16 Making Observations and Measurements in the Field

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Synopsis

Physical geography is traditionally a field-oriented science, and much of the research conducted involves the geographer working 'hands on' in the physical environment. There is a diverse assortment of questions addressed by physical geographers, encompassing the widest range of scales, from microscopic to planetary, and many of these lead geographers outdoors to observe, measure and record features of the environment. This chapter discusses some issues that are common to field-based studies: choosing the spatial and temporal context of the study; understanding the uniqueness of places and the importance of local factors in controlling environmental conditions or processes; and selecting appropriate methodologies for data collection.

The chapter is organized into the following sections:

- Introduction
- Fieldwork design
- Site selection and planning
- Making observations and measurements
- Conclusion

INTRODUCTION

For many physical geographers, doing fieldwork is the most enjoyable and rewarding part of their research, and for many students, field classes and primary research are the most memorable experiences in the undergraduate programme. Physical geographers are often driven by their curiosity about foreign places, their sense of adventure and the aesthetic pleasures of the outdoors, as well as the intellectual challenge of explaining the natural environment, how and why it has developed. While there are obvious attractions to exploring new places, geography is largely about a practical engagement with the world, and the only way to experience and understand the complexity of the real world is in the field (Roberts, 1992). Fieldwork is at the very core of physical geography, which focuses on understanding the Earth's physical environment; experiencing the environment first-hand through conducting fieldwork is a fundamental, perhaps essential, part of geographical research.

Fieldwork is often concerned with careful observation, measurements and recording of information. There are a wide range of methodologies available, and the choices of how, where and when to conduct fieldwork are based on the research questions being addressed. The diversity in field techniques used by geographers reflects the wide variety in geographical research objectives, which may also be manifold within sub-disciplines such as geomorphology, climatology and biogeography. Field methodology cannot be prescribed, but rather reflects a combination of specific research problems, opportunity, training and personal conviction (Bauer *et al*., 2001). The value of fieldwork lies in the advancement of knowledge, which is in turn determined by the successful design and execution of field-based observations and measurements, and the meaningful interpretation of data collected. This chapter will discuss several of the issues inherent in fieldwork design and implementation. Importantly, no fieldwork should ever be planned or undertaken without an awareness of health and safety procedures, nor without a comprehensive analysis of risks and their management (see Chapter 4).

FIELDWORK DESIGN

Physical geography is essentially concerned with the morphological elements of the physical environment (forms), the processes operating in the environment and the materials upon which they operate. For example, fluvial processes operating on channel sediments may form point bars and meanders; ecological processes operating in certain environments may produce a plant community; atmospheric processes in a particular environment cumulatively produce a specific climate regime. The interactions between materials, processes and forms through time and across space are the focus of geographical research, which may address these at a range of spatio-temporal scales. The nature of the fieldwork to be conducted within individual projects is largely determined by the scale (spatial and temporal) of enquiry, and the research questions underlying the field project.

Environmental change is a function of a spatially and temporally continuous system, dependent on a wide range of factors, but most studies are concerned with the development of specific forms, the operation of specific processes, or the factors that control these changes in space and time. Geographers have often found advantage in reducing the time- and space-scales of inquiry, in observing and attempting to measure environmental change over short periods of time. Reduction of both time- and space-scales occurs in parallel as processes that operate over smaller space-scales often operate during shorter time-scales (Lane and Richards, 1997). Physical geographers have long recognized the problem of scale linkage, in that the results of research undertaken at one scale are not necessarily applicable to another scale. Rhoads and Thorn (1996) commented that reductionist approaches have generated more questions than solutions, and new conceptual issues emerge at every scale of interest.

The scale of enquiry of any research project is determined by the landform(s) and/or process(es) under investigation. For example, sediment transport within a fluvial channel may be examined within a particular reach or within a watershed, by researchers interested in the influence of bedforms on sediment transport mechanics or the impact of deforestation on sediment yield, respectively. The choices of how the field observations and measurements are to be made are concerned with issues of *space*, *time* and *place*. These are issues that are both logistical, referring to the choice of field sites and the length of time available for data collection, and are theoretical, as they impact on how the data may be interpreted and the conclusions that may be drawn.

A consideration of space is implicit in any decision to conduct field observations, through the choice of an appropriate field site. Consider an investigation into the controls on a beach profile. While seasonal changes to a beach profile may follow some predictable patterns, where the beach undergoes construction during summer months with low wave energy and then displays erosion and removal of sediment under stormy winter conditions, the profile form of an individual beach is also determined by the sediment characteristics, tidal range and local topographic conditions. This variation in environmental systems across space, or spatial contingency, is a reflection of geographical variability in environmental processes and controls (Phillips, 2007). The inferences that can be drawn from a series of profiles measured between seasons on a single beach are restricted to some extent, due to the importance of local factors in determining beach response to changing wave action. On the other hand, a comparison between beaches with differing sediment compositions or tidal ranges would allow conclusions to be drawn regarding the importance of these controls, if other variables can be assumed to be relatively constant.

Controlling for independent variables when taking measurements across space can facilitate an investigation of the influence of other factors impacting on landform response to physical processes. An illustration of the utility of this approach might be found in catenary relationships linked to hillslope processes. The relationship between soil-profile characteristics and distance downslope on a temperate hillslope might be examined, to test models of hillslope equilibrium (Selby, 1993). If the distance downslope were held constant, sampling on adjacent slopes with differing parent rocks would investigate the relationships between geology, soil characteristics and hillslope processes. If distance downslope and geology were held constant, observations on adjacent slopes with differing vegetation cover (e.g. forest and grass) would investigate the relationships between vegetation, soil characteristics and hillslope processes. This approach uses stratified sampling to compare environmental systems across space and identify patterns or distributions of forms, to determine the importance of controlling variables on process and response.

Environmental change over time may be observed directly through monitoring of the process of interest for a period of minutes, days, weeks or months. Collecting weather data is an example of environmental monitoring that may be performed at regular intervals; these data may be collected by the researcher in person by frequent visits to a weather station, or may be collected remotely by automatic loggers that record and store data. Measurement of stream discharge during rainfall events of differing magnitude and duration and measurement of rates of sand grain transportation across a windy beach are examples of monitoring of processes over time that may lead to understanding of their operation under changing environmental conditions. The time frame during which observations are made imposes some limitations on the interpretation of the data collected, however, as the changes observed are determined, in part, by historical contingency, or inheritance effects that are specific to each place and time. Inheritance involves features inherited from parent material or from previous environmental regimes, which differ from the contemporary environment (Phillips, 2007).

The influence of previous states of an environmental system might be usefully illustrated by returning to the question of distribution of soil profiles on a hillslope. Clearly, the expected relationship between soil depths and profile characteristics will not be identified if a transect down a hillslope crosses a recent landslide. In this case, the relationship between hillslope processes and soil development will be skewed by the recent occurrence of a large-scale erosion event. Eventually, the hillslope may 'recover' from this event, and an equilibrium-slope profile may be established; the period of time required for the impact of a high-magnitude event to be diminished is the relaxation time of the landform (Brunsden and Thornes, 1979).

Environmental monitoring is useful where processes operate at a fairly consistent rate, frequently and within a predictable range. Some physical processes, such as landsliding, are inactive for long periods, and when they do operate they can act very rapidly. Further, processes may vary markedly in their intensity and duration under contrasting climatic conditions. River discharges may vary in response to rainfall events in a humid environment within an order of magnitude, whereas fluvial systems in semi-arid regions may vary by several orders of magnitude (a factor of 100 or 1000) in response to large storm events (Summerfield, 1991). When investigating high-magnitude or low-frequency events, it is appropriate to examine the evidence for the process, and it may be possible to recognize a temporal sequence of system response.

Where geomorphic, ecological or historic evidence indicates a series of events of differing ages, it is possible to investigate changes through time using an ergodic approach, where sampling in space is substituted for sampling through time. For example, to investigate the dynamics of forest recovery from wildfire, stands of forest that have experienced wildfire events 10, 50 and 100 years ago can be examined, if it may be assumed that initial conditions (ecological composition) were similar. In an area prone to landslides, the nature and rate of hillslope recovery may be examined if historical evidence exists that allows scars to be accurately dated, and other structural or topographic factors can be held relatively constant. A sequence of rock weathering may be identified by examining gravestones in a cemetery of a range of ages that are cut from the same rock type and have the same aspect. The success of this approach will depend on the absence of controls other than time that may be responsible for landform change (e.g. lithology) and the existence of evidence to support the sequential development of adjacent landscape features.

In summary, there are three approaches to fieldwork design that are commonly used. First, samples or measurements may be taken across space, where the points of data collection are chosen to control for some independent variables. Second, change in a landform or system may be monitored over time. Third, observations may be made of landforms or systems of varying ages, an ergodic approach that uses space as a substitute for time. In many cases, a combination of the first three strategies may be used. A general survey may be undertaken initially at many sites to establish an overall pattern, and intensive measurements or monitoring may be performed at strategic sites within this broader framework. On a hillslope, soil depths may be measured at many locations on several downslope transects; a smaller number of soil pits may be examined to characterize soils at contrasting elevations within each transect. The usefulness of this combination of approaches lies in the integration of an extensive research design that identifies patterns, or responses, and a case-study approach that investigates specific processes.

SITE SELECTION AND PLANNING

Fieldwork is most often undertaken during a few short weeks or months and in a specific location, such as a hillslope, drainage basin, forest, beach or mountain. The researcher is faced with the prospect of choosing an appropriate field site and making pertinent observations during the time available to complete the project. The choice of field site is driven primarily by the research question to be addressed, but there are other considerations to be included in the decision, such as suitability, accessibility and feasibility. The field site must be representative of the environmental system under investigation, and should be adequately researched in advance. In many areas, previous studies of landscapes have been documented and observations or theories of landscape development are available to the researcher to provide background to the site. It is useful to gather other sources of information regarding the site, such as topographic or geologic maps, climate data, or aerial photographs. The suitability of the field site may be finally determined by a reconnaissance of the area, if it can be visited in advance of the fieldwork. Accessibility to an area may be restricted, so permission for access and for scientific study (if destructive methods are to be used or samples are to be collected) should be obtained. Accessibility is also dependent on the ability of the researcher to travel to the area, and in some inhospitable environments, such as high mountain, desert or Arctic environments, this may require considerable planning. The feasibility of research in these areas will depend on the researcher confirming that equipment can be transported to the area, that samples can be safely transported, and that the safety of the researchers is ensured. Research in remote locations is often possible through expeditions organized by groups of researchers; local fieldwork can be accomplished by one or two people, depending on the type of fieldwork being conducted.

Whether fieldwork is to be conducted during a discrete period, perhaps in a remote location, or by repeated visits to a local site, careful and thoughtful planning will significantly enhance the success of the endeavour. The researcher should prepare for fieldwork by identifying specific objectives and an estimated time-frame for completing them. A sampling strategy should be developed and prioritized, and a clear strategy for data collection and recording should be established. It may be useful to prepare worksheets for recording information and measurements, which standardizes measurements taken at different times and in different places. The appropriate equipment should be calibrated and tested, and be accompanied by replacement parts or batteries as required. Safety precautions should be taken as needed (Chapter 4) and all travel and logistical arrangements should be completed before fieldwork commences. Not all fieldwork is arduous or hazardous, but in all cases the researcher should try to prepare for unexpected changes in conditions, or risk associated with particular terrains.

Once in the field, it is likely that the researcher will re-evaluate the objectives of the fieldwork, the priorities of the work and the sampling strategies to be employed. It is not always the case that field observations will proceed entirely as planned, and there may be unforeseen circumstances or contingencies that require some adaptation of the plan of work. For example, my first experience as a field researcher was in Death Valley, USA, where I had naïvely hoped to survey alluvial fans at the foot of the Panamint Mountains. I soon discovered that surveying a ten-mile fan in such extreme heat was not feasible, and reassessed my research strategy! More importantly, as measurements and observations are collected the researcher may identify other interesting questions in the light of the findings as they are produced, and many geographers in the field follow their curiosity to new, productive avenues of enquiry that were not evident from literature-based research. As Burt (2003) suggests, one very important field tool is a curious eye. It is important to be flexible and revisit the research objectives as fieldwork proceeds in order to maximize the time and effort spent in data collection.

MAKING OBSERVATIONS AND MEASUREMENTS

A useful first step in fieldwork is description of the overall site, accompanied by photographic survey, sketches and notes. One element of this is to describe environmental features, which involves classification of types of landscape features and assumptions about the boundaries of the features. In some cases this is a simple enough task; recognizing a river channel, outwash plain or sand dune is fairly straightforward. In other cases it may not be easy, for example defining the boundary between two soil types or boundaries between plant communities. Field-site description is a prelude to choosing sites to make observations or measurements, and will improve with increasing familiarity with the field site. While it may be necessary to arbitrarily delimit the extent of a feature, if it is consistently defined, measurements will still be comparable.

Once the target features have been identified and delineated, the sampling strategy must be chosen (see Chapter 17). This is again driven by the research questions being addressed, but more pragmatic concerns, such as time and resources available in the field, will force some compromise between the ideal and the possible number of observations and/or measurements that can be made. If a large number of measurements are to be taken, a random or stratified sampling strategy will allow subsequent statistical analysis. If a case-study approach is to be adopted, following an intensive research design (Richards, 1996), it is important to select sample sites that allow testing of the hypotheses under investigation, and that allow detailed accounting of local conditions. Chapter 17 offers a comprehensive discussion of the type of sampling strategies that may be employed in geographic research.

When making observations and measurements, two considerations are important: the frequency of measurements in relation to process rate and the spatial distribution of measurements in relation to the distribution and size distributions of forms. Some examples of fieldwork methods will demonstrate the range of options that may be considered, and the type of choices to be made by the field researcher.

First, an investigation into geomorphic processes often derives information from analysis of the sedimentary body that has been transported by the process in question. Particle size is a key parameter to consider as it is a major contributor to particle resistance in sediment transport. As an example, the sediment size distribution on an alluvial fan may be investigated with a view to inferring the processes of sediment transport onto and down the fan. In this context, the sediment might be sampled along transects from the apex to the toe of the fan; particles all along the line might be measured, or quadrats established at regular intervals along the transect, within which a certain number of particles can be sampled. The number of transects, sample points and particles measured will be constrained by the time available, but should include sufficient numbers to facilitate statistical analyses. At each sample point, a random selection of particles can be chosen by forming a grid within the quadrat and sampling at each grid point; alternatively all particles within a small area might be sampled. The use of a well-defined strategy to choose clasts at random is important to avoid operator bias, the tendency of the observer to choose particles of a convenient size or an interesting appearance. Each particle can be measured along the a-, b- and c- axes with a ruler or calipers. As is often the case in fieldwork, more than one measurement method may be required, and the presence of fine sediments would necessitate the use of sieves (either in the field or in a laboratory) to ascertain sediment size distributions. Detailed methods for sediment analysis are available in geomorphology texts (e.g. Goudie, 1990; Kondolf and Piegay, 2003).

Second, the collection of meteorological data has many applications, such as agricultural meteorology or urban climatology. An example of a field-based study might be an investigation into the existence of an urban-heat island effect in a city, where the boundary between rural and urban areas exhibits a steep temperature gradient to the warmer city centre (Santamouris, 2001). To test this model, temperature measurements must be taken both within and around the city at similar times. The locations of the temperature measurements might follow a transect through the city to the surrounds, or be situated in a grid pattern across the urban area and adjacent countryside. The frequency of measurements will vary depending on the opportunity for remote measurement and automatic data logging as opposed to a researcher travelling across the city to measurement points. At each measurement point, care must be taken to avoid local factors that may influence temperature measurements, such as heat outflow from a building, and measurements must be taken and recorded in a consistent manner. The time at which temperature is recorded is also important; the urban-heat island is likely to be best developed under clear skies and light winds just after sunset, and data collected at other times during the day or night, or under adverse weather conditions, may not produce data suitable for the research question being addressed. General meteorology texts (e.g. Stull, 1988) are useful sources of methodological descriptions.

Third, a biogeographer may be interested in investigating the distribution of a plant species of community in an area. In biogeographical studies, there are many standardized methods available to the researcher (e.g. Tiner, 1999). One example of such a project might be to map the salinity gradient across an estuary, using distributions of salt-tolerant plants as an indicator of salinity. In this case, the researcher may traverse the area and select plots for analysis that are thought to be representative of stands of vegetation, and delineate plots of sufficient area to sample most of the species in the area. An alternative to preferential sampling is to select plots randomly, or within topographic units. Vegetation plots should be removed from obvious disturbances, roads and other infrastructure. The attributes to be measured in the plot might include areal cover, density, basal area, or frequency of plants; plots may be analysed by strata or point sampling may be performed. In ecological studies, the timing of the fieldwork is obviously important, due to seasonal variations in vegetation assemblages. Several visits may be required during the growing season to account for ecological changes, and it is also important to note that plants may respond to periods of dryness or wetness differently, in which case antecedent weather conditions may partially control the timing of fieldwork.

However measurements are made, the researcher should make every effort to minimize instrument error and observer error, and to maintain consistency in the measurement system. Observations may be recorded manually or digitally, and it is worthwhile to make copies of data, clearly labelled, as field observations are often irreplaceable. Making observations in the field is probably the most expensive (in terms of time, money and effort) part of geographical research; careful planning and execution will contribute to excellent research.

CONCLUSION

Physical geography has by tradition been a field-oriented science (Petch and Reid, 1988) and conducting fieldwork provides opportunities for learning and appreciating the natural environment that cannot be duplicated in the library, classroom or laboratory. For many geographers, fieldwork is the most rewarding part of their work, and great pleasure can be derived from working outdoors with colleagues and friends. Beginning a field-based research project is challenging, but provides an opportunity to be creative and satisfy intellectual curiosities, through engaging directly with the physical environment. When planning fieldwork, the researcher should always be cognizant of the theoretical framework underlying the project, and explicitly consider the issues of space, time and place in designing the study. A structured and rigorous approach to making observations and measurements will help to ensure that the data are of high quality, but the researcher should keep an open mind when in the field. In spite of our efforts to explain it, the natural environment can be full of surprises!

Summary

- Fieldwork design is determined by the research questions underlying the study and the spatial and temporal scale of enquiry.
- Field observations may be made across space, to eliminate variables from the investigation; observations may be made frequently to monitor change through time.
- Spatial and historical contingency, the unique geography and history of any place, must be considered when interpreting findings from field observations.

- The choice of field site, sampling strategy, measurement methods and sample size will reflect both theoretical and practical considerations.
- A structured, but flexible, approach to making field observations will contribute to collection of quality data and interesting outcomes from the study.
- No fieldwork should ever be planned or undertaken without an awareness of health and safety procedures, nor without a comprehensive analysis of risks and their management (see Chapter 4).

Further reading

- Gregory (2000) provides a comprehensive overview of the development of physical geography, the research that physical geographers conduct and the methods they use. The text discusses the nature of contemporary physical geography in detail, and suggests directions of future research in the twenty-first century. This is an excellent resource for physical geography students, and presents most of the literature central to the discipline.
- Goudie (1990) offers an extensive overview of the range of field techniques used by geomorphologists. The text is arranged thematically, including information on how to observe and measure form; collect evidence of processes; measure material properties; and reconstruct palaeoenvironments. This detailed examination of suites of field methodologies is extremely useful to geographers beginning a field-based research project.
- Trudgill and Roy (2003) have edited a volume that offers insights into why physical geographers do what they do. While this volume is short on practical help for the student of physical geography, it does offer some interesting debates on the nature of geographic science, and the sources of inspiration for physical geographers who have shaped the discipline over the course of their careers

Note: Full details of the above can be found in the references list below.

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