THE UNIVERSITY OF CALGARY

The Presentation of Temporally Changing Distributions: A Comparison of Conventional and Dynamic Mapping Techniques

by

KAREN KANE

A THESIS SUBMITTED TO
THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Master of Science

DEPARTMENT OF GEOGRAPHY

CALGARY, ALBERTA
January, 1991

ISBN 0-315-66947-0

THE UNIVERSITY OF CALGARY

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, the thesis entitled "The Presentation of Temporally Changing Distributions: A Comparison of Conventional and Dynamic Mapping Techniques," submitted by Karen Margaret Kane in partial fulfillment of the requirements for the degree of Master of Science.

Dr. M.R.C. Coulson, Supervisor
Department of Geography

Dianne Draper
Dr. D. L. Draper
Department of Geography

Philip Simony
Dr. P.S. Simony
Department of Geology and Geophysics

December 20, 1990

ABSTRACT

In this study, the effectiveness of two methods for cartographically representing a temporally changing distribution was investigated. Telemetred locations of black bears in Banff National Park, collected over an entire "bear year", were used as the data set. A conventional map, consisting of four acetate overlays, was constructed. The passage of time could be simulated, to a degree, by superimposing successive overlays. A dynamic map was produced using a video camera and standard, manual animation principles. Each of these maps was then presented to independent groups of respondents, who answered a questionnaire.

The results were analysed using the Chi-square test. The dynamic map generally provided significantly more correct answers than the conventional map. Respondents using the dynamic map scored particularly well in pattern recognition tasks and at identifying simple interactions. It was marginally better than the conventional map at rates and distance questions. Although the conventional map

produced more consistent answers in the delineation of area and area measurement tasks, it was found that this was a map reading skill that many subjects had a weakness in. Both groups performed equally well in locational tasks. The result of this comparison of the dynamic map with the conventional map for representing a temporally changing distribution supports the argument that the dynamic map can convey such information better than a conventional map.

ACKNOWLEDGEMENTS

I would like to thank Dr. M. Coulson for his patience with me and his perseverance with this project. I would also like to thank Rick Kunelius for providing the data set and his insights into selecting the three bears. To the sixty-six subjects who volunteered to answer the questionnaire, many of whom spent forty-five minutes or more, thank you for your time. I would also like to thank Dr. D. Draper and Dr. P. Simony for their contributions to this final text. This project was funded in part by the Department of Geography, through teaching assistantships, and in part by Province of Alberta Graduate Scholarships.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

The objective of this research project is to compare two methods of mapping a temporally changing spatial distribution. The two methods in question are,

i) a conventional mapping approach, and

ii) a dynamic mapping approach.

There are a number of alternatives through which conventional maps can illustrate temporal change. A single static image, showing areas where change has occurred, can be produced. Also, the recorded distributions of two instants in time can be symbolized separately on the same image. Thirdly, a series of static images, representing different instants in time, and which are intended to be viewed in quick succession, can be produced. Through conventional mapping, each map presents the map reader with a 'snap-shot' image of a given instant.

The most significant difference between conventional and dynamic mapping is that dynamic maps show a continuous process of change over time, instead of the 'snap-shot'.

While dynamic maps have been referenced in the literature since at least 1959 (Thrower), no published studies have been found on how readily the information content of a dynamic map is available to its map readers. Testing needs to be carried out to determine whether map readers can extract meaningful information from a dynamic map, or whether the dynamic nature of the map leads to information overload and confusion. Dynamic maps can be produced on film, video-tape, or by a sequence of computer generated images.

The data set used in this study consists of black bear telemetry locations from the summer of 1988. This data was collected as part of an earlier black bear study in Banff National Park (Kansas and Raine, 1989). The three black bears, whose distributions are illustrated on the test maps in this current study, were monitored approximately once every 24 hours during the earlier study. The bears were active from May 1st until November 1st, therefore there are over 100 chronologically recorded locations for each bear.

The conventional mapping approach employs a base map and four acetate overlays to map the distribution of the bear locations. Each overlay contains the bear locations for a specific portion of the summer. Superimposing all four overlays forms a scatterplot of the entire sequence of bear locations.

The dynamic mapping approach uses a video-taped animated sequence. A daily accumulation of black bear locational information is shown. At the end of the sequence, when the video calendar reaches November 1st, a scatterplot of the entire sequence of bear locations is shown.

Both test maps were designed to show the temporally changing spatial distribution and locations of the three bears. A questionnaire, developed to test and compare the effectiveness of each of these representations, was designed to test for information in a number of categories of map interpretation tasks. These categories are; locations, rates and distances, pattern recognition, delineation of areas, area measurement and identifying interactions.

A number of volunteers answered the questionnaire. The results were analysed to show whether or not there were any statistically significant differences between the understanding derived from the conventional and from the dynamic mapping approach. This was determined by assessing whether or not one method was more successful at answering the questions posed in the questionnaire.

The analysis focussed on the merits and drawbacks of the dynamic presentation, primarily because of the lack of any existing studies. Studies have been carried out to evaluate the effectiveness of a number of differently designed conventional maps, in terms of the level of information which users can extract from the map.

Previous to this research, there had been some discussion in the literature on the merits of dynamic mapping. One of the concerns (for example) with dynamic mapping was whether or not dynamic maps would be perceived as 'confusing' by map users, because of information overload.

To date, there have not been any published empirical studies, which could either validate or refute the concerns with dynamic mapping. The information collected during this research project led to some interesting conclusions and some areas of dynamic mapping which require further investigation were indicated.

CHAPTER 2

DYNAMIC MAPPING

Many processes and phenomena that we, as geographers, are concerned with have a temporal component. Conventional mapping (specifically a single map) "has definite limitations for indicating change through a considerable length of time. For showing progressive development in the physical and cultural landscape it has been customary to use maps or diagrams in series" (Thrower, 1961 p.20). Alternatively, dynamic processes have been simulated on conventional maps through the use of arrows and flow lines (Cornwell and Robinson, 1966). Dynamic mapping offers an alternative to the use of a series of conventional maps for showing temporally changing spatial distributions.

Dynamic mapping, which is often referred to as animated mapping, has been given formal, albeit infrequent, attention in the literature since 1959 (Thrower). In his articles Thrower (1959, 1961) discusses the properties and advantages of dynamic maps.

The most basic limitation in portraying change through a series of maps is that, while in reality changes may occur more or less continuously, each map in the series represents an instantaneous cross-section or "snapshot" in time. This is suitable for processes which occur in steps. For continuous processes, animation provides a stronger means of representation. Through animation, the inter-snapshot periods can be inferred with supplementary maps and an impression of continuous change can be produced (Thrower, 1961).

Dynamic mapping incorporates time, the fourth dimension, into cartography. Thrower (1959) pointed out that great liberties could be taken with the representation of time during animation. The time scale utilised in the dynamic map is under the control of the cartographer, and can be adjusted to suit the purpose of the map, much like the graphic scale of conventional maps can vary. Slow, long term processes can be speeded up, while rapid motion can be slowed down, allowing easier interpretation of complex processes and phenomena.

The area, point and line symbols which are utilized by cartographers are relatively easy to animate. Therefore, the production of dynamic maps should not be hindered by symbology representation. Thrower (1961) surveyed some examples of animated maps, which occurred in existing motion pictures or educational films. He found that the entire range of symbols used in conventional cartography has appeared in animated productions. Qualitative symbols, including the "pictorial point symbol" (Thrower, 1961, p.26) were the most common.

Lettering becomes a design concern of its own with respect to dynamic mapping. Perhaps the most intriguing characteristic is that it can be quite effectively used through adding it at the appropriate moment, and then removing it when it is no longer needed. Another point about lettering which must be recognized is that lettering can effectively be replaced by a verbal message on the tape, as there is usually a very limited time for reading any lettering. For this reason, lettering is usually restricted to indicating place names and numerals used for indicating dates and/or the passage of time (Thrower, 1961).

Thrower (1961) surveyed a number of animated sequences, which included dynamic maps of varying lengths, and found that a number of cartographic elements, regarded as essential in conventional mapping, were often not included in the dynamic maps. One of these elements was scale.

Thrower reasons that scale is often not used because the size of the map image being viewed is variable, depending on the available equipment. The map scale is ultimately proportional to the size of the projected or transmitted images. However, the use of a bar scale, which would also vary in size, along with the map, would seemingly solve this problem (as it does with maps published in journals).

Quite often a time scale, such as two seconds of projection time equals one day, was used in place of the distance scale. Yet time and distance are different dimensions, so the substition of one for the other is not cartographically valid. The fact that maps have been produced using this invalid substitution can be explained by the fact that many of the maps which Thrower viewed were produced by animators, not cartographers. Moellering (1980) pointed out that dynamic time scales, which communicate the passage of time as the sequence progresses, can also be used.

Other elements often not included in the sequences which Thrower surveyed were some kind of grid system and either a legend or symbol key. Thrower (1961) favours the use of a grid system as useful for scale, orientation and location purposes. The legend or symbol key can be replaced by an accompanying verbal narration in the cases of video-tapes and films.

Even though existing dynamic maps have these distinct breaks from cartographic convention, optimum design has not yet been achieved. "These and other breaks with cartographic convention, appear to be a reflection of the fact that much animated cartography is the work of artists rather than scientists" (Thrower, 1961, p.27). Some computer animated sequences such as the Jet Propulsion Lab production "L.A. The Movie", produced using digital information collected by satellite, may be too detailed for any meaningful information to be extracted. Also, in some cases, fieldwork requirements demand hard copy maps and a video format would be impractical. It will require some degree of user testing to determine the merit of the breaks with convention which are used in dynamic maps.

One of the factors which has prevented much research in dynamic mapping has been the high cost of preparing animated cartography, especially when compared to the research and educational dividends returned (Cornwell and Robinson, 1966). Generally speaking, the most cost intensive process of animation has been the amount of time needed to produce the necessary drawings. Using the graphic capabilities of computers has reduced this aspect, thus with computer graphics and 'computer recorders' the production of dynamic maps becomes increasingly feasible, from both the technologic and economic point of view. The limiting factor for large scale animations, showing complex movements, is now the development and availability of appropriate software packages to provide the desired succession of images. In this project, the motion to be illustrated was simple enough that the dynamic map was produced using a video camera with manual animation techniques.

The use of computers also poses another question, and that is whether we should utilize raster or vector graphics. There are significant implications in the difference between raster and vector graphics (Moellering, 1980). Vector displays can only produce line drawings of graphic objects. Raster systems can handle objects defined in three dimensional space, but are ultimately limited by the resolution capabilities of the system (Moellering, 1980; Cornwell and Robinson, 1966).

The alternatives to conventional cartographic design need to be systematically investigated. "Much more specific work by cartographers remains to be done in order to ascertain the most effective methods of creating and displaying spatio-temporal dynamics" (Moellering, 1980). Many people experience difficulty thinking and visualizing in three dimensional space. Animation adds a fourth dimension and undoubtedly this will also add visualization difficulties (Cornwell and Robinson, 1966).

Dynamic mapping can be a valuable asset to cartographers. It provides many additional possibilities for cartographic design (Moellering, 1980). The creativity of cartographers can be challenged by dynamic mapping in much the same way as by computer cartography. The technical limitations of a video production are very different than the technological constraints of pen, paper, and the printed map. Cartographers should push beyond the conventional constraints, and strive to produce the best map possible, for whichever method of production they are using. If cartographers fail to develop a product which transcends the traditional constraints of pen and paper, then there will never be any real advancement in cartography, except that the production process may be quicker.

CHAPTER 3

THE COMMUNICATION SYSTEM MODEL

This chapter reviews some of the theories and principles which have been developed by cartographers over the last forty years (since Robinsons' 1952 work, "The Look of Maps"), and how they relate to dynamic mapping. The focus is on map design research (appropriate as dynamic mapping has distinct design requirements).

Communication theory has been a major component of map design research, attracting researchers using either a psychophysical or, more recently, a cognitive approach. The results of such research have allowed cartographers to evaluate the effective use of specific map symbols, as well as the overall effectiveness of many kinds of maps (for example: contour maps versus hypsometric tints).

MAP DESIGN RESEARCH

Petchenik (1983) has attributed much of the recent cartographic research in map design and cartographic communication to the themes expressed in "The Look of Maps" (Robinson, 1952). A major theme, expressed in Robinsons' book, was the need to pay explicit attention to the display of cartographic data. Several other ideas, which have been the foundation of the last forty years of cartographic research, were also introduced in Robinson's work. Petchenik (1983, p.39) outlined them as follows;

i) "The ability to gather and reproduce data has far outstripped our ability to present it" (Robinson, 1952,p.4).

ii) The function of the map "provides the basis for the design" (Robinson, 1952, p.13).

iii) In many fields, services were being adjusted to suit user needs. Robinson (1952, p.13) noted that a similar change was long overdue in cartography.

iv) "When presentations of factual materials become widely used, the manner of presentation (ie:map design) becomes of primary significance" (Robinson, 1952, p.7).

v) The development of the small-scale, special purpose map early in the 1950s. Robinson (1952, p. viii) wrote "the scientific map rarely should be examined out of context, so to speak, for its raison d'être determines, or limits, to a considerable degree, its visual character."

The designing of a dynamic map touches on each of these points. First, dynamic mapping allows us to present a larger quantity of data, in a temporal sense. With the continued development of satellites and computers, large, temporal data bases exist. Instead of being restricted to illustrating the conventional before/after shots, we can use dynamic mapping to illustrate all the in-betweens as well. This would save cartographers from having to make what is often a subjective decision about which instants in time are chosen to be represented through conventional mapping. A greater portion of the collected information can be mapped.

Second, if the purpose of the map in question is to show an event over a period of time, why not show the event in its entirety (at an appropriate time scale). Dynamic mapping can enable us to map hundreds of years worth of data, whether measured or interpolated, and view them as a continuous action lasting only a few minutes.

Third, many youngsters are gaining such a familiarity with video as a communication tool through television, that dynamic maps may become useful teaching aids as well as research tools.

Finally, as in all forms and classes of maps, there are limits to the visual character of dynamic maps and what they can illustrate. Their raison d'être is presumably to show a temporal phenomenon. The visual character of the map would relate to the phenomenon being mapped.

Apart from the considerations unique to dynamic mapping, one of the most important cartographic developments to evolve out of design research has been increased attention to user needs and abilities. Methodologies from other fields (especially psychology) have been adapted to the study of maps and the identification of map user needs, the most predominant area of study being cartographic communication.

COMMUNICATION THEORY

Maps are usually initiated because of the desire to show some spatial phenomenon graphically or geographically. The map will thus portray significant spatial knowledge. It is a fair assumption that the map author would like this information to pass to the map user. Therefore, the primary objective of any map should be to communicate (Robinson, 1975). Olson (1984, p.512) also stated this when she defined map design as the "process of organizing spatial information in logical fashion such that it makes sense and is later accessible in a spatially meaningful form". When referring to dynamic maps, we can rephrase this to include the presentation of the temporal dimension of spatial data in both a spatially and a temporally meaningful form.

Cartographic communication and map design research can focus on either one of two transformations which occur in the cartographic process (Eastman, 1985). The first of these transformations is from reality (the environment) to the map. It involves the cartographer "observing reality" then putting his/her "perception of reality" into a graphic (map) format. The second transformation, from the map to the user, requires that the map user observe and interpret the graphics of the map to obtain usable information. This process is referred to as "visual perception". Although the full scope of cartographic communication involves both these aspects, the rest of this chapter concentrates on only the visual perception aspect, as the main thrust of this research is how much information map users can extract from either a dynamic map or a series of conventional maps, both displaying the same data.

"For communication to occur we need to be able to predict the perceptual consequences of the way we use the marks we put on a map" (Robinson, 1975, p.13). This statement reflects the importance of knowing how map users perceive the visual variables. The visual variables, which were formalized in the cartographic literature by Bertin (1973), include shape, size, value (tone), pattern, colour, direction and location (orientation). One of the primary objectives of communication theory in cartography has been to develop the ability to be able to predict or predetermine the activities and responses of map users through an understanding of these visual variables. To meet this objective, cartographers (as well as psychologists) have examined the psychophysical dimensions of these visual variables through a variety of experiments.

While a variety of models have been put forward to define the relationship between cartographer, map and percipient, they are all based on electronic analogies (Guelke, 1979). In communication systems, there is always a unidirectional flow. Information from a source passes through a channel to a receiver. In the cartographic analogy, reality is the source, the cartographer is the encoder, the map is the transmitter and the map user is the receiver/decoder (Figure 1). One advantage in the simplicity of a unidirectional model is that it can be conceptualised as a closed system. As Fisher (1978, p.101) pointed out, this is "deterministic, which is a natural theoretical perspective for the conducting of empirical research." The effectiveness of the dynamic map produced for this research was tested using the techniques of past

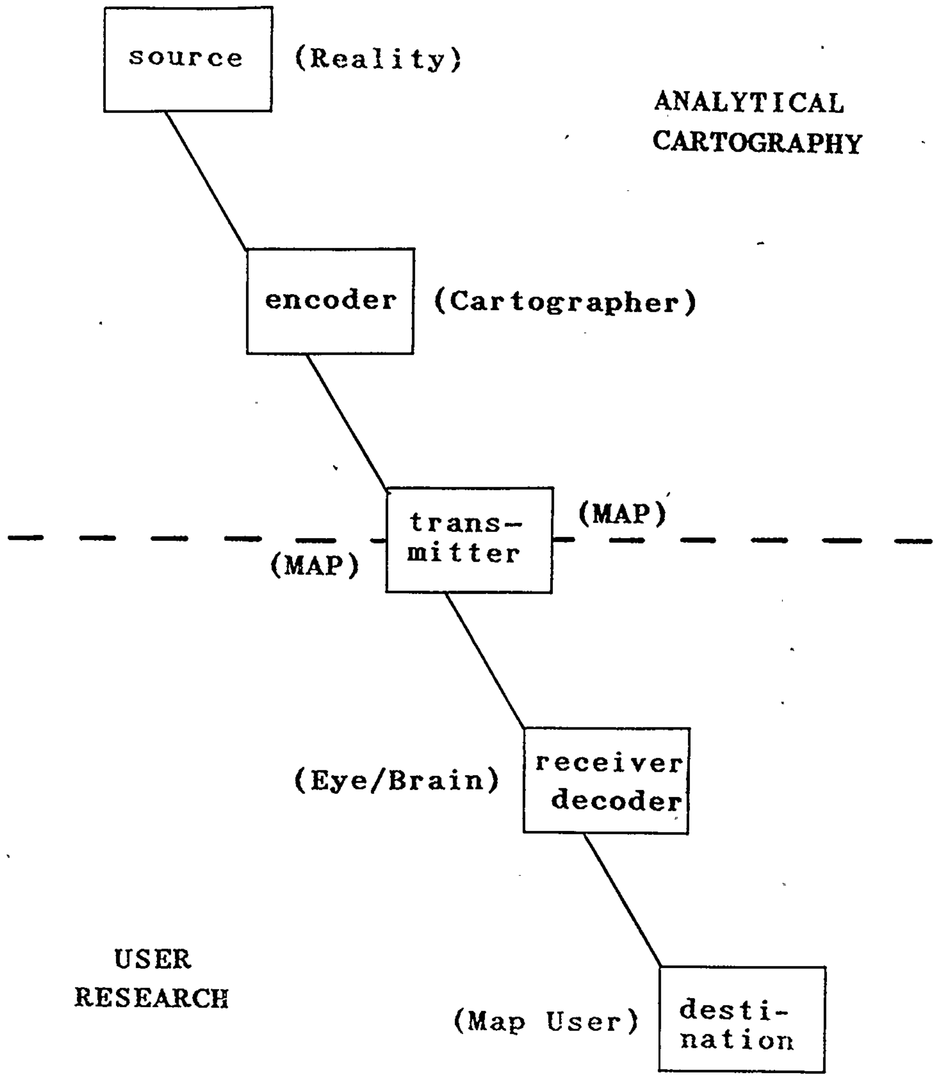


FIGURE 1: COMMUNICATION SYSTEM MODEL DIAGRAM and its RELATION to CARTOGRAPHIC DESIGN RESEARCH

After Eastman, 1985, p.96

research in cartographic communication.

Cartographic communication research involving map users and their perceptions can be broken down into two categories. The predominant, referred to as psychophysical research, deals with perceptual processes. The other, referred to as cognitive research, deals with mental processes. Both categories have contributed to cartographic knowledge, as map use is not restricted to simple perceptual tasks. Olson (1976) has defined the following three levels of map reading tasks;

Level 1: Comparison of the characteristics of individual symbols,

Level 2: Recognition of the properties of symbol groups on the map as a whole, and

Level 3: Use of the map as a decision-making or content-knowledge-building device through the integration of symbols with other information.

To test for and better understand the processes involved in higher level tasks, the trend among researchers is to adopt a more cognitive approach in communication studies.

Psychophysical Studies

Psychophysical studies were the first studies designed to test what a map user was "getting" from a map. Eastman (1985, p.95) has written "given a knowledge of what information had been encoded on the map, it seemed a simple matter to gauge the reader's subsequent knowledge of that information, and thereby to calibrate the mapping technique used." The term "psychophysical" comes from the similarities it has to early concerns for the more basic aspects of visual perception, such as perceptual sensitivities to changes in symbol size, brightness, colour and shape. An early study of this kind was Flannery's 1956 doctoral dissertation on the perceived relations among graduated circle sizes.

Experimental psychology had, by the 1950s, developed techniques which offered the potential for objectively testing some of the impressions map viewers formed (Petchenik, 1983). "It was found that map users might not only see different colours (for example) as different, but might also form some impression about the nature of the difference as well" (Petchenik, 1983, p.45). Psychophysical studies could also contribute to developing a visual hierarchy for symbols, as it was found that "focal attention distinguishes information on the basis of visual variables-differences in location, size, colour, orientation and the like" (Eastman, 1985, p.99).

In the case of dynamic maps, focal attention may be drawn towards moving or blinking symbols. Incorporating the results of psychophysical studies into map design, it was believed, would create more effective maps, improving the efficiency of maps through conveying appropriate visual impressions. It would follow then, that a dynamic map would be more efficient than conventional maps at illustrating temporal phenomena, because of the visual impression of change and the passage of time which can be created using the animation medium.

Criticisms of Psychophysical Studies

The actual contribution of psychophysical research to improved map design has been questioned. Olson (1976) pointed out that map interpretation tasks vary in complexity, from simple comparisons, to situations where inferences about the relationship between symbols must be drawn (see above). Chang (1980, p.161) is even more explicit with the statement "the stimulus-response relationship for circles is fairly complex, and any correction in map design based on one psychophysical study alone is of limited value, especially given the incompatibility between the conditions of the experiment and of real map use." Another problem in the psychophysical approach, as pointed out by Shortridge and Welch (1980) is that it has repeatedly been shown that map user impressions of stimulus magnitude variation will vary with the questions asked of them.

Other criticisms which have been thrown at psychophysical studies include weak methodology, lack of general theories and a general feeling that only a limited contribution to the understanding of cartographic communication is being made (Blades and Spencer, 1986; Olson, 1976; Guelke, 1979; Gilmartin, 1981). The reasoning behind these criticisms is that;

i) "Even when thematic maps have been tested, the use that is made of them may resemble inventory use, insofar as the focus is on point-to-point symbol comparisons, not on any perception of spatial structure (Petchenik, 1983)

ii) Testing a single variable in isolation ignores the map contexts in which these symbols may be used (Petchenik, 1983)

iii) From Ratajskis' (1973) discussion, it is clear that there is an important contribution from the map reader in map interpretation. Psychophysical studies ignore the ole of the map reader.

Expanding on this last point, Blades and Spencer (1986, p.2) have suggested that "the map readers' cognitive processes, memory and previous experience are integral parts of map interpretation".

The criticisms do not imply that psychophysical studies and work on the perception of map symbols has been an entire waste. The more complete our understanding of the principles of perception and design is, the better the quality of cartographic products will be. Now that the weaknesses in psychophysical research have been pointed out, future researchers can implement a more sophisticated experimental design, to correct for the known weaknesses.

In the other approach to communication studies, the cognitive, methods similar to those used by Thorndyke and Stasz (1980) and Shimron (1978) provide the scope and potential for understanding more about the processes involved in the higher levels of map interpretation. There is a drift away from point-to-point comparisons. Instead of concentrating on one variable, the whole map is used, and the contribution of the map user is considered important.

Cognitive Studies

Cognitive processes are the higher mental processes. Blades and Spencer (1986) define a cognitive task as one which "involves mental processes in which information is perceived, selected, compared, stored and recalled". This implies learning, which in turn, implies meaning. Although there have been fewer experiments to examine map readers' cognitive processes than the number of psychophysical studies the results have been more significant. Cognitive studies gained prominence when people became interested in knowing more than "what" is at a given location. It became of interest to know something of the "character" of the relationships among physical and observed phenomena (Petchenik, 1983).

One of the most important concepts related to cognitive studies is the increased attention paid to the map reader. The map user has come to be seen as a much more active agent in the communication process. Map users are rarely limited to information explicitly encoded on the map, as they each bring a different set of background and past experiences to the experiment (Eastman, 1985).

The Relation Between Cognition, Learning and Map Design

There have been some valuable points made, as a result of cognitive studies. First, cartographic researchers have to realize that they may be dealing, at least to some degree, with recognition. Petchenik (1983, p.56) wrote that "generally speaking, ones' initial perception/cognition of some newly encountered phenomenon provides little or no sense of meaning. It is only in the act of recognition (re-cognition) that one tends to acquire or attribute meaning to a map, in terms of something already known or previously encountered". Thus the background and previous experiences of the map user become a significant factor, and the closed, deterministic system described by Fisher (1978) no longer exists. This could be a significant consideration in the evaluation of a dynamic map, as the video has become a medium that most people are familiar with, even though the subject matter may be new. In a sense, a dynamic map may be less intimidating than a conventional map simply because of the users' familiarity with animated material.

Second, it has been found that "complexity in maps may be less related to the number of features on a map, than to the organization that relates them" (Eastman, 1985, p.99). Eastman made this statement on the basis of experiments by Gatrell (1984), Thorndyke and Stasz (1980) and his own work (Eastman, 1982), all of which found that the definition of spatial chunks (regions), in the process of map learning, was strongly influenced by the graphic organization employed in the map that was learned. "In fact, the absence of any global characteristics to cohere the map may be an important determinant of visual complexity" (Eastman, 1985, p.100). On a similar line of thought, Guelke (1979, p.113) wrote "the crucial feature of a map is not the information it contains per se, but whether that information is set in an appropriate context." In a dynamic map, context can be established through the animation sequence used. This should provide an apparent high degree of organisation and global coherance, thus lessening visual complexity and increasing the conveyed meaning. If this really does occur, map users should find dynamic maps visually simplistic.

Third, it is not possible to have a predefined form or content for cartographic symbols (Eastman, 1985). This would establish a set of relationships between symbols which would be naturally perceived. However, relationships are established through use of the visual variables. Bertin (1973) identified some powerful aspects of the visual variables such as similarity, difference, proportion and order. When a map user scans a map, important aspects are selected for further "processing" based on their various characteristics such as colour, size, location, orientation and so on. This leads the map reader to reach decisions on the relationships being illustrated. In a dynamic map, we can add temporal stability (which symbols and/or areas are/are not undergoing change) to the list of variables the percipient must deal with when reaching those decisions.

There have been some interesting discussions on how the map user actually comes to decisions on the relationships between symbols. Cognitively, it has been argued, we are dealing with the right hemisphere of the brain, which (conveniently) is also used when viewing television images. This is generally held to be the visual thinking side of the brain (Taylor, 1985), excelling at spatial tasks such as completion of patterns, recognizing spatial relationships and grasping whole contexts (the left hemisphere is characteristic for sequential logic and rational thinking).

Problems With Cognitive Methods

In a large survey you can expect to run into a wide range of user capabilities. As Petchenik (1983) pointed out, experience and familiarity with certain kinds of maps can cause map users to perform better with these maps, as well as to perceive these maps to be more realistic. Eastman (1985) also noted that it has repeatedly been shown that reader experience has a significant effect on performance, particularly if the task approaches any reasonable level of complexity. Consider the places and uses of animation that we have all seen. It is used for entertainment (cartoons), education (instructional films) and advertising (television commercials). With respect to dynamic mapping, users may not be familiar with the specific map being questioned, but they will be familiar with the video medium.

Another difficulty is that very often two entirely different user strategies will yield the same result. Petchenik (1983) offered the following ways of compensating for this difficulty, (but also stated that they are seldom used). Research observations can be conducted through individual interviews, with open-ended questioning in which it is easier for the subject to respond spontaneously. Another approach would be to follow up paper-and-pencil interviews with less formal questioning that would elicit introspective comments from the subject, illuminating the process by which judgements were made, offering thoughts about the testing problem and so forth. This technique of recorded introspection has been shown to be extremely effective in providing evidence for the cognitive processes that subjects utilize spontaneously in working with maps (Thorndyke and Stasz, 1980).

SUMMARY

Both theories discussed in this chapter, the psychophysical and the cognitive approaches, have proven helpful in developing better cartographic design and/or an understanding of how the map user relates to the map. The psychophysical studies are designed to test map users responses to a single visual variable and to gauge the quantity of information that a map user can extract from a map. Cognitive studies are directed more towards the character of the information which map users extract from a map. Cognitive studies also recognize that each map user brings a different set of background experiences into any test situation.

Although these theories have not been applied directly to dynamic cartography in the past, parallels have been pointed out in this chapter. The next chapter looks at animation principles, rather than cartographic theories, and shows how they were applied in the production of the dynamic map used for this research.

CHAPTER 4

ANIMATION AND PRODUCTION OF THE DYNAMIC MAP

Invented by Frenchman Antoine Plateau in 1831 (Levitan, p.12), animation creates an illusion of movement through the presentation of a series of images in rapid succession, with the content of each varying slightly from the preceding one. The eye will momentarily retain the preceding image and the incremental movements become integrated into a smooth motion (Thrower 1961, Moellering 1980). The ability of the eye to integrate images is known as the "phi phenomenon" (Thrower 1961). This smooth visual integration does not hold true for colour gradations (Kolers and von Grunau, 1976).

Modern movie projectors show about 24 frames per second. In animation, each image is usually on two consecutive frames, as this gives a smoother appearance to the motion. Thus it requires 12 images for one second of animation. This rule applies to both manual and automated animation.

There are many techniques of animation. In North

America, the most commonly used technique is known as cel animation, in reference to the celluloid and/or acetate overlays which are used. Computer animation, which has only become a significant part of animation over the last decade, will no doubt be the way of the future. This chapter looks at both cel and computer animation.

CEL ANIMATION

Cel animation was developed to save work and time. Earlier animation had required that the backgrounds be continually redrawn. In cel animation, by painting characters on acetate overlays, the backgrounds do not have to be continually redrawn. Only those parts of the scene which undergo change need to be redrawn. This saves a substantial amount of time.

Technical Problems

Many of the technical problems which will occur in cel animation relate to the acetate layers. Reflection, either in the form of a glare or the camera being reflected back on itself, can be a problem. Wrinkles and shadows, caused by not having enough pressure to keep all the layers flush; or Newton rings, caused by having too much pressure, are also problems.

Other technical problems, which are not unique to cel animation, involve obtaining correct registration of images, continuity between scenes, and smoothness of motion. A modification of cel animation was used to produce the dynamic map for this research. Several attempts were needed to arrive at a satisfactory end product as many of the problems described above were experienced.

COMPUTER ANIMATION

The earliest known computer animation sequence was produced on the Whirlwind computer at MIT in 1951 (Halas and Manvell, 1968 p.321). The most significant difference between computer and cel animation will be noticed in the interpolation and creation of in-between images and the actual preparation or drawing of images.

In cel animation, the images must be hand drawn. In computer animation, once the extremes and the number of in-between images required for smooth motion have been programmed, the computer can interpolate and thus create the in-between images. These images can usually be photographed successively as they are produced by the computer, without having to be redrawn.

Types of Computer Animation

"Many of the calculations done on a computer are of essentially dynamic phenomena. One wants to see the unfolding or evolution of a process, either as a function of time or some other variable. Motion pictures are the obvious way of accomplishing this" (Hals and Manvell, 1968, p.320). Laybourne (1979, p.161) defines three approaches to computer produced motion pictures. One, computer interpolation ("in-betweening") was discussed above. There are also digital computer animation and analog image synthesis, (also called video synthesis).

Digital computer animation is a series of single images, displayed on a monitor, and photographed individually. The subject matter is usually abstract. Analog image synthesis involves scanning an existing image to raster format and then achieving various visual effects. These effects can result from shrinking, oscillating, rotating or spinning the image. It can also involve changing the height, width, shape and position of the image on the screen, as well as zooming in or out.

With an image synthesizer, all of these functions can be executed in real time. The result is a continuously changing image, which may be photographed with a motion-picture or video camera, or fed directly to a video recorder. The analog image synthesizer is versatile in that it will work with black and white or colour monitors in either continuous tone or high contrast.

Technical Aspects of Computer Animation

The technical aspect of computers is a concern in animation. The familiar geographic information system discussion of raster versus vector is an issue in animation also. Computers are better suited to animating line drawings (Levitan, 1979), which is only logical. Lines can be programmed as coordinates, new positions can be entered as coordinates, and the computer can interpolate as many in-between images as you ask for.

However, when using line drawings, it becomes visually confusing when a figure is superimposed on a background and you can see the background through the figure. Using a raster format will allow an infilling of the figure to prevent this. Raster systems are also more suitable for working with three-dimensional images.

While format is important, so too is the language being used and what it will allow the animator to do. The ideal computer language, according to Halas and Manvell (1968), will allow the animator to zoom in or out, pan the image and to fade or dissolve an image. Levitan (1979) adds that this should be achievable through a number of interactive graphics programs. Turner (1986) has stated that hardware requirements (if continuous motion is to be shown) include a computer with a double buffer, so that one image will be displayed as the next image enters the buffer, and so on.

Finally, it is significant to note that registration of images is not a concern with computer animation. The CRT or monitor will control that for you, replacing the light-table registration system. As long as the camera remains stable, all images will be registered automatically.

When animation capabilities, in terms of software, are combined with an automated cartographic package, computer produced dynamic maps should become more widely available. Having correct registration, and computer interpolated in-betweens will give a top quality product.

ANIMATION PRODUCTION

The data used for this dynamic map were radio telemetry locations of black bears in Banff National Park. This data, collected as part of an earlier study (Kansas and Raine, 1989), was provided by Rick Kunelius, senior wildlife warden in Banff. A number of black bears fitted with radio collars were monitored on a daily basis. Three of those bears, on the suggestion of Rick Kunelius, were selected to be included in the dynamic map. These three were; Bear #11- Kootenay, Bear #18- Sunshine and Bear #19- Sludge.

The bears were active from approximately May 1st to November 1st, a period which was divided into four "bear seasons", based on the feeding strategies of the bears (Kansas and Raine, 1989). The daily data consists of UTM coordinates as well as a number of ecological parameters (elevation, ecosite, etc...). The UTM coordinates were used directly in this study. Ecosites were condensed into three ecoregions, which tend to be good indicators of elevation also. The ecoregions (montane, lower and upper sub-alpine) were shown on the base map. The UTM coordinates have been included in this report as Appendix A.

In total, four efforts towards producing a dynamic map of presentable quality were needed. The first two attempts were on super 8mm motion film; the third and fourth (final version) attempts were produced using a video camera with time lapse exposure capabilities. An initial concern had been the high cost of using a video camera. However, technical problems combined with a lengthy film processing time, and the inability to view the product until it was processed, were the main discouragements to the use of super 8mm film.

No matter what type of animation is being considered, the basic steps in the production of a silent animation are the same. What follows is a description of the basic, ten step procedure (as modified from Halas and Manvell, 1968). Also, the application of the ten step procedure to this project is discussed. Note that there would be some additional steps in the production of a narrated piece of animation. The ten steps are as follows:

1. Workbook (Storyboard) Preparation
2. Character Models
3. Design and Layout

4. Prepare Exposure Chart
5. Key Animation
6. In Between Animation
7. Background
8. Cel (Image) Preparation
9. Photography
10. Editing

The Storyboard

This is the starting point. You must be able to visualise the entire story which you want to tell. An order of events and how long each event will last is created. Based on the timing, the number of images needed for each action is determined. Everything else follows from the storyboard.

The story to be told through the project dynamic map related to information on the movements of the bears. There were approximately 180 days of data, which had already been categorized into four seasons. The order of events in the dynamic map was controlled by the chronological sequence of observations.

As far as the length of the dynamic map, Andrews and

Gersmehl (1986) suggested a maximum length of 10 to 15 minutes for instructional videos. Applying this guideline to the dynamic map, it was decided that 600 seconds (ten minutes) which would allow 3.5 to 4.0 seconds per day of bear data would be suitable. Combined with an introduction (Appendix B), this would bring the total running time of the dynamic map to the desired 10 to 15 minutes.

In the super 8mm format, this worked out to 72 frames per day. With the video camera set for time lapse photography, each exposure was 0.5 seconds. This reduced the number of exposures to eight for each day, which meant sacrificing some smoothness of motion (which is affected by the number of exposures) in order to solve some of the other technical problems.

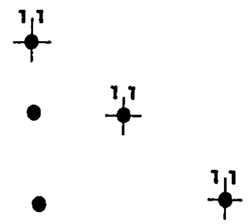
Character Models

From the workbook, the number of characters are known. This step involves the development of their characteristics and proportions. There were only three characters in this dynamic map, the three bears.

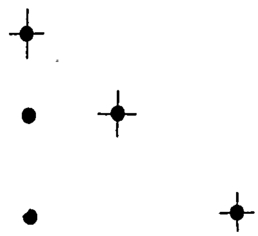
A few different methods were tried in order for the bears to be distinguishable from the background and from each other. These are summarized in Figure 2. The first method involved using different coloured dots, with cross-hairs, but without the collar number of the bear (figure 2a.). The second method involved using different coloured dots cross-hairs, with the collar number of the bear above them (figure 2b.). The third method, rather than use a special symbol for the current location of an individual bear, was to trace the daily movement of each bear with a coloured marker as the movement was being photographed (figure 2c.). A large `X', drawn with a colour marker (figure 2d.), was then used to represent the current location of each bear. This last method was used in the final video production.

In all cases, as the sequence of events progressed, coloured dots were left on the base map at all recorded bear locations. A view of the dynamic map of bear movements, as of June 1st has been reproduced as Figure 3 in the text. The effect of this was that the dynamic map appeared as a

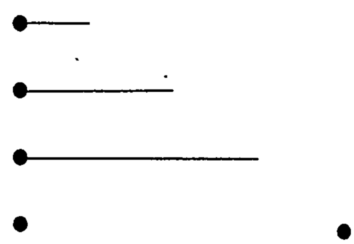
a) Coloured Dot With Cross-Hairs and Radio Collar Number.



b) Coloured Dot With Cross-Hairs, No Radio-Collar Number.



c) Continuous Line Between Points.



d) Using a Symbol "X", to Represent the Bear.

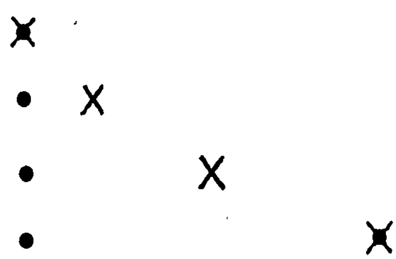
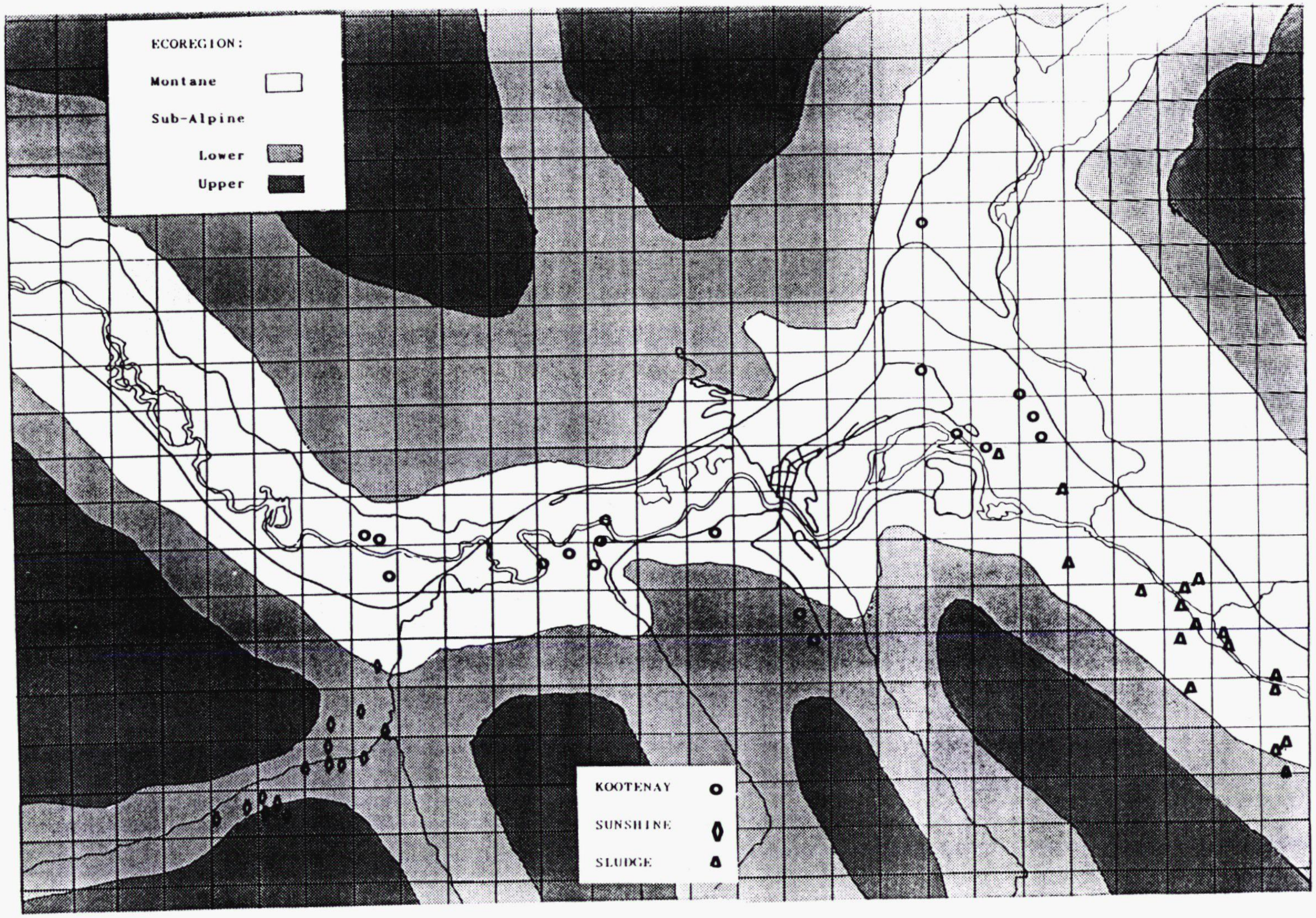


FIGURE 2: SYMBOLS EXPERIMENTED WITH FOR REPRESENTING THE CHANGING LOCATIONS OF THE BEARS.

FIGURE 3: DYNAMIC MAP OF BEAR MOVEMENTS AS OF JUNE 1ST

- Reproduced at 65% of the original scale.
- On the original map the bear:
    - KOOTENAY (○) was represented by RED DOTS
    - SUNSHINE (◊) was represented by GREEN DOTS
    - SLUDGE (▵) was represented by BLUE DOTS


ECOREGION:
Montane
Sub-Alpine
Lower
Upper
KOOTENAY
SUNSHINE
SLUDGE

growing scatterplot of all known locations. Kootenay was symbolized with red dots, Sludge was symbolized with blue dots and Sunshine was symbolized with green dots. The different colours allowed any overlap of home range to be visibly evident in the final scatterplot at the end of the season.

Design and Layout

The exact pictorial appearance of the production must be made final at this stage. This will include dimensions (which are usually in a 3:4 ratio), allowing for some edge which will be within the cameras field of vision, but not within the television viewing area. Colours and other qualities must also be decided upon. Registration problems are worked out at this point and continuity from one screen to the next must be assured.

The area of Banff National Park to be included in this dynamic map was determined by the extent of the movements of the bears being studied. An approximate ratio of 3:4 was maintained, as suggested by Levitan (1979). At first, it was decided to simply show the bear movements on a UTM grid with only the rivers and roads being illustrated. This appeared too simple and plain, it was not conveying as much information as should be possible. It was therefore decided to add some tints to represent the three ecoregions which were present in the study area, as well as having a tint for the urban extent of the Banff townsite.

Prepare Exposure Chart

Based on the timing which was decided upon in the workbook stage, the exposure chart serves as a frame by frame exposure guide for the entire production. This was a straight forward step for the dynamic map, as exposures were controlled by the desired length of the dynamic map and the number of days of bear data. These were determined as eight exposures of 0.5 seconds per day, for a total of 180 days.

Key and In-Between Animation

Key frames are individual images, often referred to as extremes, and are useful to make sure the animator "gets to the right place at the right time". These could include the most important poses, or simply represent logical "breaks" in the motion, such as, for example, the initial thrust, the highest point, and the landing in a jump. If one second is allowed for the jump, then a total of twelve images is necessary to illustrate the jump, including these three extremes. The rest of the jump is completed with nine other drawings, and these are referred to as in-betweens. In-betweens fill the gaps between the key drawings, on a frame by frame basis, to create a smooth motion.

The key points for this map were conveniently present in the data set itself. Each recorded position of a given bear served as an extreme (or key point) for that bear. The in-between images were interpolated on the assumption that the bears travelled in a straight line between successive recorded positions, which were usually at 24 hour intervals. This assumption is more than likely unrealistic, but it served the purpose of simplification, and no other assumption could be justified.

In the final production, the distance between recorded positions on consecutive days was divided into eight equal portions and each portion became an in-between image. In some cases recorded positions were not available for consecutive days. This gap in the data was filled by adding more in-between images. As an example; if a recorded position was only available for the day after next, then the distance between key points was divided into sixteen equal portions (each serving as an in-between image). In this way the amount of elapsed time on the final product was the same for each day the bears were active.

Background and Cel Preparation

Once the characters have been drawn through their full motion the backgrounds can be created to a scale suitable to cover the full range of this motion. At this stage, the drawings (which have previously been drawn on thin paper) are transferred to the celluloid (acetate) and individually painted (Halas and Manvell, 1968).

The background was determined by the perimeter of the home range of Kootenay. The range of this bear was entirely on one map sheet, as well as entirely within the park boundaries. Only a portion of the home ranges of the bears Sludge and Sunshine was included, being those parts overlapping with the home range of the bear Kootenay.

As all movements being shown were cumulative, individual cels did not have to be produced for each key or in-between image. A single piece of acetate was placed over the base map and all movements were illustrated on this acetate. Symbols representing the bears on in-between images were drawn with water soluble markers so that once they were not needed they could be erased. The telemetred position for each day was marked by the addition of a coloured dot, which was then left in place for the remainder of the video.

Photography

In animation productions, once all the cels and backgrounds have been prepared, the whole sequence is filmed. Ordinarily, the exposure guide created in step 4 would be constantly referred to at this stage. In filming the data for this project, all of the guidelines from animation handbooks were followed as closely as possible. All of the technical problems of cel animation, described earlier in this chapter, were very real and became evident.

There were shadows from a wrinkling of the base map caused by not having enough pressure on it. There was also a glare from the lighting used. Also, the first super 8mm camera, which was rented, did not fit on any available tripod, so it appeared that registration was very poor. The use of daylight for illumination resulted in the tint of the film varying, depending on what time of day the image was recorded. The fact that the super 8mm film had to be mailed to Toronto for processing made it impossible to detect these problems until after the entire film had been exposed and processed.

Once the switch to a video camera format was made, immediate playback of any filming done was possible. This meant that any errors could be corrected or compensated for, without putting in 20 or more hours of filming first. The video camera fitted on a tripod and, through the use of time lapse programming, there was no physical contact with the camera needed for exposure (thus there was no camera movement). The photographic set-up used with the video camera is shown in Figure 4.

Editing

In animation, the term editing usually refers to the synchronizing of the sound tracks with the picture track. Differences between the original storyboard and the final product will now be evident. Editing did not play a major role in the production of this dynamic map. Once the entire "year" of bear data had been recorded by the video camera (an 8mm format was used), the image was transferred directly to a VHS video. The only editing was the addition of some

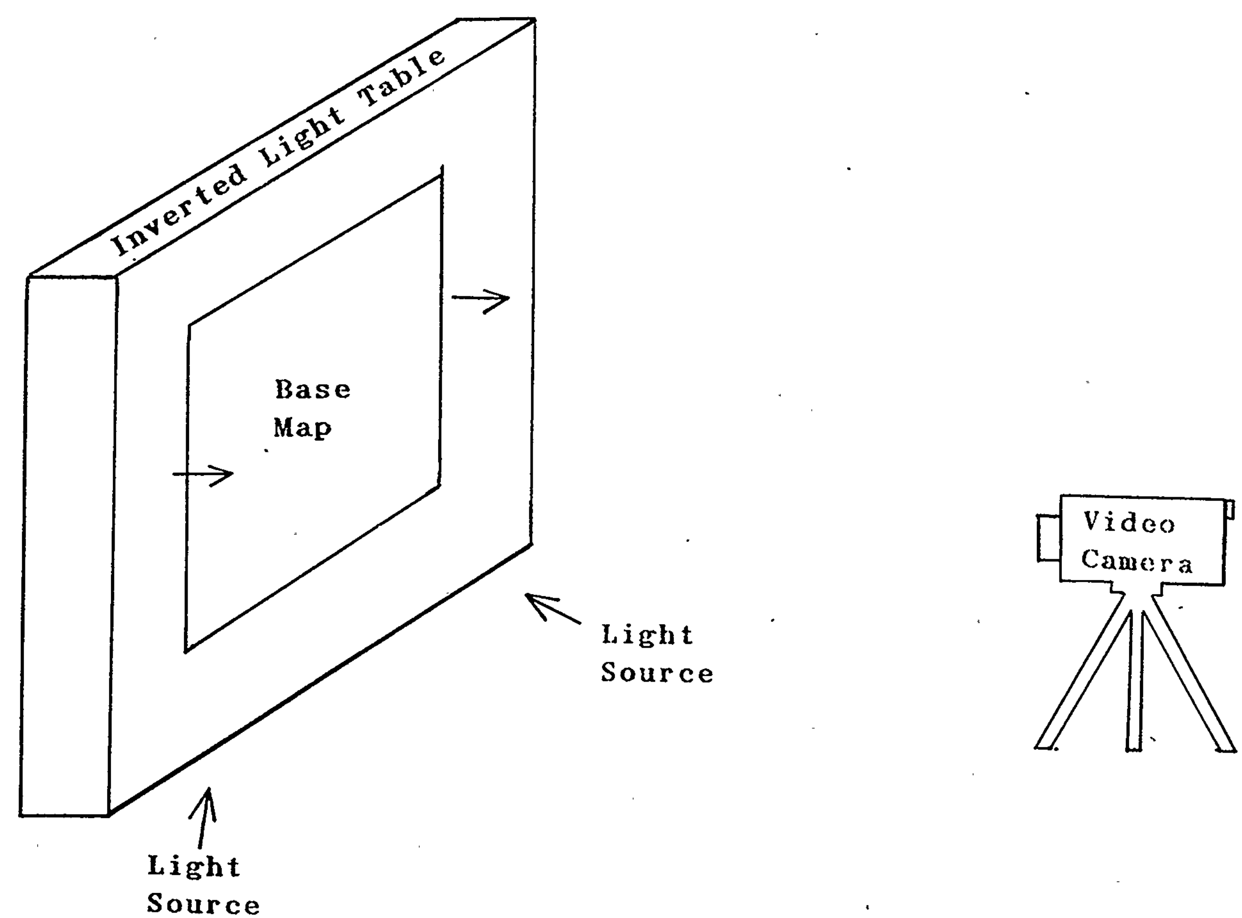


FIGURE 4: THE PHOTOGRAPHIC SET-UP

written information in the form of an introduction. The dynamic map was then ready to be used in the questionnaire survey.

PRODUCTION OF THE CONVENTIONAL MAP

The conventional map was designed so that the presentation of the data would be as similar as possible to that in the dynamic map. The "bear year" is divided into four seasons, which were indicated on the dynamic map. It was decided then, that the passage of time could be simulated by using a series of four acetate overlays for the conventional map, where each overlay would represent one season within the "bear year".

All telemetred locations for each bear within a given season are included on the acetate overlay for that season. By superimposing all four overlays, the entire "bear year" of data becomes available to users of the conventional map, just as it is at the end of the dynamic map.

Also provided with the acetate overlays was a base map.

This base map, which is shown in Figure 5, was identical to the background used with the dynamic map. It illustrated the ecoregions of the area, and the Banff townsite was indicated.

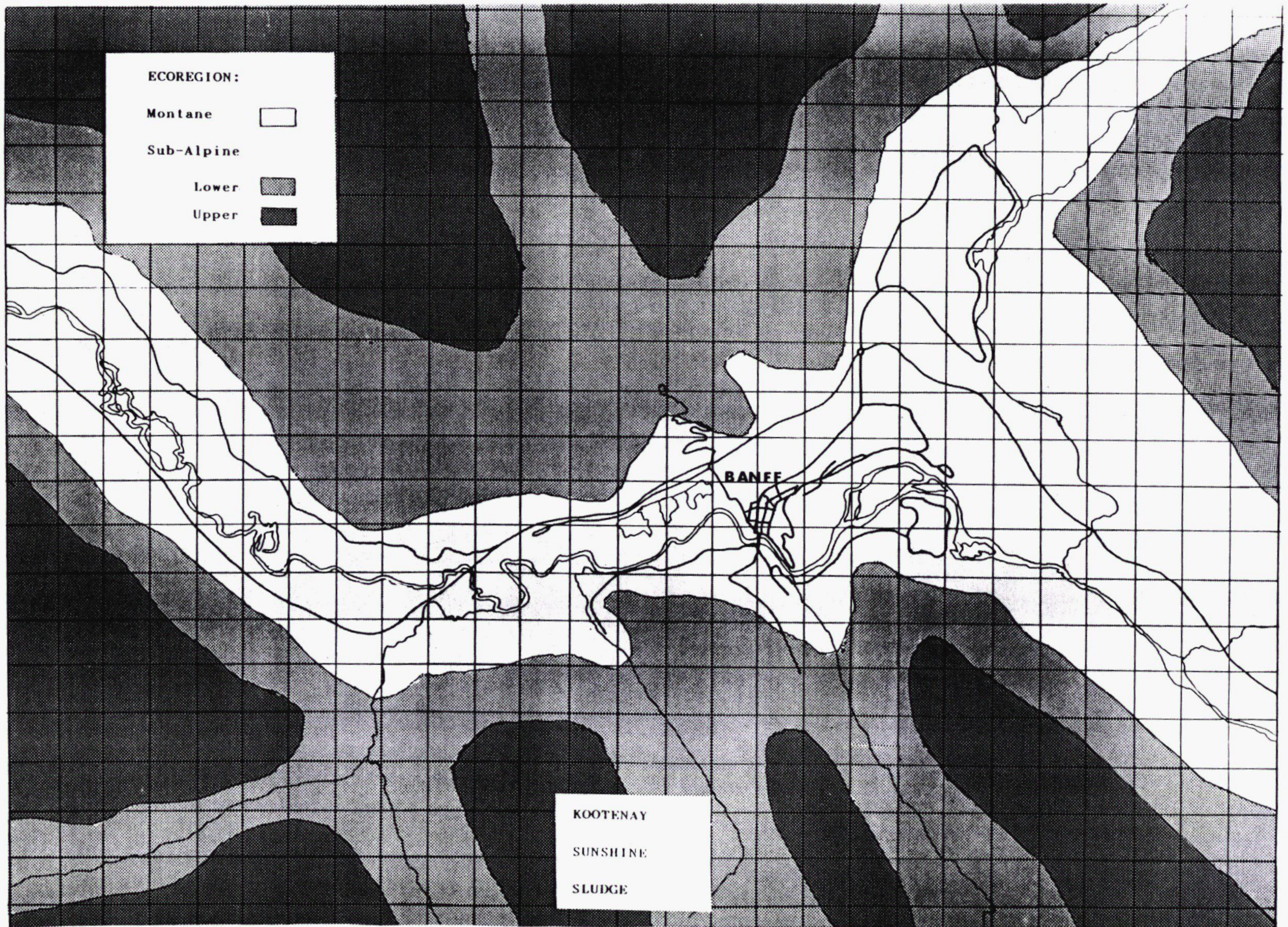


FIGURE 5: THE BASE MAP USED FOR BOTH CONVENTIONAL AND DYNAMIC MAPS (reproduced at 65% of the original).

SUMMARY

The production of the dynamic map was carried out in house, following the basic guidelines established in animation handbooks. It took a number of dry-runs before a final product of satisfactory quality was produced. The video used in the experiments had a running time of 15 minutes, which included a textual introduction (no soundtrack was used). The video showed the movements of three bears during a full "bear year", a period of 180 days. Each day was assigned eight exposures of 0.5 seconds each, for a total of four seconds per day. The background was a portion of Banff National Park, near the Banff townsite, which was identified. Three ecoregions were also identified on this background. In use, the legend on the video map was supplemented by a paper copy of the base map (background).

CHAPTER 5

RESEARCH DESIGN AND THE QUESTIONNAIRE

In order to compare the two different mapping methods, an indication of how much information map users could get from each map was needed. In cartographic research, the standard approach to this problem is to design and administer a questionnaire.

A three part questionnaire was designed for this study. It is included as Appendix B. A number of volunteers were presented with either the conventional or the dynamic map and were asked to answer the questionnaire. The results were then analysed.

Below is a description of the reasoning used in developing the questionnaire. Also, the administration of the questionnaire and the statistical procedures used in the analysis are discussed.

REASONING BEHIND THE QUESTIONNAIRE

There were three types of information which needed to be gained through the questionnaire;

(i) General information: Age, gender, experience, etc.

(ii) Map reading ability of respondents

(iii) Ability to answer questions related to the bear data.

Each of these types of information served its own purpose in the analysis.

The first category, general information, is standard to most questionnaires, and can be used as a means of dividing respondents into groups of similar age, sex or background.

The second category, map reading ability of each respondent, served as a control. The questions used in part 2 of the questionnaire were structured to test for a variety of map reading tasks. The results of these questions were used to determine that both samples were drawn from the same population. Also, if large discrepancies are encountered in the accuracy of responses between the conventional map and the dynamic map, a partial explanation might be found in the responses in this category of information.

The third category of information comprised the essence of the research questionnaire, to provide data to allow direct comparisons between the conventional and dynamic maps. The following criteria were used to develop the questions for this part of the questionnaire:

i) What information should we expect to gain from conventional maps of the movements of bears? This would include; size of the home ranges; distribution of known locations within the home range, both seasonally and annually; overlapping and sharing of home ranges; and the elevations where bears are active.

ii) What information would we like to, or should we be able to, get from this type of data (referring to the telemetry locations)? This would include; patterns and cycles in movements; are the distances covered daily constant throughout the year; do certain locations get revisited; and can the effect of bear-bear interactions be noticed?

The questionnaire consisted of three parts and posed thirty-six questions. The first part contained six questions which dealt with the characteristics of the respondents, such as age, gender and background experience. The second part tested for map reading skills. There were fifteen questions in part two of the questionnaire. Skills such as location, orientation, direction, boundary identification and area measurement were tested. The third part of the questionnaire also posed fifteen questions, which dealt with the information one would desire from telemetred data. The questions required skills similar to those which were tested for in the map reading ability portion of the questionnaire.

ADMINISTRATION OF THE QUESTIONNAIRE

All subjects used the same questionnaire and either the conventional map or the dynamic map (on video tape), but never both. Subjects using the dynamic map completed their questionnaire in a variety of situations, while many completed it using classroom monitors at the University of Calgary, some completed it using television monitors at home. This caused some variation in the quality of the viewing equipment and the size of the image screen. On small screen televisions, the legend became illegible. To compensate for this technical problem, a base map of the area (which includes the legend) was given to respondents in the group using the dynamic map. Subjects using the conventional map to complete the questionnaire generally did this within the facilities of the Department of Geography. The questionnaires were labelled once they had been completed. This kept answer sheets from the two groups separate for analysis purposes.

In total, sixty-six people were surveyed. These people were split into two groups, thirty-four people in Group A and thirty-two people in Group B. Each of these groups worked with only one of the test maps. The test maps were prepared so that each group was given the same data in as similar a manner as was possible, despite the difference between animated and conventional cartography.

Group A respondents worked with the conventional presentation of the data. Their test map consisted of four acetate overlays and a base map. Each overlay represented a `bear season', as determined by the bears' food preference (Kansas and Raine, 1989). By viewing all four overlays simultaneously, the respondent was in effect viewing a scatterplot of the 1988 locations for the bears.

Group B respondents worked with the dynamic presentation of the data. This consisted of a video which illustrated a chronological and cumulative sequence of locational information. The date and `bear season' were indicated through the use of a dynamic legend. As the bears moved on from a known location, a dot was left to record the position. Thus, at the end of the summer, the respondent was in effect viewing a scatterplot of the 1988 bear locations.

STATISTICAL TESTS USED IN THE ANALYSIS

Statistically, the analysis focussed on determining whether or not there were any significant differences between the responses given by the group using a conventional map, and the group using a dynamic map. As the responses were grouped as frequencies, and could be arranged in the form of a contingency table, the chi-square test was applied.

The limitations of the chi-square test (Matthews, 1981) are:

1. The data must be in the form of frequencies.
2. The contingency table must have at least two columns.
3. Expected frequencies in any cell of the contingency table should not be less than five.
4. Samples are assumed to be independent.
5. Random sampling is assumed.

There were instances where the chi-square test could not be applied, due to low frequencies in one or more of the cells in the contingency tables. In those cases, it was noted directly under the contingency table that no test was applied.

Student's t-test was used twice. In one instance it was to ensure confidence that the map reading skills of each group of respondents was statistically the same. That is, both samples were drawn from the same population, with respect to map reading ability. In the second instance it showed that the overall scores attained by each group of respondents, and the answers resulting from the two types of maps were significantly different.

SUMMARY

Data were collected by the administration of a questionnaire which included sections on background characteristics and map reading ability for each subject, as well as the main section eliciting answers based on the interpretation of the map of bear movements. Subjects worked with either the conventional map or the dynamic map, but never both. All subjects answered the same questionnaire. The resulting data were analysed using the Chi-square test, plus some limited use of Student's t-test. The results of the data analysis are discussed in the following chapter.

CHAPTER 6

RESULTS AND DISCUSSION

This chapter examines the results of data analysis for the project. Responses in all three parts of the questionnaire were totalled separately for the two groups (respondents using the conventional map and respondents using the dynamic map). Summaries of responses to the questions are presented in tables throughout this chapter. The general question addressed has been, is a dynamic map more or less effective than a conventional map in conveying information to the map reader. An answer was pursued, not only in general terms, but also by examining a number of specific map reading tasks.

BASIC CHARACTERISTICS OF THE SAMPLE

In the following discussion, the personal information for respondents using the conventional map and the dynamic map, respectively, is summarized. The average age of respondents using the conventional map was 26.0 (standard deviation = 10.7), the average age of respondents using the dynamic map was 32.9 (standard deviation = 9.1).

Respondents who used the conventional map had completed more geography courses, but fewer computer courses than respondents who used the dynamic map. The number of cartography courses completed was roughly the same in each group; however in the group using the dynamic map this was concentrated among a few individuals. The level of reported map use was slightly higher in the group using the conventional map.

MAP READING SKILLS OF THE SUBJECTS

This discussion summarizes the answers given in part 2 of the questionnaire. This part of the questionnaire was to determine the level of conventional map reading skills in each group of respondents, thereby ensuring that both samples were drawn from the same population. The average score for the group of respondents who used the conventional test map was 12.3/15 (82.0% correct) and the average score for respondents who used the dynamic test map was 11.9/15 (79.3%).

A Students t-test was performed to compare the two samples. The calculated t-value was 0.74. Using 64 degrees of freedom (using [n-1]+[m-1], where n and m represent the number of respondents in each of the two test groups), and a significance of 95% the critical t-value is 1.997. Since the calculated t-value is less than the critical t-value, the null hypothesis that there is no significant difference between the map reading skills of the two test groups can be accepted.

SUMMARY AND DISCUSSION OF ANSWERS FROM THE TEST MAPS

There were eleven questions in this part of the questionnaire which were either a Yes/No or multiple choice answer. The average correct score for these eleven questions was 6.1 (55.5%) for respondents using the conventional map, and 7.3 (66.4%) for respondents using the dynamic map. The standard deviation in each case was 1.8.

A Student t-test was performed to compare these two results. The calculated t-value was 2.66, and there were 64 degrees of freedom. The critical t-value, at the 95% confidence level, was 1.997. This result shows that the null-hypothesis of no difference must be rejected. Overall, the respondents using the dynamic map scored significantly higher in interpreting information on bear movements from this map.

A chi-square test was performed to compare the number of incorrect responses per question in each group of respondents. The aim of this test was to determine if there was a significant difference in the distribution of incorrect responses, Student's t-test, described above, having shown that there was a statistical difference in the absolute number of correct (or incorrect) responses. The chi-square test is to determine if there is any significant difference in which questions are being answered incorrectly.

The null hypothesis is that there is no difference in the distribution of incorrect answers between the two groups. The calculated chi-square value was 21.9. At a significance level of 95%, the critical chi-square value, at 10 degrees of freedom, is 18.31. Since the calculated chi-square is larger than the critical value, the null hypothesis is rejected. There is a significant difference between the distribution of responses in the two test groups.

This result suggests that specific questions should be tested to see whether or not the responses for particular questions were significantly different. The questionnaire was designed so that a number of different types of map reading tasks were included. These tasks required skills of; locating points and features, judging rates and distances, pattern recognition, identifying interactions, delineation of area and area measurement. The following sections will look at the answers to each of these categories separately.

Locations

In map reading and interpretation, a very basic concern is the location of points and features. Questions 5 and 8 addressed this. Both dynamic and conventional map users scored equally well. Question 5 asked if the bears revisited any locations and 98.4 % of all respondents answered correctly. Question 8, asked which ecoregion was the most important for the bear named Kootenay. 100% of respondents who used the conventional map answered correctly, while 86% of respondents using the dynamic map answered correctly. The results of these questions are shown in Table 1. It does not require a statistical test to determine that there is no real difference between the two map designs for these questions.

TABLE 1: SUMMARY OF ANSWERS TO THE LOCATION QUESTIONS RELATING TO THE TEST MAPS.

Question 5: Do locations get revisited?

Correct Response: YES

Answer:	YES	NO	DON'T KNOW
CONVENTIONAL	30	-	1
DYNAMIC	32	-	-
TOTAL	62	0	1

The Chi-Square test can not be applied in this example due to the low frequencies in both the `NO' and in the `Don't Know' categories.

Quetsion 8: List the three ecoregions shown in the legend in order of their importance to Kootenay.

Correct Responses:

Most Important: Montane
Second in Importance: Lower Sub-Alpine
Least Important: Upper Sub-Alpine

Results:

CONVENTIONAL: 34 out of 34 (100%) responses were correct
DYNAMIC: 24 out of 28 (86%) responses were correct, four respondents did not answer.

Rates and Distances

Map readers are continually faced with questions of distance between map features. This was addressed with two questions, 4a and 4b, which required the map user to try to determine whether bear movements were constant on a daily or seasonal basis. The results are shown on Table 2.

The information necessary to answer these questions is not directly available on the conventional map. Respondents using the conventional map were required to logically deduce the fact that the distance travelled each day, and the average daily distance in each season, varies. The logic used by the respondents was to be that, since the dots on the overlays are not spaced equally, the bear movements must vary from day to day. Also, since the spread of locations is different for each season, the average daily distance which the bear covered must vary from season to season.

The information needed to answer these questions was directly available from the dynamic map. The fact that the information is directly available explains why the respondents using the dynamic map had a statistically

TABLE 2: SUMMARY OF ANSWERS TO RATE AND DISTANCE QUESTIONS RELATING TO THE TEST MAP AND CHI-SQUARE RESULTS

Question 4a: Is daily distance constant?
Correct Response: NO

Answer:	YES	NO	DON'T KNOW
CONVENTIONAL	2	10	22
DYNAMIC	7	23	2
TOTAL	9	33	24

Null Hypothesis: No difference between the response of either group.

Degrees of Freedom: 2
Level of Significance: 0.05
Critical Chi-Square: 5.99
Calculated Chi-Square: 24.3

Result: Reject the null hypothesis, there is a significant difference between the answers of the two groups.

Question 4b: Is seasonal distance constant?
Correct Response: NO

Answer:	YES	NO	DON'T KNOW
CONVENTIONAL	10	14	9
DYNAMIC	4	18	6
TOTAL	14	32	15

Null Hypothesis: No difference between the response of either group.

Degrees of Freedom:2
Level of Significance: 0.05
Critical Chi-Square: 5.99
Calculated Chi-Square: 3.80

Result: Accept the null hypothesis, there is no significant difference between the answers of the two groups.

significant better response to question 4a.

The respondents using the dynamic map did not, however, answer question 4b (seasonal distance) significantly better than their counterparts using the conventional map. The most probable reason for this is an inability to compare information which has been viewed early on in the video, to information appearing near the end of the video. A similsr result would be expected if you gave a map user a static map, took it away, then presented that map user with a similar static map and asked the map user to compare the two maps, without having the opportunity to view them simultaneously.

Pattern Recognition

There were six questions; 2,3,6,7,9 and 10, which dealt with pattern recognition in one form or another. Questions 9 and 10 dealt with the distribution pattern of Kootenay's locations over an entire year (question 9), and within each season (question 10). Essentially, these questions were asking whether the distribution of recorded locations was regular, random or clustered, except that those terms were replaced with the words equally, randomly and selectively. Results are shown on Table 3.

The response of the dynamic map group was statistically better than the response of the conventional map group of respondents for questions 9 and 10 combined. This differs from what was expected. Both groups had the same information, since the correct response simply relates to looking at the distribution of known locations. We would therefore expect the answers from each group to have been similar. Perhaps being able to visualize the path which the bear takes from one location to the next was beneficial.

Questions 6 and 7 were two other questions relating to pattern identification. Question 6 asked whether or not there was an identifiable pattern in the movements of Kootenay. Question 7 simply asked for a verbal description of the pattern, as a method of confirming that the response to question 6 was not simply a random selection. In this case it was expected that respondents using the dynamic map should produce a statistically better response and that was indeed the result (Table 4).

TABLE 3: SUMMARY OF ANSWERS TO PATTERN RECOGNITION QUESTIONS (DISTRIBUTION) RELATING TO THE TEST MAPS AND CHI-SQUARE RESULTS.

Question 9: How is the home range utilised annually?

Correct Response: SELECTIVELY

Answer:	EQUALLY	RANDOMLY	SELECTIVELY	DON'T KNOW
CONVENTIONAL	6	5	14	8
DYNAMIC	7	1	19	4
TOTAL	13	6	33	12

Question 10: How is the home range utilised seasonally?

Correct Response: SELECTIVELY

Answer:	EQUALLY	RANDOMLY	SELECTIVELY	DON'T KNOW
CONVENTIONAL	4	10	12	7
DYNAMIC	4	2	20	5
TOTAL	8	12	32	12

Combined totals of Questions 9 and 10

Answer:	EQUALLY	RANDOMLY	SELECTIVELY	DON'T KNOW
CONVENTIONAL	10	15	26	15
DYNAMIC	11	3	39	9
TOTAL	21	18	65	24

Null Hypothesis: There is no difference between the combined response of either group.

Degrees of Freedom: 3 Critical Chi-Square: 7.81
Level of Significance: 0.05 Calculated Chi-Square: 12.2

Result: Reject the null hypothesis, there is a significant difference between the combined responses of the two groups.

TABLE 4: SUMMARY OF ANSWERS TO PATTERN RECOGNITION QUESTIONS (MOVEMENTS AND CORRIDORS) RELATING TO THE TEST MAPS AND CHI-SQUARE RESULTS.

Question 6: Is there a pattern to the movements?

Correct Response: YES

Answer:	YES	NO	DON'T KNOW
CONVENTIONAL	16	7	11
DYNAMIC	26	4	2
TOTAL	42	11	13

Null Hypothesis: There is no difference between the response of either group

Degrees of Freedom: 2 Critical Chi-Square: 5.99
Level of Significance: 0.05 Calculated Chi-Square: 9.20

Result: Reject the null hypothesis. There is a significant difference between the answers of each group.

Question 2: Are there "corridors" in the home range?

Correct Response: Yes

Answer:	YES	NO	DON'T KNOW
CONVENTIONAL	29	3	2
DYNAMIC	30	-	2
TOTAL	59	3	4

The Chi-Square test can not be applied in this example due to the low frequencies in both the `NO' and in the `Don't Know' categories.

A number of respondents using the conventional map answered that there was a pattern to the movements of Kootenay. This answer was based on the clustering of dots representing known locations, as was indicated by the responses to question 7. The verbal descriptions of the pattern given by respondents using the conventional map included circular, linear, and east-west statements.

Respondents who used the dynamic map were relatively consistent at identifying a back and forth pattern, with some respondents calling it a linear pattern. The fact that 81.3% of respondents using the dynamic map could identify that there was a pattern indicates that dynamic mapping can be useful for identifying patterns in changing spatial distributions.

The other two questions relating to pattern recognition were questions 2 and 3. This was similar to the questionnaire design described above, where a verbal answer was used to verify the response to a Yes/No question. Both groups were successful with question 2, which had an overall score of 89.4% correct (see Table 4).

By combining the responses for all of the pattern recognition type questions within each group the results show the dynamic map to be superior. Respondents using the dynamic map scored a combined total of 95 correct out of 126 responses (80.2%) on questions 2,6,9 and 10, while respondents working with the conventional map scored a combined total of 71 correct out of 134 responses (64.9%). Showing continuous changes in spatial distributions, instead of selecting representative instants, is an effective method for communicating patterns.

Identifying Interactions

In any study of spatio-temporal dynamics involving more than one variable or element it is important to be able to identify interactions. Responses to questions 11, 14 and 15, which dealt with identifying interactions between the three bears, are shown in Table 5.

Question 11 asked if the location of one bear was affected by the locations of the other bears. This would be a very difficult question to answer with overlays which do not

TABLE 5: SUMMARY OF ANSWERS TO IDENTIFYING INTERACTION QUESTIONS RELATING TO THE TEST MAP AND CHI-SQUARE RESULTS.

Question 11: Does the location of one bear affect others?

Correct Response:YES

Answer:	YES	NO	DON'T KNOW
CONVENTIONAL	28	2	4
DYNAMIC	18	6	7
TOTAL	46	8	11

Null Hypothesis: No difference between the response of either group.

Degrees of Freedom: 2 Critical Chi-Square: 5.99
Level of Significance: 0.05 Calculated Chi-Square: 5.00

Result: At the 95% confidence level, there is no significant difference between the responses of each test group.

Question 15: How often are bears within 5 km of each other?

Answer:	<7 DAYS	7-14 DAYS	14-30 DAYS	>30 DAYS	DON'T KNOW
CONVENTIONAL	3	4	6	5	15
DYNAMIC	7	10	8	3	4
TOTAL	10	14	14	8	19

Null Hypothesis: No difference between the response of either group.

Degrees of Freedom: 4 Critical Chi-Square: 9.49
Level of Significance: 0.05 Calculated Chi-Square: 11.60

Result: Reject the null hypothesis. A significant difference between the responses of each group exists.

specifically show the location of any bear at any one point in time. The respondents using the conventional map were however quite successful at answering this, with 82.3% answering correctly. It is highly likely that respondents were basing their answers on previous knowledge, rather than on information coming from the test maps. The majority of respondents using the dynamic map also indicated that the location of one bear was affected by the location of the other bears, but there was a higher degree of uncertainty. This may be related to the fact that, while bear movements are affected by neighboring bears at times, a large portion of their movements are seemingly quite independent of the other bears.

Question 14, is an open-ended style question, which asks whether overlapping territory is used simultaneously by two or more bears, or whether one bear moves out before another will move in. The responses indicated that respondents who used the dynamic map had a clearer picture of how the three bears were moving relative to each other. Answers such as "usually one moves away, but in September they are together" show that the dynamic map can convey at least an approximate idea of what is going on.

The answers to question 15, which asks how often bears are within 5 km of each other, suggests that, while the general picture of interactions is clear, more specific questions are harder to answer. The answers to question 15 are significantly different between the two groups of respondents, due primarily to the high number of Don't Know responses from those using the conventional map.

In actuality, the responses to question 15 do not differ statistically from what could arise purely from chance. The given responses were tested against a result which would arise through randomness. No statistical difference was found between the collected responses and those which would be expected to arise from a random sequence.

To answer this question correctly, the map viewer would have to follow the movements of all three bears concurrently. This would require a degree of skill and concentration, which in the setting of a questionnaire probably did not happen. The results show that general interactions can be detected, but any degree of detail requires either more skill or more effort than that available in this sample.

Delineation of Areas and Area Measurement

Two questions dealt strictly with the problem of delineating an area, question 1 required respondents to delineate the area and then to measure it. Questions 12 and 13 asked respondents to determine whether or not the home ranges of two or more bears overlapped seasonally or annually, respectively. The results to these questions are shown in Table 6.

Conceptually, it is possible for the home ranges to overlap over the course of a year, but not within the same season, which is why two separate questions were posed. This caused some misinterpretation of the question by respondents, as many indicated they could not answer question 13 with only one year worth of data. Thus the high proportion (29.2%) of Don't Know answers for question 13.

For question 12, 81.2% of the respondents indicated that there was a seasonal overlap of home ranges. This is actually a surprisingly low percentage, considering that on the video, in the first week of September, all three bears are within 200m of each other. Also, on the overlay prepared for Season

TABLE 6: SUMMARY OF ANSWERS TO DELINEATION OF AREA QUESTIONS AND CHI-SQUARE RESULTS

Question 12: Is there a seasonal overlap of home ranges?

Correct Response: YES

Answer:	YES	NO	DON'T KNOW
CONVENTIONAL	25	7	-
DYNAMIC	27	5	-
TOTAL	52	12	0

Null Hypothesis: No difference between the response of either group.

Degrees of Freedom: 1　　Critical Chi-Square: 3.84
Level of Significance: 0.05　　Calculated Chi-Square: 0.41

Result: Accept the null hypothesis, there is no significant difference between the answers of the two groups.

Question 13: Is there an annual overlap of home ranges?

Correct Response: YES

Answer:	YES	NO	DON'T KNOW
CONVENTIONAL	23	6	5
DYNAMIC	15	2	14
TOTAL	38	8	19

Null Hypothesis: No difference between the response of either group.

Degrees of Freedom: 2　　Critical Chi-Square: 5.99
Level of Significance: 0.05　　Calculated Chi-Square: 9.20

Result: Reject the null hypothesis, there is a significant difference between the answers of each group.

3, there is an area where symbols representing all three bears are overlapping each other. However, looking back to part 2 of the questionnaire, questions 14 and 15 in the map reading skill portion (which dealt with distribution boundaries and overlap) are similar questions. Only 75.8% of respondents answered those questions successfully. The low scores in questions 12 and 13 from the test map may relate to limitations in the abilities or reading skills of the respondents.

This is reflected in the other question which requires an area to be delineated and then measured. Question 1 asks for an estimate of the size of the home range of Kootenay. To answer this question was really a simple matter of counting the grid squares within the home range, as all subjects were informed that each grid square on the map was 1 km². A summary of the responses is included in Table 7.

It was expected that the group using conventional maps would perform better for this question. In fact, the mean estimate of 160.2 km² for home range size, in the group using the dynamic map, was actually closer to the home range value of 153 km² published by Kansas and Raine (1989), however,

TABLE 7: SUMMARY OF ANSWERS TO THE AREA MEASUREMENT QUESTION

Question 1: Approximately how many km^2 is the home range of Kootenay?
Correct Response: 153 km^2

	MEAN ESTIMATE	STANDARD DEVIATION
CONVENTIONAL	113.7	73.7
DYNAMIC	160.2	181.7

A complete list of responses is included in Appendix D

Corresponding map reading skill questions:

Question 6: Area estimation

CONVENTIONAL: 22 out of 34 correct, 64.7%
DYNAMIC: 22 out of 32 correct, 68.8%

Question 14: Draw a boundary around a distribution

CONVENTIONAL: 29 out of 34 correct,
DYNAMIC: 24 out of 32 correct,

there is such a large standard deviation (181.7) that this value can hardly be considered as accurate. Respondents using the conventional map underestimated the size of the home range, with a group mean of 113.7 km². The standard deviation (73.7) shows more consistency within this group.

The range of answers in each group shows a relatively poor ability to estimate area. This is not surprising considering the results of the area measurement question (question 6) in the map reading skill portion of the questionnaire. The respondents were asked to estimate the area of a rectangular area, and were provided with a bar scale and the formula to use (length x width). Even with this information, 33.3% of all respondents answered incorrectly. Also, to estimate Kootenay's home range required the respondents to delineate the area first, and as discussed above, many respondents experienced difficulty with that skill also.

OTHER RELEVANT COMMENTS AND CONSIDERATIONS

Respondents who viewed the dynamic map were asked to provide comments on the strategy they used (if any) in answering the questions, and also to comment on the map itself. Most of the respondents viewed the video twice in order to answer the questions. A few repondents were creative, using the still frame and fast scanning capabilities of the VCR. Most however simply watched the video in its entirety at regular playback speed.

Many respondents criticized the clarity of the video, especially the lack of a strong colour contrast between the three bears and the need to use a conventional map for the legend. A number of respondents also indicated that it was difficult to follow the movements of three bears simultaneously, but that to follow an individual bear was relatively easy.

One respondent commented that perhaps peoples' ability to interpret dynamic maps would improve if there were more examples of dynamic maps available. Practice would improve the dynamic map reading skills.

SUMMARY

In this comparison of two methods of presenting a temporally changing spatial distribution, some interesting results were attained. Respondents to the questionnaire were asked to extract information from the maps in a number of different categories. These categories were; location, pattern recognition, rates and distances, identifying interactions, delineation of areas and area measurement.

It was shown statistically that, overall, the responses from the dynamic map were more accurate than the responses from the conventional map, with an average correct score of 66.4% for respondents using the dynamic map versus an average correct score of 55.5% for respondents using the conventional map.

The dynamic map was superior in answering pattern recognition questions, with respondents using the dynamic map having an average score of 80.2% on the six questions which related to pattern recognition. Respondents using the conventional map had an average score of 64.9% on the same six questions. Dynamic map users also scored better on the questions dealing with identifying interactions, providing the interactions were not too complex. The dynamic map also provided marginally better information in the rates and distance category.

Both maps were equally efficient at conveying information related to locations. The conventional map led to more consistent answers in the questions dealing with area delineation and area measurement.

In this project, primary investigation has been conducted into a number of categories of information related to specific map reading tasks and how effectively the dynamic and conventional maps represented a temporally changing spatial distribution, relative to these categories of information. A number of possible directions for further study, which are discussed in the following chapter, have been brought to mind by these results.

CHAPTER 7

CONCLUSION

The results of the comparison of the dynamic map with the conventional map for representing a changing distribution through time supports the argument that the dynamic map can convey such information better than a conventional map. This is particularly true for pattern recognition and the identification of simple interactions.

The dynamic map produced is only representative of this one particular distribution. Whether the results from this research can be applied to the dynamic representations of other distributions is not known at this point in time. Further study using the dynamic representation of a number of distributions is needed to determine this. Also, the questions posed in this research were specific to the distribution of bear locations. There are a variety of other questions which could be posed with a dynamic map of a different distribution.

More work can also be done exploring what magnitude of complexity in interactions can be accurately attained. The results of this survey suggest that only very basic interactions can be interpreted. A future survey which has a number of illustrated interactions, progressing from extremely simple to very complex may be useful. The point at which respondents are unable to distinguish or identify the interactions will mark the upper limit of the magnitude of complexity that can be interpreted. The video can be refined through the addition of narration, to determine if this would have an effect on the transmission of information about complex interactions.

In future studies map users should be encouraged to be more creative with how they view a dynamic map. Many respondents in this survey found that the amount of information learned was disproportionately small when compared to how long it took them to watch the dynamic map. Other respondents solved that problem by using the high speed scan of the VCR, which indicates that the respondents' familiarity with the equipment (in this case a VCR) could affect the test results.

This research was far from exploring the full scope of creativity and capability of dynamic mapping. The base map was not rotated or tilted. Zooming in and out was not used. There was no sound track or narration included with this dynamic map. Future videos may be refined through the addition of one or more of the above. Through a single test map as this, it is not possible to comment on the universality of the results of this study. One would hope that the positive aspects of the dynamic map can be replicated in a number of different situations, and using the dynamic representations of a number of temporally changing distributions. These are all aspects which can be examined in future research.

The approach of this study was to keep the dynamic map as simple and straight-forward as possible, to test it for its merits as a source of information. Too many 'artistic' inclusions could have turned the dynamic map into an interesting film, with no academic or research value. It would be valuable if future studies could determine where the boundary between a functional, scientifically oriented dynamic map, and an artistic animated production lies.

BIBLIOGRAPHY

Andrews, Sona K. and Gersmehl, Philip J. (1986). "Creating and Using Video Tapes for Cartographic Demonstrations", Journal of Geography, vol.85 no.3 pp. 125-127.

Bertin, J. (1967). Semiologie Graphique, Paris, Gauthier-Villars.

Bickmore, David (1987). "Scientific Roles for the New Cartography", The Cartographic Journal, vol.24 pp.56-58.

Blades, M. and Spencer, C. (1986). "The Implications of Psychological Theory and Methodology for Cognitive Cartography", Cartographica, vol.23 no.4 pp.1-13.

Board, Christopher (1984). "Higher Order Map-Using Tasks: Geographical Lessons in Danger of Being Forgotten", Cartographica, vol.21 no.1 pp.85-97.

Campbell, Craig and Egbert, Stephen (1990). "Animated Cartography/Thirty Years of Scratching the Surface", Cartographica, vol.27, no.2, pp.24-46.

Chang, K. (1980). "Circle Size Judgement and Map Design", The American Cartographer, vol.7, pp.155-162.

Cornwell, Bruce and Robinson, A. H. (1966). "Possibilities for Computer Animated Films in Cartography", The Cartographic Journal, vol.3, no.2, pp.79-82.

Cromie, B.W. (1977). "Contour Design and the Topographic Map User", Canadian Surveyor, 31, pp.34-40.

Eastman, J.R. (1985). "Cognitive Models and Cartographic Design Research", The Cartographic Journal, vol.22 no.2, pp.95-101.

Eastman, J.R. (1982). "Graphic Organisation and the Structure of Map Data Into Memory", unpublished PhD Dissertation, Boston University, U.S.A.

Flannery, (1956). "The Graduated Circle: A Description, Analysis, and Evaluation of a Quantitative Symbol," Unpublished PhD Dissertation,Department of Geography University of Wisconsin, U.S.A.

Gatrell, A.C. (1974). <u>On the Complexity of Maps</u>, Pennsylvania State University, Papers in Geography no.11.

Gilmartin, P.P. (1981). "The Interface of Cognitive and Psychophysical Research in Cartography", <u>Cartographica</u> vol. 18 pp.9-20.

Guelke, L. (1976). "Cartographic Communication and Geographic Understanding", <u>The Canadian Cartographer</u>, vol.13 no.2 pp.107-122.

---------- (1979). "Perception, Meaning and Cartographic Design", <u>The Canadian Cartographer</u>, vol.16 pp.61-69.

Guptill, S.C. and Starr, L.E. (1984). "The Future of Cartography in the Information Age", in International Cartographic Association Commission "<u>Computer-Assisted Cartography Research and Development Report</u>", compiled by L.E. Starr.

Halas, John and Manvell, Roger (1968). <u>The Technique of Film Animation</u>, Communication Arts Books, Hastings House Publishers, New York.

Hamman, Anja (1989). Personal Communication, University of Calgary, Computer Science Department.

Kansas, J.L. and Raine, R.M. (1989). <u>Ecological Studies of the Black Bear in Banff National Park, Alberta,1986-1988 Final Report</u>. Prepared by Beak Associates Consulting Ltd for Banff National Park Warden Service.

Kolers, P and von Grunau, M. (1976). "Shape and Colour in Apparent Motion", Vision Research, vol.16, pp.329-335.

Langran, Gail and Chrisman, Nicholas (1988). "A Framework for Temporal Geographic Information", Cartographica, vol.25. no.3, pp.1-14.

Laybourne, Kit (1979). The Animation Book, Crown Publishers Inc., New York.

Levitan, Eli L. (1979). Handbook of Animation Techniques, Van Nostrand Reinhold Company, New York.

Matthews,J.A. (1981). Quantitative and Statistical Approaches to Geography. Pergamon Press, Oxford.

Moellering, H. (1980). "The Real-Time Animation of Three Dimensional Maps", The American Cartographer, vol.7, no.1, pp.67-75.

-------------- (1984). Personal Communication with D.R.F. Taylor.

Monmonier, Mark (1990). "Strategies for the Visualization of Geographic Time-Series Data", Cartographica, vol.27, no.1, pp.30-45.

Morrison, Joel L. (1980). "Computer Technology and Cartographic Change", in The Computer in Contemporary Cartography, D.R.F. Taylor (Ed.), Jon Wiley & Sons.

Muehrcke, P. (1973). "Visual Pattern Comparison in Map Reading", Proceedings of the Association of American Geographers, vol.5 pp.190-194.

Muehrcke, P. (1981) "Maps in Geography", Cartographica, vol.18 no.2 pp.1-41.

Navon, D. (1977). "Forest Before Trees: The Precedence of Global Features in Visual Perception", Cognitive Psychology, 9, pp.353-383.

Olson, J.M. (1976). "A Coordinated Approach to Map Communication Improvement", The American Cartographer, vol.3, pp.151-159.

----------- (1979). "Cognitive Cartographic Experimentation", The Canadian Cartographer, 16, pp.34-44.

----------- (1983). "Future Research Directions in Cartographic Communication and Design", in D.R.F. Taylor (ed.) Graphic Communication and Design in Contemporary Cartography, Chichester: Jon Wiley and Sons.

----------- (1984). "Video Discs and Map Design", Technical Papers of the 12th International Conference of the International Cartographic Association, vol.1, Perth Australia, pp.509-515.

Petchenik, Barbara Bartz (1975). "Cognition in Cartography", Proceedings of Auto-Carto II, pp.183-193.

------------ (1983) "A Map Maker's Perspective on Map Design Research 1950-1980", in Graphic Communication and Design in Contemporary Cartography, D.R.F. Taylor (ed.), Chichester: Jon Wiley and Sons.

Ratajski, L. (1973). "The Research Structure of Theoretical Cartography", International Yearbook of Cartography, 13, pp.217-227.

Robinson, A.H. (1975). "Map Design", Auto-Carto II, Proceedings of the International Symposium on Computer Assisted Cartography, pp.9-14.

Robinson, A.H. and Petchenik, B.B. (1975). "The Map as a Communication System", The Cartographic Journal, vol.12 pp.7-15.

Robinson, A.H. (1976). The Nature of Maps, University of Chicago Press, Chicago.

Rudmose Brown, R.N., Howarth, O.J.R. and McFarlane, J. (1922). The Scope of School Geography, Clarendon Press, Oxford.

Shimron, J. (1978). "Learning Positional Information from Maps", The American Cartographer, 5, pp.9-19.

Steinke, T. and Lloyd, R. (1983). "Images of Maps: A Rotation Experiment", The Professional Geographer, 35, 4, pp.455-461.

Taylor, D.R.F. (1985). "The Educational Challenges of a New Cartography", Cartographica, vol.22 no.4 pp.19-37.

Thorndyke, P and Stasz, C. (1980). "Individual Differences in Procedures for Knowledge Acquisition From Maps", Cognitive Psychology, 12, pp.137-175.

Thrower, N.J. (1959). "Animated Cartography", Professional Geographer, vol.11, no.6, pp.9-12.

------------- (1961). "Animated Cartography in the United States", International Yearbook of Cartography, vol.1, pp.20-30.

Turner, Scott (1986). "Dynamic Cartography in a Prototype Satellite Monitoring System", Technical Papers ACSM-ASPRS Annual Convention, vol.1, pp222-227.

APPENDIX A: Telemetry locations of black bears in this study. Coordinates relate to the UTM coordinates on NTS map sheet 82 O/4.

BEAR #11- KOOTENAY

MAY

DATE	SEASON	XXX	YYY
03/05	1	0	678
05/05		3	671
06/05		2	671
07/05		40	713
09/05		51	719
10/05		25	732
11/05		48	728
12/05		980	694
13/05		956	689
14/05		958	697
15/05		957	694
19/05		950	690
20/05		910	684
21/05		24	764
22/05		24	764
24/05		50	723
25/05		33	718
27/05		908	693
28/05		907	692
29/05		905	692
30/05		943	688

KOOTENAY - JUNE

DATE	SEASON	XXX	YYY
01/06	1	37	730
02/06		38	749
03/06		52	712
04/06		51	726
05/06		53	723
06/06		55	722
07/06		55	706
08/06		38	725
09/06		20	711
10/06		24	747
12/06		19	711
15/06		937	623
16/06		967	693
17/06		52	719
18/06		25	758
19/06		43	785
20/06		56	718
21/06		68	722
23/06		4	730
29/06	2	952	689
30/06		43	728

KOOTENAY - JULY

DATE	SEASON	XXX	YYY
01/07	2	37	729
02/07		68	690
03/07		954	682
07/07		940	697
08/07		945	695
10/07		926	682
11/07		23	669
12/07		982	709
13/07		945	690
14/07		927	635
15/07		20	660
16/07		968	680
17/07		987	718
18/07	3	996	688
19/07		972	704
20/07		922	678
21/07		969	697
22/07		966	702
23/07		35	725
24/07		17	715
25/07		971	704
26/07		946	684
29/07		23	718
30/07		23	718

KOOTENAY - AUGUST

DATE	SEASON	XXX	YYY
02/08	3	870	730
03/08		969	703
04/08		971	704
05/08		950	698
06/08		29	764
07/08		95	815
08/08		96	815
09/08		101	818
10/08		95	815
11/08		95	815
12/08		96	815
13/08		96	815
14/08		96	815
15/08		52	718
16/08		7	671
19/08		960	689
20/08		968	685
21/08		983	685
22/08		975	707
23/08		978	746
24/08		1	682

KOOTENAY - SEPTEMBER

DATE	SEASON	XXX	YYY
03/09	3	915	638
04/09		914	622
05/09		914	622
06/09		913	622
07/09		920	620
08/09		975	727
09/09		970	750
11/09		36	702
12/09	4	975	670
13/09		968	691
14/09		23	727
15/09		26	741
17/09		979	712
18/09		980	713
19/09		979	714
20/09		979	714
21/09		979	714
22/09		979	714
23/09		986	718
24/09		35	703
25/09		38	705
26/09		40	705
27/09		40	704
29/09		39	693
30/09		37	694

KOOTENAY - OCTOBER

DATE	SEASON	XXX	YYY
01/10	4	43	704
02/10		39	694
03/10		35	705
04/10		39	694
05/10		10	707
07/10		17	678
08/10		1	682
09/10		8	701
10/10		18	708
11/10		7	708
12/10		8	698
13/10		3	702
15/10		4	700
16/10		9	706
17/10		37	694
18/10		999	712
20/10		997	717
21/10		996	717
23/10		996	717
25/10		997	695
26/10		9	707
30/10		980	689
08/11		925	664

BEAR #18- SUNSHINE

MAY

DATE	SEASON	XXX	YYY
02/05	1	882	634
03/05		883	635
05/05		883	634
06/05		882	634
07/05		882	634
08/05		884	635
09/05		884	636
10/05		886	634
12/05		905	646
13/05		898	644
14/05		900	644
15/05		894	643
16/05		880	645
19/05		888	644
20/05		888	642
21/05		897	648
22/05		904	655
23/05		904	656
24/05		903	655
25/05		909	665
26/05		910	651
28/05		898	653
30/05		888	642
31/05		872	634

SUNSHINE - JUNE

DATE	SEASON	XXX	YYY
01/06	1	867	634
03/06		870	634
04/06		872	633
05/06		870	634
06/06		870	635
07/06		885	645
08/06		889	644
09/06		890	645
10/06		901	648
11/06		902	651
12/06		899	646
13/06		886	644
15/06		876	635
16/06		865	633
17/06		860	631
18/06		860	632
19/06		865	631
20/06		874	637
21/06		888	642
22/06		893	644
23/06		911	655
24/06		898	649
25/06	2	916	653
26/06		888	638
28/06		886	644
29/06		890	643

SUNSHINE - JULY

DATE	SEASON	XXX	YYY
01/07	2	877	635
02/07		866	632
03/07		870	633
04/07		892	648
05/07		909	648
06/07		904	654
09/07		870	634
10/07		865	632
11/07		892	645
13/07		919	666
14/07		913	649
15/07		920	640
16/07		922	616
17/07		927	650
18/07		926	645
19/07	3	926	647
20/07		916	664
21/07		881	637
22/07		881	641
23/07		897	647
24/07		892	646
25/07		886	641
26/07		887	641
30/07		912	649
31/07		899	650

SUNSHINE - AUGUST

DATE	SEASON	XXX	YYY
02/08	3	883	642
03/08		880	642
04/08		900	649
05/08		913	649
06/08		916	647
07/08		917	645
09/08		898	647
10/08		899	676
11/08		917	657
12/08		879	641
13/08		883	643
14/08		876	630
15/08		892	646
16/08		922	635
18/08		921	670
19/08		913	647
20/08		917	641
21/08		901	652
22/08		923	667
23/08		918	648
26/08		912	648
27/08		926	613
29/08		916	632
30/08		910	638
31/08		890	668

SUNSHINE - SEPTEMBER

DATE	SEASON	XXX	YYY
01/09	3	921	630
02/09		926	619
03/09		926	619
04/09		914	626
05/09		915	622
06/09		917	616
07/09		916	629
08/09		908	623
09/09		920	619
10/09		930	593
11/09		910	592
12/09		918	625
13/09		917	629
14/09		912	624
15/09		918	615
18/09		939	585
22/09		916	627
23/09		918	615
25/09		935	595
26/09		935	594
27/09		935	595
30/09		934	602

SUNSHINE - OCTOBER

DATE	SEASON	XXX	YYY
02/10	4	933	588
04/10		911	623
10/10		920	595
12/10		926	605
15/10		894	648
16/10		895	647
17/10		890	647
18/10		891	647
20/10		892	648
21/10		896	650
23/10		896	650
24/10		896	649
25/10		896	649
26/10		894	649
30/10		886	634

BEAR #19 - SLUDGE - MAY

DATE	SEASON	XXX	YYY
01/05	1	105	650
02/05		107	651
03/05		108	646
04/05		123	621
05/05		121	633
06/05		125	618
07/05		130	624
08/05		134	627
09/05		127	625
10/05		125	628
11/05		108	652
12/05		108	653
13/05		86	663
14/05		59	690
15/05		42	716
16/05		58	707
19/05		84	681
20/05		104	663
21/05		94	673
22/05		84	685
23/05		75	686
24/05		87	688
25/05		105	665
26/05		105	665
28/05		93	674
29/05		84	675

SLUDGE - JUNE

DATE	SEASON	XXX	YYY
01/06	1	63	695
03/06		62	693
04/06		62	693
05/06		85	683
06/06		118	622
08/06		132	608
10/06		113	644
11/06		122	618
12/06		109	648
13/06		110	646
14/06		131	635
15/06		83	665
16/06		71	686
17/06		106	648
18/06		109	648
19/06		116	634
20/06		108	648
21/06		98	658
23/06		83	676
24/06	2	86	661
25/06		128	618
26/06		105	643
28/06		83	668
29/06		100	655
30/06		111	644

SLUDGE - JULY

DATE	SEASON	XXX	YYY
01/07	2	104	658
02/07		108	638
03/07		116	640
04/07		109	631
05/07		113	647
06/07		85	663
07/07		76	681
08/07		71	683
09/07		78	676
10/07		97	649
11/07		117	636
13/07		101	646
14/07		79	675
15/07		80	675
16/07		104	658
17/07		114	646
18/07		102	655
19/07	3	105	635
20/07		120	608
21/07		83	673
22/07		53	685
23/07		75	684
25/07		40	728
26/07		74	682
30/07		136	594
31/07		134	597

SLUDGE - AUGUST

DATE	SEASON	XXX	YYY
02/08	3	114	632
03/08		113	642
04/08		129	603
05/08		121	614
06/08		78	680
07/08		119	627
09/08		180	557
10/08		137	588
11/08		133	599
12/08		131	598
13/08		132	595
14/08		134	600
15/08		135	598
16/08		121	634
18/08		131	609
19/08		136	591
28/08		152	575
29/08		136	592
31/08		937	689

SLUDGE - SEPTEMBER

DATE	SEASON	XXX	YYY
01/09	3	918	620
02/09		926	619
03/09		913	638
04/09		915	622
05/09		913	626
06/09		911	623
07/09		915	627
08/09		920	620
09/09		923	619
10/09		915	621
11/09		914	629
12/09		915	626
13/09		925	618
14/09		916	634
15/09		912	624
18/09		921	614
22/09		916	627
23/09		915	617
24/09	4	940	620
25/09		915	630
27/09		25	673
29/09		55	691
30/09		47	692

SLUDGE - OCTOBER

DATE	SEASON	XXX	YYY
01/10	4	44	712
02/10		43	713
03/10		51	706
04/10		49	710
05/10		64	689
07/10		63	695
08/10		47	691
09/10		49	710
10/10		46	711
11/10		51	698
12/10		53	695
13/10		54	703
15/10		50	709
16/10		46	723
17/10		51	714
18/10		48	715
20/10		46	704
21/10		57	699
23/10		51	698
24/10		75	676

APPENDIX B: The Questionnaire Used For This Research

QUESTIONNAIRE

Part 1: PERSONAL INFORMATION

1. Age ______

2. Male ___ , Female ___

3. How many geography courses have you taken?
   0 __   1 __   2 __   3 or more __

4. How many cartography courses have you taken?
   0 __   1 __   2 __   3 or more __

5. How many computer course have you taken?
   0 __   1 __   2 __   3 or more __

6. How often do you use maps?
   never __
   not very often __
   fairly often __

Part 2: QUESTIONS TO DETERMINE MAP READING ABILITY

The following set of questions has been put together to test your map reading skills. If you can not answer a question, simply leave it blank and proceed to the next. There are fifteen questions in total, they relate to six maps, which are included.

MAP #1 - QUESTIONS 1 to 3

You are standing at an intersection. There is a church () on your left and, facing you across the street are three (3) buildings. You try to find the street names, but the signs have been spray-painted, and you can't read them. Not to worry, you have a map!

QUESTIONS

1) Circle the street corner you are standing on.

2) Draw an arrow to show which direction you are facing.

3) Draw a school symbol () in the SE (southeast) corner of the Blueberry Hill and Third Street intersection.

MAP #2 - QUESTION 4

You are at point A (shown on the map). You want to get to the highway at point B. The catch is that, even though you are on a mountain bike, you have an intense dislike for hills. You avoid them at all costs. So, you pull out a map with contour lines to help you find your way. The terrain is suitable for cycling, the only barrier is your dislike of hills.

QUESTION

4) On MAP #2, trace the route you would cycle, to get from point A to point B, given the above information.

MAP #3 - QUESTIONS 5 to 8

Now, imagine you are a farmer. You own Lot #21 in Knottingham County (part of which is shown in Map #3).

QUESTIONS

5) What crop do you grow? ______________________________

6) Approximately how large is your farm? Give the answer in km^2 (Area can be calculated by length X width).

____

7) What is the dominant crop in Kottingham County? ____________

8) What is the straight line distance from "A" to "B". Answer in km.

____

MAPS #4 and #5 - QUESTIONS 9 and 10

Compare and contrast these two maps.

QUESTIONS

9) Which map represents the roughest terrain? (circle one of the choices below)

a) Map #4
b) Map #5
c) Neither/Both the same.

10) Which map represents the wettest area? (circle one of the choices below)

a) Map #4
b) Map #5
c) Neither/Both the same.

MAP #6 - QUESTIONS 11 to 15

This map shows the distribution of three types of trees in an area.

QUESTIONS

Use one of the following terms to answer questions 11 to 13;
..........RANDOM..........REGULAR..........CLUSTERED..........

11) Describe the BIRCH distribution. ________________

12) Describe the MAPLE distribution. ________________

13) Describe the SPRUCE distribution. ________________

14) On the map, draw an approximate boundary for the distribution of birch trees.

15) Which tree species have overlapping distributions?
(circle all correct statements).

(a) BIRCH and SPRUCE
(b) BIRCH and MAPLE
(c) SPRUCE and MAPLE
(d) SPRUCE, MAPLE and BIRCH all overlap in the same area.

Part 3: QUESTIONS RELATING TO THE TEST MAP

INSTRUCTIONS

The following set of questions is based on the maps produced from the telemetry data provided by Parks Canada. More than one type of map was produced. However, you will only be using one type of map to answer these questions, so there may be some questions you can not answer. If this is the case, simply select the "Don't Know" option.

Read through the questions before you start looking at the map. The reason for this is that it is normal for a map user to have an idea of what kind of information he/she is looking for, before going to the map.

If you are using the video map, you may use the "PAUSE" function on the VCR.

QUESTIONS

For questions 1 to 10, refer only to the information relating to KOOTENAY (bear #11).

1) Approximately how many km ^{2} is the home range of Kootenay?
(Each grid square on the map is equal to ONE SQUARE KM)

2) Do there seem to be major "corridors", within the home range, that the bear tends to use more frquently ?

YES ________
NO ________
DON'T KNOW ________

3) If you answered YES to question #2, can you identify,these corridors ?

____
____

4) Does the daily distance travelled by Kootenay remain constant

(i) day to day : YES ________
NO ________
DON'T KNOW ________

(ii) season to season : YES ________
NO ________
DON'T KNOW ________

5) Do certain locations get revisited ?
YES __________
NO __________
DON'T KNOW ______

6) Does there seem to be a pattern (cycle) within the movements of Kootenay.
YES ________
NO ________
DON'T KNOW _____

7) If you answered YES to question #6, try to describe this pattern. (You may want to use terms such as; LINEAR, CIRCULAR, BACK AND FORTH, ETC...).

____

____

8) List the three ecoregions which are shown in the legend, in their order of importance to Kootenay.

The ecoregion used the most is : __________________________
The ecoregion used second most is : _______________________
The ecoregion used the least is : _________________________

9) Over the course of a year, Kootenay seems to use all parts of his home range (circle only one):

(a) Equally
(b) Randomly
(c) Selectively
(d) Don't know

10) Complete this statement by circling only one of the choices listed below: Within each season, Kootenay tends to use areas of his home range:

(a) Equally
(b) Randomly
(c) Selectively
(d) Don't know

For the following questions, use the data of all three bears.

11) Does the location of one bear affect or restrict the movements of another bear ?

YES ____________

NO ____________

DON'T KNOW ____________

12) Do the home ranges of any bears overlap seasonally ?

YES ____________

NO ____________

DON'T KNOW ____________

13) Do the home ranges of bears overlap annually ?

YES ____________

NO ____________

DON'T KNOW ____________

14) In cases where the home ranges do overlap, do both bears occupy the overlapping territory simultaneously, or does one only move in once the other has moved along ? (or : Don't Know)

____

____

15) How often do two or more bears seem to be within 5 km of each other ? (circle only one)

(a) Less than the equivalent of a week all summer
(b) Between one and two weeks (equivalent) all summer
(c) Between two weeks and one month (equivalent) all summer
(d) More than the equivalent of a month
(e) Don't know

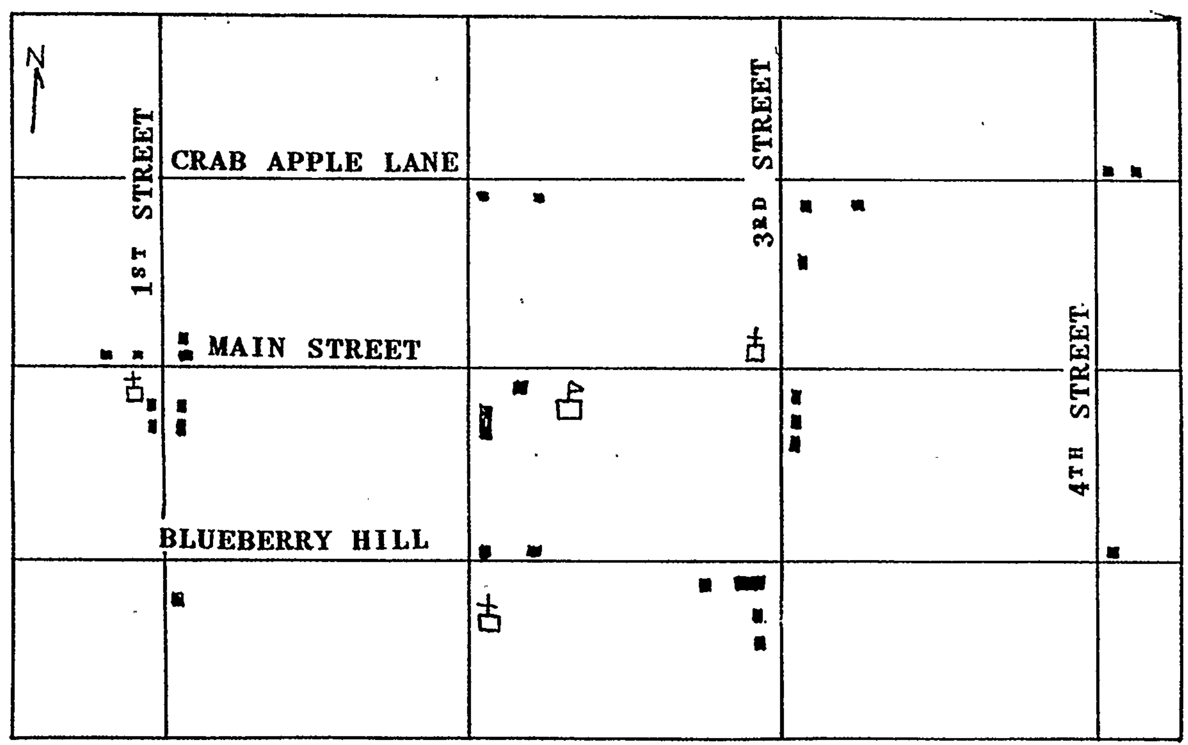
If you used the video map, please take a few minutes to write a short statement for each of the following questions.

16) How many times did you need to watch the video to answer the questions ?

17) Did you use any particular strategy or pattern to answer the questions ? If YES, please describe

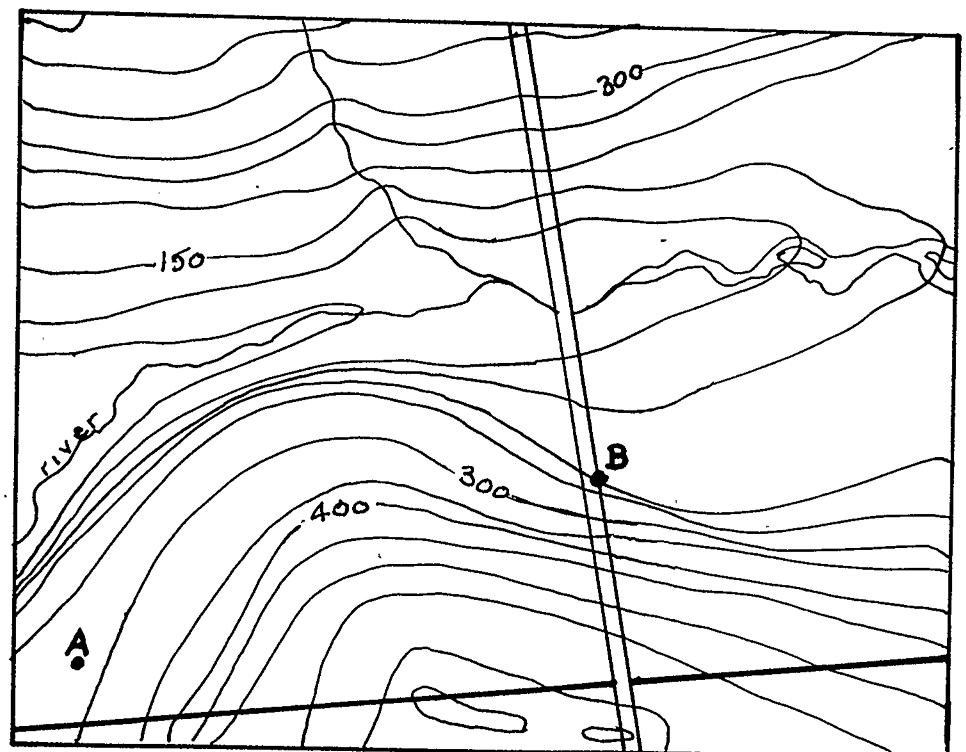
18) Did you find it relatively easy to get information from the video map ? What are the good/bad points of this map ? What is your impression of the usefulness and value of this kind of map ?

MAP #1

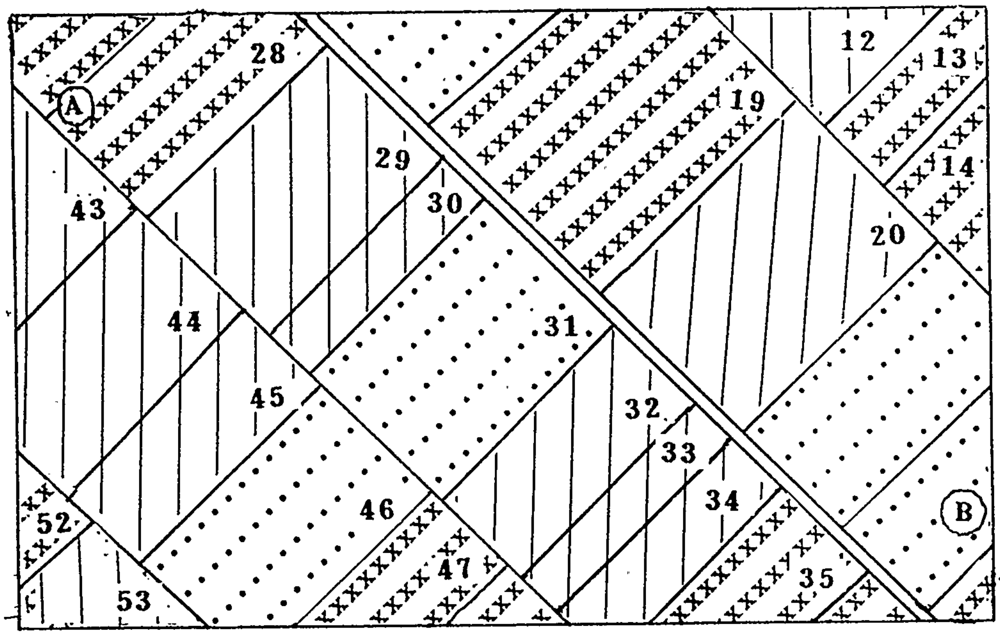


N
1ST STREET
CRAB APPLE LANE
MAIN STREET
BLUEBERRY HILL
3RD STREET
4TH STREET

MAP #2



MAP #3

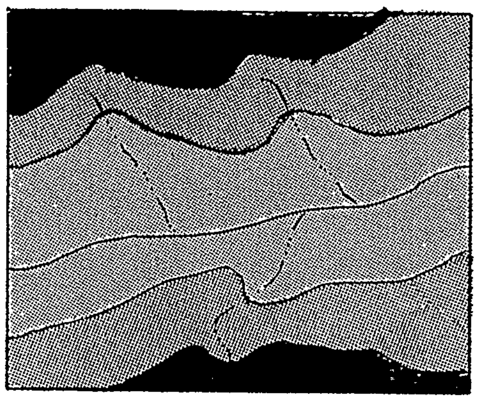


LEGEND

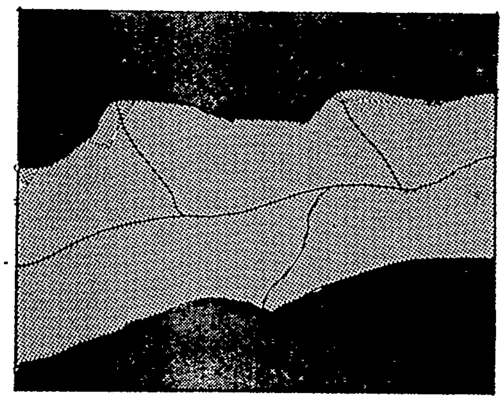
WHEAT
CORN
ALFALFA

SCALE: 0 1 2 km

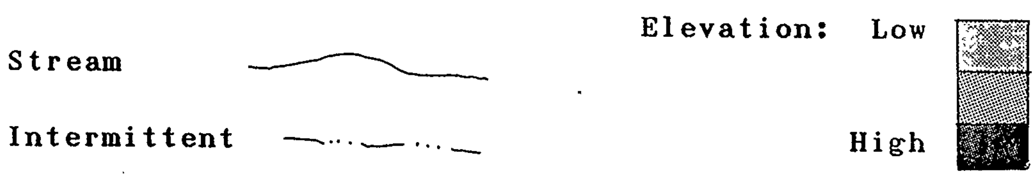
Map #4



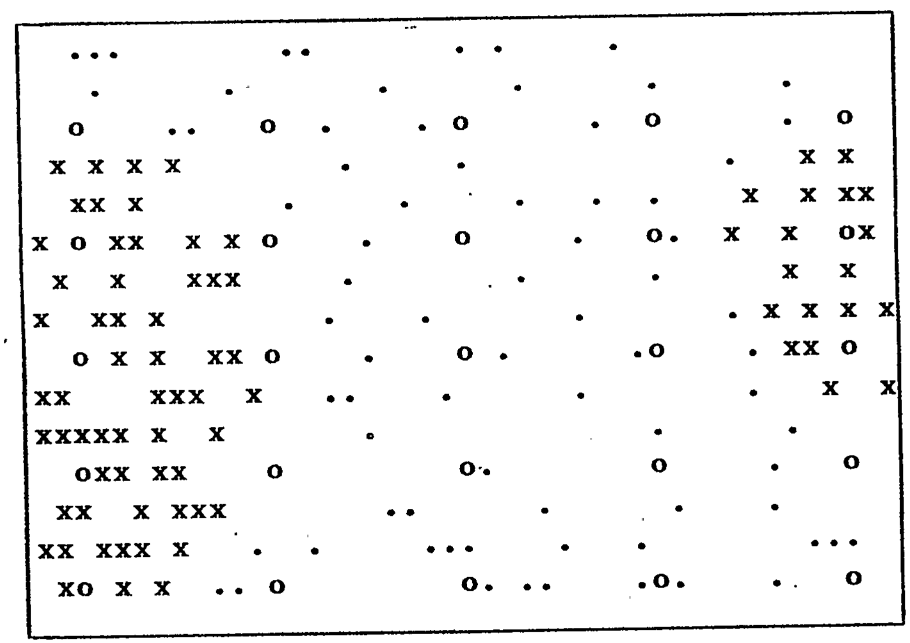
Map #5



LEGEND



MAP #6



BIRCH •

SPRUCE x

MAPLE o

APPENDIX C: Statements used as an introduction to the dynamic map. These statements were provided to respondents working with the conventional map also.

WHAT FOLLOWS IS A DYNAMIC MAP SHOWING THE MOVEMENTS OF 3 BLACK BEARS IN BANFF NATIONAL PARK DURING THE SUMMER OF 1988.

KOOTENAY IS A MALE. HIS HOME RANGE OF 1988 IS SHOWN COMPLETELY ON THIS MAP.

SUNSHINE IS A FEMALE WITH CUBS. HER HOME RANGE WAS PARTIALLY OUTSIDE OF THE AREA INCLUDED ON THIS MAP.

SLUDGE IS ALSO A FEMALE WITH CUBS. HER HOME RANGE WAS ALMOST HALF OUTSIDE THE AREA INCLUDED ON THIS MAP.

THE SUMMER HAS BEEN DIVIDED INTO 4 SEASONS FOR THE BEARS, BASED ON THEIR PRIMARY FOOD PREFERENCES AT A GIVEN TIME.

SEASON #1 - IS THE GREENUP PERIOD

SEASON #2 - IS THE ANT SEASON

SEASON #3 - IS THE BUFFALOBERRY SEASON

SEASON #4 - IS THE POST-BUFFALOBERRY SEASON

BEAR MOVEMENTS WILL BE SHOWN BY THE CONSTRUCTION OF A CONTINUOUS LINE, LINKING CONSECUTIVE POSITIONS. AS THE LOCATION OF THE BEARS CHANGE, THE 1988 CALENDAR DATE WILL COUNT UPWARDS.

THE MAP COMMENCES MAY 1^{ST}. FALL DATA IS AVAILABLE UNTIL OCTOBER 30^{TH}. THIS DATE MARKS THE END OF THE MAP.

APPENDIX D: Summaries of the Responses to the Questionnaire, From the Subjects Using the Conventional Map, and the Subjects Using the Dynamic Map.

CONVENTIONAL: SUMMARY OF ANSWERS TO MAP READING SKILL QUESTIONS

X Indicates an incorrect or blank response.

QUESTION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
		X				X										13
			X				X									13
									X							14
	X	X				X				X				X	X	9
(5)						X				X						13
						X			X					X		12
		X				X										13
										X						14
						X			X	X	X			X		10
(10)	X	X				X					X			X	X	9
						X			X	X					X	11
		X							X							13
																15
								X	X							13
(15)						X				X						13
	X	X				X	X		X							10
		X				X	X		X						X	10
																15
							X									14
(20)		X	X						X							12
		X	X	X		X			X		X	X			X	7
	X	X			X										X	11
	X	X					X									12
	X	X														13
(25)							X		X							13
									X							14
	X															14
																15
	X															14
(30)															X	14
		X							X	X	X	X				10
																15
	X		X	X					X	X					X	9
			X							X		X		X		11
Times Incorrect	9	13	5	2	1	12	6	1	14	9	4	3	0	5	8	

Average Score 12.3

DYNAMIC: SUMMARY OF ANSWERS TO MAP READING SKILL QUESTIONS

X Indicates an incorrect or blank response.

QUESTION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
		X				X			X	X						11
		X									X	X				12
			X				X									13
			X				X		X	X				X	X	9
(05)						X		X		X				X	X	10
														X		14
		X							X	X				X		11
			X			X			X	X					X	10
																15
(10)									X	X						13
				X					X							13
		X		X						X					X	11
		X	X	X			X	X							X	9
	X					X										13
(15)	X	X				X									X	11
						X										14
							X		X	X						12
		X							X							13
				X										X		13
(20)							X									14
																15
		X		X		X									X	11
		X														14
	X													X		13
(25)																15
						X			X	X	X					11
				X						X					X	12
		X		X		X				X				X	X	9
		X		X					X						X	11
(30)	X	X	X	X		X				X	X	X		X	X	5
										X						14
			X	X			X			X						11
Times Incorrect	4	12	6	10	0	10	6	2	10	14	3	2	0	8	11	

Average Score 11.9

CONVENTIONAL: SUMMARY OF ANSWERS TO TEST MAP QUESTIONS

By Respondent

QUESTION	1	2	4a	4b	5	6	9	10	11	12	13	14	15
	67	Y	N	N	Y	N	D	B	Y	N	N	?	A
	110	Y	?	?	Y	?	D	B	Y	Y	?	?	E
	60	Y	?	?	Y	?	D	D	?	N	Y	?	E
	170	?	?	?	Y	Y	C	D	Y	Y	N	?	E
(5)	110	Y	?	Y	Y	Y	C	B	Y	Y	?	?	E
	45	N	N	N	Y	N	B	B	Y	na	Y	Sim	E
	60	Y	?	?	na	N	B	A	Y	N	N	?	E
	55	Y	?	N	Y	?	A	B	?	na	Y	?	D
	60	N	?	Y	na	Y	A	C	Y	N	N	?	B
(10)	26	Y	N	Y	Y	?	C	C	Y	N	Y	?	E
	118	Y	N	Y	Y	Y	A	C	Y	Y	Y	?	C
	85	Y	?	N	Y	?	B	B	?	Y	Y	Sim	D
	91	Y	?	N	Y	N	A	C	Y	Y	Y	Sim	C
	74	Y	N	N	Y	?	C	C	Y	N	Y	?	E
(15)	123	Y	N	N	Y	Y	D	D	Y	Y	Y	?	E
	57	?	?	na	na	Y	D	C	Y	Y	?	Alt	D
	289	Y	?	?	Y	?	C	D	Y	Y	Y	Alt	C
	306	Y	N	Y	Y	Y	A	A	Y	Y	Y	Sim	C
	306	Y	N	Y	Y	N	D	D	Y	Y	Y	Sim	C
(20)	53	N	Y	Y	Y	N	B	B	Y	Y	Y	Alt	D
	na	Y	Y	Y	Y	Y	B	A	Y	Y	N	Alt	C
	80	Y	?	N	Y	?	D	D	N	Y	Y	Sim	D
	76	Y	N	N	Y	N	C	B	Y	Y	?	?	B
	75	Y	N	N	Y	Y	C	B	Y	Y	Y	Alt	A
(25)	100	Y	?	N	Y	?	C	D	?	Y	Y	Alt	E
	175	Y	?	N	Y	?	C	C	Y	Y	?	Sim	E
	100	Y	?	N	Y	Y	C	C	Y	Y	Y	?	A
	100	Y	?	Y	Y	Y	C	C	Y	Y	Y	Sim	B
	100	Y	?	Y	Y	Y	C	C	Y	Y	Y	Sim	B
(30)	200	Y	?	?	Y	Y	A	A	N	Y	N	na	E
	66	Y	?	N	Y	Y	C	C	Y	N	Y	?	E
	68	Y	?	?	Y	Y	D	B	Y	Y	Y	?	E
	204	Y	?	?	Y	Y	C	C	Y	Y	Y	Sim	E
	142	Y	?	?	?	?	na	na	Y	Y	Y	Alt	na

Question 1: Average: 113.7 km^2
Standard Deviation: 73.7

DYNAMIC: SUMMARY OF ANSWERS TO THE TEST MAP QUESTIONS

By Respondent

QUESTION	1	2	4a	4b	5	6	9	10	11	12	13	14	15
	na	Y	N	?	Y	Y	C	C	Y	N	Y	Sim	B
	30	Y	N	N	Y	N	C	C	Y	Y	Y	Sim	C
	200	Y	N	?	Y	?	D	D	Y	Y	Y	Sim	C
	524	Y	N	N	Y	Y	C	A	N	Y	?	Sim	B
(05)	na	Y	Y	?	Y	Y	na	A	Y	Y	?	?	A
	518	Y	N	N	Y	N	C	C	?	Y	na	Tend 1	C
	na	Y	N	N	Y	?	C	D	Y	N	Y	Sim	A
	225	Y	N	N	Y	Y	D	C	?	Y	Y	Sim	B
	na	Y	N	N	Y	N	A	D	Y	N	Y	Sim	E
(10)	50	Y	N	N	Y	Y	C	B	Y	Y	?	Sim	A
	567	Y	N	N	Y	Y	C	C	Y	Y	Y	Both	C
	100	Y	N	Y	Y	Y	A	C	Y	Y	?	Sim	D
	100	Y	N	Y	Y	Y	A	C	Y	Y	?	Sim	D
	90	Y	Y	na	Y	Y	C	B	Y	Y	N	Alt	B
(15)	70	Y	N	N	Y	Y	C	A	N	Y	?	Sim	C
	108	Y	?	?	Y	Y	A	C	Y	Y	Y	Sim	D
	50	Y	Y	?	Y	N	A	C	?	Y	?	Sim	E
	616	Y	Y	na	Y	Y	C	na	Y	Y	?	Sim	A
	110	?	N	N	Y	Y	C	C	?	Y	Y	Sim	C
(20)	150	Y	N	Y	Y	Y	C	C	?	Y	Y	Sim	C
	40	Y	N	N	Y	Y	C	C	Y	Y	Y	Tend 1	B
	16	Y	N	N	Y	Y	C	C	N	Y	Y	Sim	A
	60	Y	N	N	Y	Y	C	C	Y	Y	N	Tend 1	A
	162	Y	N	N	Y	Y	C	C	Y	Y	Y	Sim	B
(25)	128	Y	N	N	Y	Y	C	C	?	N	Y	Both	A
	150	Y	N	N	Y	Y	C	C	Y	Y	Y	Tend 1	B
	20	Y	Y	N	Y	Y	A	C	N	Y	?	Sim	B
	22	Y	Y	Y	Y	Y	C	C	?	Y	?	Sim	B
	25	Y	Y	N	Y	Y	A	C	N	Y	?	Sim	C
(30)	na	?	?	?	Y	Y	D	A	N	Y	?	Sim	B
	na	Y	N	na	Y	Y	B	D	na	Y	?	Alt	E
	35	Y	N	na	Y	Y	D	D	Y	N	?	Alt	E

Question 1: Average: 160.2 km^2
Standard Deviation: 181.7