38.44	313	<input checked="" type="checkbox"/>

### COMMENTS

The principal measurement line of the S-direction (determined by HSP, p5m-S11 and p10m-S) deviates 6° E from the exact geogr. S (because terrain was not appropriate for the 3m x 3m cluster at exactly geogr. S).

Entire summit Photo check <sup>8)</sup>	<input checked="" type="checkbox"/>
Use extra blank sheets for further remarks, if necessary.	
Indicate the number of extra sheets in this box	0

### Notes

- See Box 6.1 for coding. 2) Full name of the summit (from topographic maps or a working name where no official name is available). 3) The highest summit point is the culmination point +/- in the middle of the summit area (rocky outcrops which may be higher but are not centred in the summit area should be ignored).
- The angle (with its correct sign) between the direction of the geographic North Pole and of the magnetic North Pole (e.g. -6 for a magnetic declination of 6° W; +10 for 10° E; see Box 3.1). 5) Mark those checkbox where the respective point lies on the principal measurement line (e.g. p5m-N11 or p5m-N31, both are not possible; compare Fig. 3.2).
- The length of a straight surface line between the HSP and the measurement point (in metres, with two decimal places); keep the measurement tape tightened for all distance measurements (see Box 3.3). 7) The compass direction from the HSP to the measurement point in degrees (360° scale; see Box 3.1). Please note: always write the magnetic compass directions (i.e. degrees as indicated on the compass).
- Photo check: check the box after photos are taken to make sure that the photo documentation is complete (see under 4.4 for details).



### EXAMPLE

**Top cover of surface types (%)<sup>4)</sup>**

Subtypes in % of the top cover type<sup>5)</sup>

Likely *Festuca versic. ssp. brachy.*, but might also be *F. quadriflora*; *Arabis*: we think it is *A. b. ssp. stellulata*, but it also could be *A. bellidifolia ssp. bellidifolia* (for both cases see herbarium material collected outside the plot)

**Plant species cover (%)<sup>6)</sup>**

Cover sum<sup>8)</sup>

If you have used extra sheets, indicate their number (e.g. 1 of 2, 2 of 2 etc...)

1 of 1

See back page for footnotes

# Form 3 Summit area section (SAS) EXAMPLE

Codes of<sup>1)</sup>

Country	AT
Target region	HSW
Summit	MEX
SAS	E05
Date	11. August 2010
Time from	09:30 to 12:05

Researcher(s)	Maria Montalto, Yuri Serov
Comments on grazing impacts <sup>3)</sup>	Few faeces most likely from chamois and slight browsing damage

Top cover of surface types (%)<sup>2)</sup>

Vascular plants	64
Solid rock	18
Scree	10
Lichens (excl. epilithic)	0.5
Bryophytes	0.4
Bare ground	7
Litter	0.1
SUM	100%

Species <sup>4)</sup>	cf. <sup>5)</sup>	Abundance <sup>6)</sup>	%-Cover <sup>7)</sup> (optional)
1 Carex firma		c	
2 Dryas octopetala		c	
3 Festuca quadriflora		s	
4 Silene acaulis s.str.		s	
5 Saxifraga paniculata		r	
6 Carex fuliginosa		r	
7 Minuartia sedoides		r	
8 Arabis bell. ssp. stellulata	†	r	
9 Salix retusa		r	
10 Arenaria ciliata		r	
11 Draba aizoides		r	
12 Salix reticulata		r	
13 Primula clusiana		r	
14 Doronicum glaciale		r	
15 Crepis terglouensis		r!	
16 Sesleria albicans		s	
17 Campanula alpina s.str.		s	
18 Polygonum viviparum		s	
19 Poa alpina		c	
20 Draba sauteri		s	
21 Saxifraga exarata ssp.mos.		r	
22 Pritzelago alpina		r	
23 Saxifraga aizoides		s	
24 Petrocallis pyrenaica		r	
25 Myosotis alpestris		s	
26 Pedicularis rosea		r	
27 Draba stellata		r	
28 Bartsia alpina		s	
29 Potentilla crantzii		s	
30 Gentiana pumila		r	

Species <sup>4)</sup>	cf. <sup>5)</sup>	Abundance <sup>6)</sup>	%-Cover <sup>7)</sup> (optional)
31 Agrostis alpina		s	
32 Androsace chamaejasme		s	
33 Euphrasia minima		r	
34 Minuartia sp. small	g	r!	
35 Ranunculus alpestris		s	
36 Sesleria ovata		s	
37 Thymus praecox		s	
38 Selaginella selagionoides		r	
39 Pedicularis verticillata		r	
40 Gentiana orbicularis		r	
41 Potentilla clusiana		s	
42 Saxifraga oppositifolia		s	
43 Hedysarum hedysaroides		s	
44 Minuartia cherlerioides		r	
45 Saxifraga androsacea		r	
46 Ranunculus montanus		s	
47 Pedicularis rostrato-capitata		r	
48 Luzula glabrata		r	
49 Armeria alpina		r	
50 Galium noricum		r	
51 Thlaspi alpinum		r	
52 Homogyne discolor		s	
53 Aster bellidiastrum		s	
54 Soldanella austriaca		r	
55 Valeriana celtica		r	
56 Dianthus alpinus		r	
57 Euphrasia salisburgensis		s	
58 Veronica aphylla		r	
59 Huperzia selago		r	
60 Campanula scheuchzeri		s	

Comments on species recording

Total number of vascular plant species  
in this summit area section

62

Minuartia sp.: a small individuum in the lower eastern part of the summit area section. Could be Arenaria sp. as well (comparison with herbarium material collected).

See back page for footnotes

If you have used extrasheets, indicate their  
number (e.g. 1 of 3, 2 of 3, etc.)

1 of 2

# Form 3 Summit area section (SAS) EXAMPLE

## Codes of<sup>1)</sup>

Country	AT
Target region	HSW
Summit	MEX
SAS	E05
Date	11. August 2010
Time from	09:30 to 12:05

Researcher(s)
Maria Montalto,
Yuri Serov
Comments on grazing impacts <sup>5)</sup>

## Top cover of surface types (%)<sup>2)</sup>

Vascular plants	
Solid rock	
Lichens (excl. epilithic)	
Bryophytes	
Bare ground	
Litter	
SUM	100%

continued

Species <sup>4)</sup>	cf. <sup>5)</sup>	Abundance <sup>6)</sup>	%-Cover <sup>7)</sup> (optional)
1 Festuca vers. ssp. brachyst.	s	r	
2 Parnassia palustris		r	
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			

Species <sup>4)</sup>	cf. <sup>5)</sup>	Abundance <sup>6)</sup>	%-Cover <sup>7)</sup> (optional)
31			
32			
33			
34			
35			
36			
37			
38			
39			
40			
41			
42			
43			
44			
45			
46			
47			
48			
49			
50			
51			
52			
53			
54			
55			
56			
57			
58			
59			
60			

Comments on species recording

Total number of vascular plant species  
in this summit area section

62

Festuca versic. ssp. brachy.: likely it is F. versic. ssp. brachy., but it could be F. quadriflora as well.

See back page for footnotes

If you have used extrasheets, indicate its  
number (e.g. 1 of 3, 2 of 3, etc.)

2 of 2

## Form 4 Temperature loggers

# EXAMPLE

Country code <sup>1)</sup>	AT	Summit code <sup>1)</sup>	MEX
Target region code <sup>1)</sup>	HSW	Full summit name Monte Exemplario	

### First installation

Quadrat code <sup>1)</sup>	Logger serial <sup>2)</sup>	Logger type <sup>3)</sup>	Start date	Start time <sup>4)</sup> (local time)	UTC diff. <sup>5)</sup>	Dist-1 <sup>6)</sup>	Dist-3 <sup>7)</sup>	Photo check open <sup>8)</sup>	Photo check closed <sup>8)</sup>	Researcher(s)	Comments
N22	A43702	GeoPrecision	12. August 2010	13:05	+ 2	1.76	2.07	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Montealto, Serov	
E22	A55632	GeoPrecision	12. August 2010	14:30	+ 2	2.05	2.67	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Montealto, Serov	
S22	A87354	GeoPrecision	12. August 2010	15:21	+ 2	1.80	1.20	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Montealto, Serov	
W22	A22154	GeoPrecision	12. August 2010	17:15	+ 2	2.08	2.04	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Montealto, Serov	

### Data read-out

### De-installation needed<sup>11)</sup>

Quadrat code <sup>1)</sup>	Logger serial <sup>2)</sup>	Logger type <sup>3)</sup>	Stop date	Stop time <sup>9)</sup> (local time)	Researcher(s)	Comments <sup>10)</sup>	New logger serial <sup>12)</sup>	Logger type <sup>3)</sup>	Start date	Start time <sup>4)</sup> (local time)	Photo check open <sup>8)</sup>	Photo check closed <sup>8)</sup>
											<input type="checkbox"/>	<input type="checkbox"/>
											<input type="checkbox"/>	<input type="checkbox"/>
											<input type="checkbox"/>	<input type="checkbox"/>
											<input type="checkbox"/>	<input type="checkbox"/>

1) See Box 6.1 for coding. 2) The logger serial number is usually indicated somewhere on the logger and is the reference number for identifying a logger when launching and reading out the data. 3) Indicate the logger type, e.g. GeoPrecision, TidBit or TinyTag. 4) Indicate the time after finishing the installation of each logger in the field (use your local time). 5) Indicate the time difference, i.e. the number of hours to be added or subtracted from your local time to the UTC/GCT (Coordinated Universal Time/Greenwich Mean Time); for example, if the local time is 14:00 and UTC 12:00, the value to be entered is -2. 6) Distance (in m with two decimal places) from the logger to the left lower cluster corner (e.g. p5m-S11; see Fig. 4.5). 7) Distance (in m with two decimal places) from the logger to the right lower cluster corner (e.g. p5m-S31; see Fig. 4.5). 8) Photo check: Check the box after photos are taken to be sure that the photo documentation is complete (documentation of the logger position with the hole open and documentation after the hole is closed with substrate material; see Fig. 4.5). 9) Indicate the time of data read-out (use your local time). In cases where de-installation is necessary indicate the time before digging out the logger. 10) Comment on logger failure and de-installations; in any case when you de-install the logger, indicate **DR** for data read-out (e.g. in the case of TidBit loggers), **BC** for battery change, or **LC** for logger change. 11) Only to be filled out when you de-install the logger. 12) Indicate the new logger serial number. In cases of installing the same logger (battery change or TidBit data read-out), indicate "ident" for identical logger.

## Form 4 Temperature loggers

### EXAMPLE

Country code <sup>1)</sup>	AT	Summit code <sup>1)</sup>	MEX
Target region code <sup>1)</sup>	HSW	Full summit name	Monte Exemplario

### First installation

Quadrat code <sup>1)</sup>	Logger serial <sup>2)</sup>	Logger type <sup>3)</sup>	Start date	Start time <sup>4)</sup> (local time)	UTC diff. <sup>5)</sup>	Dist-1 <sup>6)</sup>	Dist-3 <sup>7)</sup>	Photo check open <sup>8)</sup>	Photo check closed <sup>9)</sup>	Researcher(s)	Comments
N22	A43702	GeoPrecision	12. August 2010	13:05	+ 2	1.76	2.07	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Montealto, Serov	
E22	A55632	GeoPrecision	12. August 2010	14:30	+ 2	2.05	2.67	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Montealto, Serov	
S22	A87354	GeoPrecision	12. August 2010	15:21	+ 2	1.80	1.20	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Montealto, Serov	
W22	A22154	GeoPrecision	12. August 2010	17:15	+ 2	2.08	2.04	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Montealto, Serov	

### Data read-out

### De-installation needed<sup>11)</sup>

Quadrat code <sup>1)</sup>	Logger serial <sup>2)</sup>	Logger type <sup>3)</sup>	Stop date	Stop time <sup>9)</sup> (local time)	Researcher(s)	Comments <sup>10)</sup>	New logger serial <sup>12)</sup>	Logger type <sup>3)</sup>	Start date	Start time <sup>4)</sup> (local time)	Photo check open <sup>8)</sup>	Photo check closed <sup>9)</sup>
N22	A43702	GeoPrecision	03. August 2013	11:25	Montealto, Serov	BC	ident		03. August 2013	12:05	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
E22	A55632	GeoPrecision	03. August 2013	12:33	Montealto, Serov	LC no signal from the logger	A23234	GeoPrecision	03. August 2013	12:59	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
S22	A87354	GeoPrecision	03. August 2013	13:19	Montealto, Serov	BC	ident		03. August 2013	13:50	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
W22	A22154	GeoPrecision	03. August 2013	14:45	Montealto, Serov	BC	ident		03. August 2013	15:10	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

1) See Box 6.1 for coding. 2) The logger serial number is usually indicated somewhere on the logger and is the reference number for identifying a logger when launching and reading out the data. 3) Indicate the logger type, e.g. GeoPrecision, TidBit or TinyTag. 4) Indicate the time after finishing the installation of each logger in the field (use your local time). 5) Indicate the time difference, i.e. the number of hours to be added or subtracted from your local time to the UTC/GCT (Coordinated Universal Time/Greenwich Mean Time); for example, if the local time is 14:00 and UTC 12:00, the value to be entered is -2. 6) Distance (in m with two decimal places) from the logger to the left lower cluster corner (e.g. p5m-S11; see Fig. 4.5). 7) Distance (in m with two decimal places) from the logger to the right lower cluster corner (e.g. p5m-S31; see Fig. 4.5). 8) Photo check: Check the box after photos are taken to be sure that the photo documentation is complete (documentation of the logger position with the hole open and documentation after the hole is closed with substrate material; see Fig. 4.5). 9) Indicate the time of data read-out (use your local time). In cases where de-installation is necessary indicate the time before digging out the logger. 10) Comment on logger failure and de-installations; in any case when you de-install the logger, indicate **DR** for data read-out (e.g. in the case of TidBit loggers), **BC** for battery change, or **LC** for logger change. 11) Only to be filled out when you de-install the logger. 12) Indicate the new logger serial number. In cases of installing the same logger (battery change or TidBit data read-out), indicate "ident" for identical logger.



### Form 5-S Subplot-frequency counts in the 1-m<sup>2</sup> quadrat

## EXAMPLE

[illegible]

If you have used extra sheets, indicate its number (e.g. 1 of 2 2 of 2 etc...)

1) See box 6.1 for coding. 2) Each cell in this form represents a 0.1 m x 0.1 m cell of the grid frame (see Fig. 5.1) = 100 possible cells for each species. Where the presence of the species will be indicated with an X. 3) Grazing impact: frequency of impacts caused by livestock grazing (impacts caused by wild-living mammals are also included, because the latter may hardly be distinguishable from livestock impacts). 4) Species (all vascular plants; bryophytes and lichens are optional): indicate species either by using species names or by (provisional) codes. A species is considered as present when showing plant parts within the boundary strings of a 0.1 x 0.1 m grid cell (always in view perpendicular to the grid frame plane), regardless of where it is rooted. 5) Use the "cf." column if the identification of the taxon is doubtful (use **g** if for the genus level, **s** for the species level, **t** for a lower taxonomic level).





**GLORIA target region****Taxa input sheet****EXAMPLE**TARGET REGION CODE<sup>1)</sup>: AT-HSW

Date: 14.08.2014

Responsible Person(s): Maria Montealto (maria.montealto@aufnberg.com), Yuri Serov (yuri.serov@aufnberg.com)

**FIELD DESCRIPTION:**

FULL\_NAME

PLANT\_TYPE

RANK

FLORA

FAMILY

GENUS

SPECIES

TAXON

REFERENCE

SYNONYMS

SPECIES\_No\_in\_FLORA

B\_LIVERWORT

COMMENT

HERBARIUM\_SPECIMEN

Full taxon name including the taxon author(s) or its/their abbreviation(s)

V = vascular plant, B = bryophyte, L = lichen

Taxonomic rank; possible entries: "species", "subsp.", "aggr." (aggregate species), "var." (variety)

Abbreviation of the flora (literature) used; maximum 15 characters; in addition indicate the full citation of the flora in the box below; wherever possible, please use floras with a large geographical coverage, preferably with checklists accessible in the internet

Plant family

Genus name

Species name

If RANK is "species", enter again the species name; if rank is a lower taxonomic level, enter the name of the subsp. or var.

The nomenclatorial reference; i.e. the reference indicating where the taxon's author(s) published the name (enter abbreviation(s) and the full citation in the box below the field description)

Add synonymous names of the taxon, particularly when widely used ones exist (including the taxon author or its abbreviation) - if more than one, divided by a semicolon

Species number in flora: code number (numerical or alphanumerical) which is used in the flora, where applicable - this always refers to the entry in column "FLORA"

Only relevant for bryophytes: enter "TRUE" if the bryophyte is a liverwort

Text field for comments; e.g. on taxonomical details in the case of a critical taxon

Enter the code of your herbarium voucher: Herbarium acronym, collector, voucher number (this is obligatory for doubtful cases) - further, indicate the name of the herbarium and location in the box below the field description

Full citation of the reference flora(s) indicated in the field "FLORA"<sup>2)</sup>

FE\_042001: Tutin et al. 1964-1980, Flora Europaea, volumes 1-5, Cambridge University Press. Digital version 2001.  
 BBS2010: British Bryological Society (2010). Checklist of the mosses of Europe and Macaronesia; <http://rbg-web2.rbge.org.uk/bbs/resources/Eurochecklist.htm>  
 IndexFung\_201101: Index Fungorum: <http://www.indexfungorum.org/Names/Names.asp>

Name of herbarium(s), location(s)<sup>3)</sup>

Herbarium WU; Institute of Botany, University of Vienna; A-1030 Vienna, Rennweg 14, Austria

FULL_NAME	PLANT_TYPE	RANK	FLORA	FAMILY	GENUS	SPECIES	TAXON	REFERENCE	SYNONYMS	SPECIES_No_in_FLORA	B_LIVERWORT	COMMENT	HERBARIUM_SPECIMEN
Carina acaulis L.	V	species	FE_042001	Compositae	Carina	acaulis	acaulis	Sp. Pl., ed. 1, 828 (1753).		3171	FALSE		WUGloria30012
Adenostyles alliariae (Gouan) A.Kern. subsp. alliariae	V	subsp.	FE_042001	Compositae	Adenostyles	alliariae	alliariae	Österr. Bot. Zeitschr. 21:		5965	FALSE		WUGloria30017
Arctostaphylos uva-ursi (L.) Spreng.	V	species	FE_042001	Ericaceae	Arctostaphylos	uva-ursi	uva-ursi	Syst. Vag., ed. 16, 2, 28	Arctostaphylos a	19542	FALSE		WUGloria30014
Epipactis atrorubens (Hoffm.) Besser	V	species	FE_042001	Orchidaceae	Epipactis	atrorubens	atrorubens	Prim. Fl. Gall.: 2: 220 (1816)	Epipactis atrorub	39603	FALSE		WUGloria30015
Lark decidua Mill.	V	species	FE_042001	Phacaceae	Lark	decidua	decidua	Gard. Dict., ed. 8, no. 11		663	FALSE		WUGloria30027
Loiseleuria procumbens (L.) Desv.	V	species	FE_042001	Ericaceae	Loiseleuria	procumbens	procumbens	Jour. Bot. Appl. 1: 35 (18		19506	FALSE		WUGloria30001
Rhododendron ferrugineum L.	V	species	FE_042001	Ericaceae	Rhododendron	ferrugineum	ferrugineum	Sp. Pl., ed. 1, 392 (1753)		19514	FALSE		WUGloria30051
Juncus trifidus L. subsp. monanthos (Jacq.) Asch.	V	subsp.	FE_042001	Juncaceae	Juncus	trifidus	monanthos	Syn. Mitteleur. Fl. 2(2): 4	Juncus monanth	36211	FALSE		WUGloria30020
etc.													
Tortella tortuosa (Hedw.) Limpr.	B	species	BBS2010	Polypodiaceae	Tortella	tortuosa	tortuosa	Laubm. Deutschl. 1: 604		123	FALSE		WUGloria40002
Cetraria islandica (L.) Ach.	L	species	IndexFung_20110	Parmeliaceae	Cetraria	islandica	islandica	Method. Lich.: 293 (1803)		382416	FALSE		WUGloria60019
etc.													
Not identified species:													
Poa in AT-HSW <sup>4)</sup>	V	genus	NN_vasc	Gramineae	Poa		0001ATHSW				FALSE	probably P. m	WUGloria30044
Cerastium in AT-HSW-ZIK <sup>5)</sup>	V	genus	NN_vasc	Caryophyllaceae	Cerastium		0001ATHSWZIK				FALSE	dwarf, abovele	WUGloria30008
Cerastium in AT-HSW-GHK-E31 <sup>6)</sup>	V	genus	NN_vasc	Caryophyllaceae	Cerastium		0002ATHSWGK				FALSE	dwarf, round-le	WUGloria30015

**Notes**

- 1) The target region code must be the same code as you have written on the backboard, used for plot photo documentation.
- 2) For other regions some examples for useful web check lists: Tropicos (MOBOT); <http://www.tropicos.org>; USDA (United States Department of Agriculture); <http://plants.usda.gov>.
- 3) Herbarium acronym; full name of herbarium and location.
- 4) The unidentified taxon was found in several of your summit sites (be sure that all cases belong to the same species).
- 5) The unidentified taxon was found only on one summit (be sure that all cases belong to the same species).
- 6) The unidentified taxon was found only in one plot.

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# THE GLORIA FIELD MANUAL

## MULTI-SUMMIT APPROACH

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### ANNEX III: CODING OF THE PHOTO DOCUMENTATION

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Any item which is included into the GLORIA *photo documentation* must have a GLORIA-wide unique code. This code has to be indicated on the blackboard included in the photo view, wherever applicable. Moreover, digital photos which are to be sent to the *Central GLORIA Database* must have their filenames coded accordingly.

The software for maintaining your *digital photo documentation* (GPDM, GLORIA Photo Data Management) as provided by the GLORIA coordination is designed to compose these filenames automatically for you in order to prevent typing errors as far as possible. Moreover, it is the basis for including your photos in the logical structure of the *Central GLORIA Database* and of the GLORIA website. Therefore, it is highly recommended that you use this software. You can download this software from the GLORIA website ([www.gloria.ac.at](http://www.gloria.ac.at)), please also see the explanations included in the software package on how to use it.

#### FORMAT AND SIZE OF THE PHOTO FILE

Only JPEG files (\*.jpg) are accepted for the *Central GLORIA Database* and website. Use high pixel resolution and do not use a high JPEG-compression factor of your digital photos. Keep in mind that with low resolutions and high compressions you may lose some valuable visual information of the photo. Pictures should have at least about 2000×1500 pixels with a JPEG compression of not more than 20 (on a compression scale of 2 to 255, high quality to low quality). The resulting files should have a size of at least 1.5MB. Higher resolutions and file sizes, of up to about 5-7MB, are accepted and may be preferable, but do not use TIFF or RAW IMAGE formats.

#### STRUCTURE OF PICTURE CODING

The codes are composed of several elements. These elements are defined below. Some of them are required, while others are not. Likewise, some elements have a fixed character length, others do not, due to already established *coding* conventions according to this manual (compare [Fig. 3.2](#) and [Box 6.1](#)).

#### NAMES OF DIGITAL PHOTO FILES

It should be possible to sort all digital photo files logically by their filenames. Therefore, any element must have a constant length in the filenames. If a code is shorter than the required element length, one or more underscores ( \_ ) have to be appended. The code elements themselves also have to be separated by underscores in the filename (and not blanks or dots or hyphens, as opposed to the writing on the blackboard).

In many cases, more than one photo exists for the same item. Therefore, the rightmost fixed-length code element in the filename (i.e., element7, see below) is defined as ordering number. Each photo file of your target region must have a unique ordering number. The software GPDM creates this automatically for you. If you want certain photos (of the same item) to appear in a certain order at the GLORIA website (e.g. because of decreasing importance or quality), reflect this order in the numbering of this code element.



## DEFINITION OF CODE ELEMENTS

ELEMENT	CATEGORY	REQUIRED ON BLACKBOARD	REQUIRED IN FILENAMES	ELEMENT LENGTH	REMARK
Element 1	<i>Monitoring cycle</i>	No	Yes	Fixed length: 2	The monitoring cycle of your <i>target region</i> (01 = first field survey, 02 = first re-survey, 03 = second re-survey, etc.)
Element 2	Country code	Yes	Yes	Fixed length: 2	Constant for the whole <i>target region</i>
Element 3	<i>Target region</i> code	Yes	Yes	Fixed length: 3	Constant for the whole <i>target region</i>
Element 4	Summit code	Yes	Yes	Fixed length: 3	If the photo cannot be related to a distinct summit, use three underscores ( _ ). This is only the case for the element5-categories PLANT____, LANDSC____, and OTHER____.
Element 5	Item code (plot codes, corner point codes, summit overview photo, etc.)	Yes	Yes	Fixed length: 8	For shorter codes, append underscores ( _ ) to reach a total length of eight characters in the filename; avoid these underscores on the blackboard to save space.
Element 6	Date of photo	Yes	Yes	Fixed length: 8	Use the format <i>yyyymmdd</i> in file names: indicate 00 for any unknown day or month on the blackboard. You may use the format <i>yyyy/mm/dd</i> on the blackboard and write this element in the upper left corner of, for better reading.
Element 7	Ordering number	No (not applicable)	Yes	Fixed length: 5	Use 5-digit numbers in ascending order that are unique within your <i>target region</i> (starting with 00000, 00001, etc.); if you use GPDM, this number is calculated automatically.
Element 8*	Indication, or plant species name	No	No	Variable length, limited to 150 characters	Short description of the photo item; limited to 150 characters; use a hyphen ( - ) as word separator. However, this is only required in the following cases: <ul style="list-style-type: none"> <li>◆ Description of item if LANDSC____, or OTHER____ is used for element5;</li> <li>◆ Description of viewpoint if SU-OV____ is used for element5 (SU-OV: summit overview);</li> <li>◆ Plant species name if PLANT____ is used for element5; in this case, separate the genus and species name by a hyphen ( - )</li> </ul>

\* Not required (optional) on blackboards in all cases; only required (obligatory) for digital photo filenames if the element5- categories PLANT\_\_\_\_, LANDSC\_\_\_\_, SU-OV\_\_\_\_ or OTHER\_\_\_\_ are used





