Cumulative effects modeling for grizzly bears in the Greater Yellowstone Ecosystem
by Beverly Gail Dixon

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University
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Abstract:
The Cumulative Effects Model (CEM) is a computer package designed to facilitate the evaluation of human impacts upon grizzly bear habitat. Although there are various versions of the CEM currently utilized in different geographic locations, this document will deal specifically with the model developed for the Greater Yellowstone Ecosystem (GYE). The purpose of this thesis is to document the development of the GYE CEM; a process which has spanned the time period from 1983 to present. This thesis will address the purpose and need for the CEM, its history and evolution, and the people involved with development of the model. The database upon which the model runs will be described in detail, including discussions of data collection methodologies and database maintenance. An explanation of the conceptual model will be presented, including descriptions of the coefficients and formulas that drive the computer model. Finally, future development needs will be evaluated. The intended audience for this thesis includes resource managers in the GYE, agency biologists and modelers, and interested members of the general public and scientific community.

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Beverly Gail Dixon

A thesis submitted in partial fulfillment
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of

Master of Science

in

Fish and Wildlife Management

MONTANA STATE UNIVERSITY — BOZEMAN
Bozeman, Montana

December 1997

N378
D6433

APPROVAL

of a thesis submitted by

Beverly Gail Dixon

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

Harold D. Picton _____ (Signature) 12/3/97 Date

Approved for the Department of Biology

Ernest R. Vyse _____ (Signature) 12/3/97 Date

Approved for the College of Graduate Studies

Joseph J. Fedock _____ (Signature) 12/4/97 Date

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Signature Beverly G. Dixon

Date December 3, 1997

ACKNOWLEDGEMENTS

This thesis was reviewed by those individuals whom I consider to be the leading experts in grizzly bear cumulative effects issues in the Greater Yellowstone Ecosystem and beyond. I owe thanks to Dave Mattson, Collin Bevins, Roy Renkin, Kim Barber, Rodd Richardson, Tom Puchlerz, Don Despain and Jay Gore for reviewing this thesis and making it a better product with their comments and suggestions. I am grateful to the Yellowstone Modeling Team for their input and support of this documentation effort.

I'd like to thank Marion Cherry, Rich Inman and Dave Garber of the Gallatin National Forest for advocating this document as a benefit to the agencies involved in grizzly bear management. I appreciate Pattie Soucek of the Bozeman Ranger District office for allowing me the flexibility to arrange my busy work schedule around the writing of this thesis. In addition, I'm grateful to Wendi Urie of the Bozeman Ranger District, and Ralene Maw of the Forest Service Regional Office in Utah for lending their expert GIS assistance in the preparation of many graphics included in this document.

I'd like to thank my graduate committee of Dr. Harold Picton, Dr. Robert Moore, Dr. Andy Hansen and Dr. Tom McMahon for approving this project, for insisting on quality work and for teaching me many new things over the past few years. Last, but not least, I want to convey my heartfelt thanks to my family and friends who have always been there for me and have expressed genuine interest and pride in my work. I especially want to thank my husband and best friend, Randy Wold, for providing emotional support, reviewing my thesis, and devoting many hours as my personal computer wizard, particularly in the creation of graphics.

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ABSTRACT

The Cumulative Effects Model (CEM) is a computer package designed to facilitate the evaluation of human impacts upon grizzly bear habitat. Although there are various versions of the CEM currently utilized in different geographic locations, this document will deal specifically with the model developed for the Greater Yellowstone Ecosystem (GYE). The purpose of this thesis is to document the development of the GYE CEM; a process which has spanned the time period from 1983 to present. This thesis will address the purpose and need for the CEM, its history and evolution, and the people involved with development of the model. The database upon which the model runs will be described in detail, including discussions of data collection methodologies and database maintenance. An explanation of the conceptual model will be presented, including descriptions of the coefficients and formulas that drive the computer model. Finally, future development needs will be evaluated. The intended audience for this thesis includes resource managers in the GYE, agency biologists and modelers, and interested members of the general public and scientific community.

CHAPTER 1

INTRODUCTION

Why Model?

Wildlife managers often must make critical decisions based on limited information. Increasing interest in natural resources has elevated the scrutiny of management decisions by both the general public and the scientific community. Wildlife managers are responsible for extremely complex systems and are held accountable for their decisions. In this situation, the question becomes not whether to model, but how to model information in a way that will be most efficient and useful (Starfield 1997).

A model is basically an abstraction used to represent a process or system. Models are generally designed as analytical tools that help us to understand the mechanisms which drive the processes or systems of interest. They help us to define and understand the problem at hand and to organize our thought processes with regard to the problem as defined. Modeling may allow us to better understand the data that are available and identify additional data required to address the problem. Models may facilitate the simulation of natural processes so that we can make predictions and projections on which to base our management decisions (Starfield and Bleloch 1986).

Simulation is one of the key functions of models. With this property, we can ask "what if..." questions and examine the potential consequences. This capability not only makes modeling more efficient than trial and error, but also allows us to avoid risking potentially devastating effects of our actions. Richard Dawkins (1989) wrote, "No amount of simulation can predict exactly what will happen in reality, but a good simulation is enormously preferable to blind trial and error." Let us turn now to a discussion of one particular natural process simulation model, the Greater Yellowstone Grizzly Bear Cumulative Effects Model.

The term "Cumulative Effects Model" (CEM) as used in this document, generally refers to the computerized modeling technology designed to facilitate the assessment of human impacts upon grizzly bears (*Ursus arctos*) and their habitat. Various versions of a CEM have evolved in different geographic locations. Although these concurrent efforts will be addressed occasionally to provide context, this document will focus primarily on the design, development and use of the CEM and associated database for the Greater Yellowstone Ecosystem (GYE).

The GYE encompasses an area of approximately 6 million acres, primarily of federal lands administered by the United States Forest Service and the National Park Service. The GYE grizzly bear recovery zone includes parts of the Beaverhead, Gallatin, Custer, Shoshone, Bridger-Teton, and Targhee National Forests, as well as Yellowstone and Grand Teton National Parks. (See Figure 1).

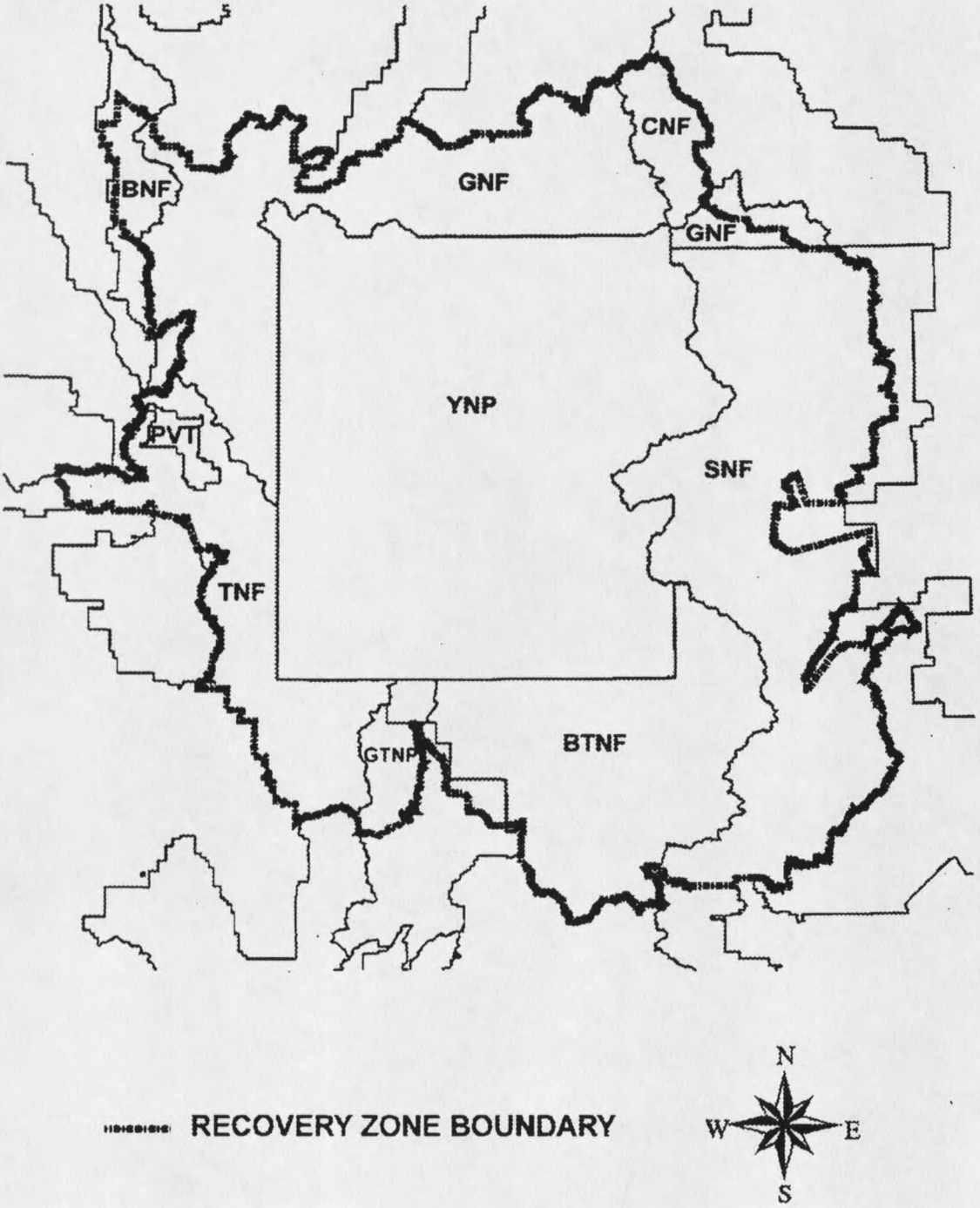

Figure 1: GYE Grizzly Bear Recovery Zone with administrative boundaries for the Beaverhead (BNF), Gallatin (GNF), Custer (CNF), Shoshone (SNF), Bridger-Teton (BTNF) and Targhee (TNF) National Forests, Yellowstone (YNP) and Grand Teton (GTNP) National Parks and private (PVT) land.

Purpose and Need

Activities of natural resource management agencies are governed by a suite of laws, regulations and policies. The development of the GYE CEM was initiated at least partly in response to such legal requirements. In the lower 48 United States, the grizzly bear is listed as a threatened species under the Endangered Species Act (ESA 1973). Legislation mandates that the effects of actions and an analysis of any cumulative effects of land uses and management activities be evaluated as part of the biological assessment process for listed species. The National Forest Management Act requires that the US Forest Service maintain sufficient habitat to sustain viable populations of native species (NFMA 1976). The National Environmental Policy Act requires an assessment of the cumulative impacts of human activities upon the environment (NEPA 1969). With respect to grizzly bear habitat modeling, cumulative effects has generally been described as "the combined effect upon a species or its habitat caused by the activity or program at hand, as well as other reasonably foreseeable events which are likely to have similar effects upon that species or its habitat. Cumulative effects can result from individually minor but collectively significant events taking place over a period of time" (USDA 1985).

Historically, analyses of cumulative effects have occurred at the individual project level and have been limited to the immediate project area. The problem with this strategy for assessing the cumulative impacts of human activities on grizzly bears, is that the grizzly is a wide-ranging animal with home ranges that can exceed 965 square miles (Weaver, et al. 1985). Also, the legal mandate for cumulative effects assessment requires

consideration of the potential for collective human activities to produce an adverse effect on survival of a *population*. By this standard, the impacts from individual projects, even including cumulative impacts within the immediate project area, will rarely be determined to produce a negative effect on the entire grizzly bear population. However, if viewed collectively, the accumulation of a multitude of individual projects and activities could threaten the viability of the population (Mattson 1993a). The CEM provides managers with a tool to quantitatively and qualitatively assess human impacts over a broad spatial scale that has biological relevance to the grizzly bear population in the GYE.

Background and History

Early attempts at modeling the effects of human activities on grizzly bear populations were pioneered on the Flathead and Kootenai National Forests in the Selkirk and Cabinet-Yaak ecosystems of northwest Montana in the early 1980s (Christensen and Madel 1982). This process involved mapping human activities on mylar overlays, then using these overlays to position and schedule events so as to minimize the spatial and temporal overlap of human activities within grizzly bear habitat. Although this effort gave us a new perspective for assessing effects of human activities on grizzly bears, the manual manipulation of geographic information on mylar overlays was cumbersome and time consuming (Weaver et al. 1985).

In January 1984 the Yellowstone Ecosystem Grizzly Bear Subcommittee appointed an Ad Hoc Work Group to "define the goals, objectives and scope of work" associated with the cumulative effects assessment process for grizzly bear habitat within

the GYE. Members of this group included Forest Supervisors of the Gallatin, Targhee and Shoshone National Forests, Superintendent of Yellowstone National Park and a representative of the US Fish and Wildlife Service (USDA 1984).

As directed, this work group produced the stated goal of: "Develop methodology to quantitatively and qualitatively assess the cumulative effects of human activity on grizzly bear habitat and bear use of that habitat in the Yellowstone Ecosystem." Objectives were listed as:

1. Evaluate the current methodology of cumulative impact assessment developed for the Kootenai and Lewis and Clark National Forests.
2. Develop a habitat component mapping system for the Yellowstone Ecosystem following review of IGBST/NPS data.
3. Develop a list of assumptions.
4. Collate, evaluate, and provide criteria of determining the influence zone of human activity, related to bear behavior.
5. Develop a rating system to qualitatively and quantitatively display relative influences of various human activities.
6. Determine the quantitative and qualitative thresholds for habitat availability, both spatially and seasonally, that are necessary to meet bear management objectives.
7. Develop criteria for describing Bear Management Units (USDA 1984).

With goals and objectives established, the work group appointed a task force to conduct an initial scoping of the GYE agencies regarding development of the CEM. After several workshops and brainstorming sessions, a small technical committee was

appointed to develop the conceptual model (Puchlerz 1984). The technical committee expanded upon earlier cumulative effects modeling efforts to develop a methodology to quantify the spatial and temporal impacts of human activities on grizzly bears and their habitat. Due to the large size of the Yellowstone grizzly bear ecosystem and the complex nature of human activities within this ecosystem, it was recognized that computer implementation would be necessary to efficiently manage the required data, and thus spawned the CEM (USDA 1985).

A first draft of the Cumulative Effects Analysis Process for the Yellowstone Ecosystem (hereafter referred to as the "Blue Book") was released for review in October 1984. This document described the conceptual framework, assumptions, equations and coefficients associated with the GYE CEM. Copies of the manual were sent out for review to Forest Supervisors of the GYE National Forests, Montana Fish Wildlife and Parks Department, Yellowstone National Park, Plum Creek Timber Company, US Fish and Wildlife Service Grizzly Bear Recovery Coordinator, Forest Service Regions 1, 2 and 4, Intermountain Forest and Range Experiment Station, Interagency Grizzly Bear Study Team, University of Montana, Wyoming Game and Fish Department, and Idaho Fish and Game Department. Responses were requested by November 30, 1984 (Breazeale 1984).

Responses were received from the majority of reviewers. A meeting was held in January 1985 at which the "Blue Book" was again reviewed. Comments received were analyzed and incorporated into a revision of the document. Another draft of the "Blue Book" was sent out to the same mailing list for use and further review in June 1985 (undated memo to FS files).

Using the "Blue Book" as a guide, the first version of the CEM was programmed in 1984 and 1985 by Kim Barber and Dave Winn, Forest Service personnel of the Regional Office in Ogden, Utah (Winn and Barber 1985). This prototype was used to assess the impacts on grizzly bears for large-scale and very controversial projects such as the Ski Yellowstone resort proposed on Gallatin National Forest land near West Yellowstone, Montana (Grotzinger 1987), the renovation of Fishing Bridge campground in Yellowstone National Park (USDI 1988) and an evaluation of Management Area 9 on the Targhee National Forest (USDA 1988).

These first attempts at using the CEM were somewhat frustrating, as the model was very complex and run-time for a single analysis could take several days. Nevertheless, these pioneering efforts were viewed positively as they allowed biologists to quantify the impacts from a multitude of human activities over large areas of land in a relatively expeditious manner. The same process would have taken much longer if attempted without the aid of computer processing. Also, these first efforts would lend great insight for future evolution of the CEM.

The original CEM (1985) used the Map Overlay Statistical System (MOSS), one of the first Geographic Information Systems (GIS), to process the data and algorithms developed for the GYE. Although MOSS was very powerful software and considered "state of the art" at the time, the first CEM was slow and cumbersome and could monopolize significant amounts of time on a main-frame computer, often to the detriment of other users. Also, MOSS was the GIS used nationally by the Forest Service, but other agencies involved in grizzly bear management in the GYE were typically using other GIS

packages such as GRASS, ERDAS and ArcInfo. These factors sparked the first serious revision of the model.

In 1987 the technical committee was called together at the request of the Yellowstone Ecosystem Grizzly Bear Subcommittee to review the cumulative effects analysis process and the current version of the CEM to "evaluate the need for further development, revision, or complete overhaul." This review resulted in a recommendation to the Subcommittee to re-program the CEM from scratch in order to circumvent the complications associated with MOSS software (Puchlerz and Weaver 1987).

John Weaver, National Grizzly Bear Habitat Coordinator for the Forest Service at the time, took on the first revision of the CEM in 1987. Upon the advice of the technical committee, he elected to pursue an independent contractor for the task to increase ownership of the CEM process among all involved parties, and to avoid complications associated with turnover of agency personnel. The project was awarded to Collin Bevins of Systems for Environmental Management (SEM) in Missoula, Montana. The new version of the model (CEM2) would still rely on MOSS for map display purposes, but not for the actual model processing and calculation of numerical outputs (Bevins 1988). CEM2 was used to evaluate the impacts of various timber harvest proposals on the Gallatin, Targhee and Bridger-Teton National Forests.

The new version improved upon the original CEM in several ways. It employed a menu-driven interface, thereby reducing the complexity of the model operation. CEM2 was capable of processing an entire Grizzly Bear Management Unit (BMU) at one time whereas the original version was limited to processing single quads of data at a time. The

new version employed a more efficient mechanism for calculating the zone of influence around activities, and was capable of measuring the effects of overlapping zones of influence. CEM2 provided a means for storing the results of each analysis and producing comparative reports (Bevins 1988). However, the processing of an analysis using CEM2 still made considerable time demands on a main-frame computer. Also, the newer version was configured for the Data General computer system, the standard used by the Forest Service, but not generally available to the sister agencies.

The next major revision of the CEM was initiated in 1988 with the appointment of a new Forest Service Grizzly Bear Habitat Coordinator, Rodd Richardson. This effort would emphasize two major considerations for the next version of the model. First, the CEM would be made more compatible among all agencies in the GYE by converting to a personal computer (PC) platform. The second consideration reached beyond the GYE to include other grizzly bear ecosystems in the conterminous United States and the models being used to assess human impacts in those areas.

By this time, CEMs were being developed in the Greater Yellowstone Ecosystem (GYE), the Northern Continental Divide Ecosystem (NCDE) and the Selkirk and Cabinet-Yaak (S/CY) ecosystems. All of these drew on the basic concepts developed early on in northwest Montana and the GYE, but beyond that there was little coordination of the cumulative effects modeling efforts between these ecosystems. Many of the original modeling teams and task forces had dissolved due to personnel turnover. It was recognized that, other than for ecologically-based differences between the ecosystems, there was a need for more consistency in the modeling efforts.

A comparison between models was conducted by Forest Service personnel in 1986. This work indicated that the objectives and basic model design were similar between ecosystems, but that biological differences and disparate data availability among the ecosystems necessitated variation in specific model design. The most notable differences between the models occurred between the GYE and the northern ecosystems. (Escano 1986). Subsequent efforts were made by the USFS National Grizzly Bear Habitat Coordinator at that time, to coordinate modeling efforts between the ecosystems with the purpose of standardizing basic model structure, terminology and outputs (Weaver 1987). However, results of these efforts are not well documented.

In January 1989, official modeling teams were re-established for the various grizzly bear ecosystems and team leaders were designated. Team leaders met periodically to review the existing grizzly bear models and develop strategies for standardizing grizzly bear CEMs across all ecosystems. As Team Leader for the GYE modeling team, I conducted a comprehensive model comparison in March 1989. This effort resulted in a report on model attributes such as analysis units, seasons, submodels, outputs, habitat/displacement/mortality variables, activity groups and definitions, zones of influence, and application of disturbance and mortality coefficients (Dixon 1989).

This model comparison provided a starting point for modeling teams to standardize CEMs across grizzly bear ecosystems. Differences based on ecological variation between grizzly bear populations, and/or data availability among the ecosystems were identified and documented as such. All other model variations were standardized for all ecosystems and the resulting conceptual CEM was referred to as the "Unified Model".

A document describing the Unified Model titled CEM - A Model for Assessing Effects on Grizzly Bears (hereafter referred to as the "Green Book") was prepared. The first draft of this document was released for review by modeling teams in June 1989. Comments received were incorporated, the document was revised, and a second draft was released in December 1989. Further comments were received, the document was again revised, and the final was released in April 1990 (USDA 1990).

The Unified Model was programmed for PCs, with the contract again awarded to SEM in Missoula, Montana. Although some major programming changes have since been made, the standardized parameters established for the Unified Model are currently in use with the GYE CEM. Specific model design and associated parameters will be discussed later in this document.

The PC version of the Unified CEM was much more efficient in terms of processing and run-time. As most users had a dedicated machine for the CEM, the impact on other users was eliminated. Run-time for a typical analysis was reduced from a matter of days to a matter of hours. The new version was converted to a command-driven system to provide a wider range of options to model users.

At the time of this version's development there was an on-going philosophical debate about what constituted a true cumulative effects analysis versus an incremental effects assessment. In general, those most familiar with the CEM felt that it did an admirable job of quantifying the collective effects of activities at a large scale, but that the lack of a specific tie to grizzly bear demographics made the CEM fall short of a true cumulative effects analysis. Thus, the programmer (C. Bevins) bestowed upon this

version of the software a new acronym of "ICE" - which stands for "incremental cumulative effects".

The initial version of the ICE Tool Kit was made available to users in April 1991. This software package provided CEM users with multiple options for analyzing land management alternatives and displaying both numeric and graphic results (Bevins 1991). Numeric outputs were displayed in tabular form and graphic outputs (maps) were formatted so that they could be displayed with any of the various GIS technologies currently employed by the GYE agencies. The PC platform for the ICE software greatly expanded the availability to users across the GYE. Also, the ICE software was eventually ported to a UNIX platform which further improved the performance of the CEM in a more powerful workstation environment. This version of the CEM was used to assess impacts of the New World Mine project on the Gallatin National Forest, as well as to evaluate multiple land management scenarios proposed under the Forest Plan revision on the Targhee National Forest (USDA 1997).

ICE software was also tested on portions of Yellowstone Park data to compare outputs with results of previous CEM versions. A ten-fold difference in the habitat value scores for a given area was observed between model versions. This difference in habitat value was at least partially attributed to the fact that ICE software accumulations were on a 5-acre cell basis whereas previous model versions calculated habitat value on a per acre basis. Although the absolute habitat value scores differed dramatically, the relative ranking of various areas reviewed remained similar (Renkin pers. comm.)

The first version of the ICE software (ICE6) was developed to interact with ORACLE, a relational database management system. This interface was a contract requirement imposed by the Forest Service as ORACLE was the database manager used by that agency. Although the ICE6 software ran much faster than previous versions of the CEM, it still took several hours to run a typical analysis. Most of this time consumption was attributed to the tie with ORACLE. Collin Bevins proposed a much more efficient model in terms of both time and space requirements by the elimination of the ORACLE connection. The Yellowstone modeling team was in favor of such a revision, but could not secure adequate funding to proceed.

The complexity associated with data preparation and running the model limited the use of CEM to a few individuals throughout the GYE. Due to this lack of CEM skill, in 1996 SEM was awarded another contract to run a large part of the GYE through the ICE6 version of the CEM. In order to facilitate this work, Bevins re-programmed the ICE6 software to eliminate the use of ORACLE, using simple "flat" files for data management instead. The revised software package was dubbed "ICE9". This latest version of the CEM resulted in a major reduction in time and space requirements for the model. Run time for a typical analysis using ICE9 software was reduced to usually less than ten minutes.

With the ICE9 software already developed, SEM offered to provide it to the agencies at a much reduced cost than had been discussed prior to its development. At first only the Gallatin and Targhee National Forests acquired the ICE9 software in order to expedite on-going CEM analyses. By early 1997 ICE9 was revised slightly and

purchased for all major user groups in the GYE. ICE9 is the CEM software currently in place and in use in the GYE.

Over the years of development the CEM conceptual design as well as the computer model were presented at conferences and symposia on grizzly bears, habitat modeling, ecosystem management, and various other topics. This model is widely known nationally and internationally. In the early 1990s representatives of ESRI Corporation, parent company of ArcInfo GIS technology, approached Larry Warren of the Brider-Teton National Forest (GIS advisor to the Yellowstone modeling team) about the CEM. The ESRI people were curious as to why the model (being primarily based on geographic information) was not programmed directly with a GIS. Difficulties of the modeling experiences with MOSS were explained, as well as complexities of the CEM that the modeling team felt would limit the effectiveness of direct programming with a GIS; e.g. multiple attributes for individual map features and daily scheduling of activities.

The ESRI people were very intrigued with the CEM and offered to program it using ArcInfo at no cost to the agencies, although ESRI would retain the rights to distribute the end product to other consumers. This proposal was presented to the modeling team, and it was agreed to allow ESRI to proceed with Larry Warren acting as the agency liaison for the project. As with most projects of this complexity level, workload was underestimated for the "no cost to the government" version and a contract for the project was eventually awarded to ESRI. A prototype of the ArcInfo version was presented to the modeling team in June 1996.

The original contract agreement with ESRI was to port the ICE6 version of the CEM into ArcInfo. As of October 1997, these obligations have been met. However, some programming errors were discovered in the ICE6 software that have since been corrected in the ICE9 programs but not in the ArcInfo version. These problems have been identified and can be rectified in the ArcInfo programs, but current efforts are focused on ICE9 software and there are no plans to pursue further development of the CEM in ArcInfo at this time (Warren pers. comm.)

Intended/Appropriate Uses

Examples of model uses up to this point reflect that the majority of CEM applications had been to evaluate projects. This situation was attributable to the urgent need for a project-level analysis tool coupled with extensive time and personnel requirements for completion of an ecosystem-wide database. There has always been some concern as to whether the database and coefficients used with the CEM reflect the level of accuracy necessary to evaluate impacts at a site-specific project level. Although the GYE CEM database is believed to be one of the most comprehensive in the world for a project of this magnitude, it nevertheless was produced largely by extrapolation and approximation. Also, coefficients used in model calculations are based on estimates of average grizzly bear responses to habitat and human activities across the entire GYE.

At a modeling team meeting in December 1996, Richard Knight, Team Leader of the Interagency Grizzly Bear Study Team (IGBST) for over 20 years in Yellowstone, indicated that his recollection of the original intent of the CEM was to monitor GYE-wide

human activity levels and resulting effects to grizzly bear populations. He pointed out that it was never intended for use at the project level, and that the GYE was initially broken down into smaller units (BMUs and Subunits) in response to hardware/software limitations. However, development of the model was initiated at least partly in response to the legal requirements to assess the cumulative effects of projects proposed in grizzly bear habitat. Indeed, two of the main documents describing the GYE CEM make reference to use of the model for assessing impacts of individual activities.

The first comprehensive documentation of the GYE conceptual model titled Cumulative Effects Analysis Process for the Yellowstone Ecosystem (aka the "Blue Book") states that "The ... (CEM) is designed to: 1) Quantify *individual* and collective effects of land uses and activities in space and through time, and 2) Provide managers an analytic tool for evaluating *alternative decisions* relative to grizzly bear recovery goals and objectives" (*emphasis* added) (USDA 1985). The next article produced to describe the "Unified" CEM, titled CEM - A Model for Assessing Effects on Grizzly Bears (aka the "Green Book") states that "The CEM ... complements other analyses performed at the *project level* and is used in conjunction with this information to *compare project alternatives...*" (*emphasis* added) (USDA 1990).

These statements were not intentionally misleading. Managers and field biologists alike were desperately in need of a tool for evaluating cumulative impacts associated with individual projects, and at the inception, many of the developers behind the CEM believed that this model could provide the tool. However, experience has taught us that using the model for specific project assessments can set a dangerous precedent. As mentioned

above, using the CEM to quantify the effects of a given project at a scale that is biologically meaningful to the bear will almost always show that the additional or *incremental* impact of any given project will be negligible. The important factor to address is the *overall* reduction in habitat effectiveness at the landscape scale, considering *all* on-going activities.

In May 1991, the USFS Grizzly Bear Habitat Coordinator (Rodd Richardson) established a protocol for interim use of the CEM relative to specific projects. This direction basically stated that for project analyses the CEM would be run concurrent with an *independent* biological assessment. Results from the two efforts could then be compared to evaluate how well model outputs reflected the intuitive conclusions drawn by the project biologist. This protocol was established in recognition of the model's limitations, but also as an indication that it could be useful at the project level for simulation of activity placement and scheduling, simulation of mitigation measures designed to benefit those bears affected by the project, and as a record keeping and monitoring tool to keep track of incremental change.

It is important to note that the CEM as currently designed has the *capability* to quantify impacts of multiple human activities at any scale, but model outputs cannot be interpreted to reflect direct impacts on individual bears. It is the data and coefficients driving the model that lack the accuracy necessary to adequately assess project-level impacts. In order to use CEM in this manner, we would have to field-verify a much greater proportion of the habitat and activities mapping (an exhaustive task for an area of approximately 6 million acres) and we would have to know *specifically* how bears utilize a

given area, and *exactly* how particular human activities are likely to affect the bears using that area.

Given these considerations, in October 1996 the modeling team attempted to produce a statement of appropriate use for the CEM and came up with the following: "CEM is a tool for estimating the habitat value and habitat effectiveness for the grizzly bear in the Yellowstone Recovery Zone and to monitor fluctuations in these values due to vegetative changes and disturbance from human activities at the Bear Management Unit or Subunit level" (Barber 1996).

The Yellowstone Modeling Team

The Yellowstone Modeling Team (YMT) is a group of biologists and GIS/computer specialists that are responsible for the development, oversight and implementation of the GYE CEM and associated database. The original modeling team was the technical committee established in 1984. This team consisted of T. Puchlerz (Chairman) - Gallatin National Forest, plus representatives of the Bridger-Teton National Forest, USFS Regions 1 and 4, IGBST andYellowstone National Park (Puchlerz 1985).

The last meeting of the original technical committee occurred in October 1987. In December 1988, Rodd Richardson, USFS National Grizzly Bear Habitat Coordinator, called together agency personnel who were currently involved with the CEM. By this time only a couple members of the original technical committee remained in the GYE. A new modeling team was established with myself of the Gallatin National Forest, as Team Leader. Other team members included representatives of the Bridger-Teton, Targhee, and

Shoshone National Forests, Grand Teton and Yellowstone National Parks, Forest Service Regional Offices 1, 2 and 4, the US Fish and Wildlife Service, and the IGBST. In 1994, Region 4 of the Forest Service offered the services of Ralene Maw to serve as a database coordinator for the GYE CEM. In 1995, team leadership was turned over to Kim Barber, Shoshone National Forest and Roy Renkin, Yellowstone National Park as co-leaders. See Appendix A for a list of past and present modeling team members.

In 1995, the following charter was developed for the YMT: "Develop and maintain the Cumulative Effects Model (CEM) and associated databases, and provide coordination and consistency regarding all aspects of the GYE CEM." Some of the various aspects of CEM under this charter include: model parameters and rule sets, validation efforts, appropriate uses of CEM and associated database, peer review and interpretation of model outputs, data standards, definitions and formats, data collection and updates, data distribution, and coordination with other GYE databases and other grizzly bear modeling efforts (Maw and Barber 1995).

CHAPTER 2

DATABASE

The database for the GYE CEM is a massive collection of geographic and descriptive information and is probably one of the most comprehensive of its kind in the world today. GYE agencies began collecting this data in the early 1970s and did not achieve a complete database for the GYE CEM until 1997. This effort not only spanned several decades, but also involved hundreds of people and cost in the millions of dollars. The database can be broken down into four major categories: boundaries, vegetative habitat, supplemental habitat, and human activity layers. Each of these will be described in detail.

Boundaries

The CEM requires user-defined boundaries as reference for model output. There is currently no limit to the number of boundaries a user may identify for a CEM run. The standard boundaries used in CEM analyses include Bear Management Units (BMU), subunits, administrative units, and female grizzly bear home ranges. Examples of other boundaries that might be of interest for a CEM analysis include hydrologic boundaries such as a drainage or watershed, project area boundaries, wilderness areas, hunting

districts, etc. The CEM provides results of the analysis for each boundary defined. The BMU and subunit represent the minimum scale for CEM analysis that produce outputs relevant to grizzly bear management. However, smaller internal boundaries such as those listed above provide information about what proportion of impacts are occurring within areas of particular interest; e.g. female grizzly bear home ranges.

The GYE grizzly bear recovery zone covers approximately 6 million acres. In dealing with an area of this size it became necessary to break it down into smaller units, partly to accommodate the limited capabilities of early GIS/modeling technology, but also for ecological and administrative reasons. According to the "Blue Book" (USDA 1985) the GYE was divided into Bear Management Units (BMUs) and Subunits in order to:

- "be able to assess existing and proposed activities without having the impacts washed out by too large an area."
- "closely match individual grizzly bear use patterns and habitat ecology" and
- "prioritize areas where management needs would require a cumulative effects analysis"

David Mattson of the IGBST was the primary author of the BMU and subunit boundary concept for the GYE in 1984. BMU boundaries were delineated at the scale of the life range of a female grizzly bear in the GYE. The intent was to define areas that had biological relevance to grizzly bears, would serve to minimize overall fragmentation of grizzly bear habitat, and could be used for mitigation purposes in a way that would maximize benefit to those bears most impacted by human activities (Mattson pers. comm.)

BMUs were delineated based on grizzly bear radio relocation data collected between 1979 and 1983. Areas were defined according to the number of radio relocations obtained during any or all of the bears' active seasons. "Active" seasons were defined as spring (March through May), summer (June through August) and fall (September through November). Areas with concentrated use by grizzlies during all active seasons provided the core for some BMUs. Likewise, areas of one- or two-season use, as well as non-use areas served as the core for other BMUs. Prominent topographic features between the seasonal use areas were used to further define the BMUs (USDA 1985).

The initial BMU mapping effort in 1984 resulted in the following stratification of the GYE: Madison, Washburn, Lamar/Slough, Crandall/Sunlight, Firehole/Hayden, Pelican/Clear and Two-Ocean/Lake BMUs showing known areas of extensive, three-season use; Gallatin, Hellroaring/Bear, Shoshone, Thorofare, Bechler/Westslope and Teton BMUs having substantial bear use during only one or two seasons; and Boulder, Plateau, and Henry's Lake BMUs receiving little or no bear use (USDA 1985).

Initial BMU delineations were derived from IGBST radio relocation efforts that were concentrated in and around Yellowstone National Park. Data from state and federal biologists around the GYE indicated that there were additional grizzly bear use areas and important habitat in the Taylor/Hilgard area of the Gallatin and Beaverhead National Forests, the Buffalo/Spread Creek area of the Bridger-Teton National Forest and the South Absaroka area of the Shoshone National Forest. Therefore these units were added to the original BMUs to create a total of 18 in the GYE. Figure 2 shows the original BMU boundaries as delineated in 1984.

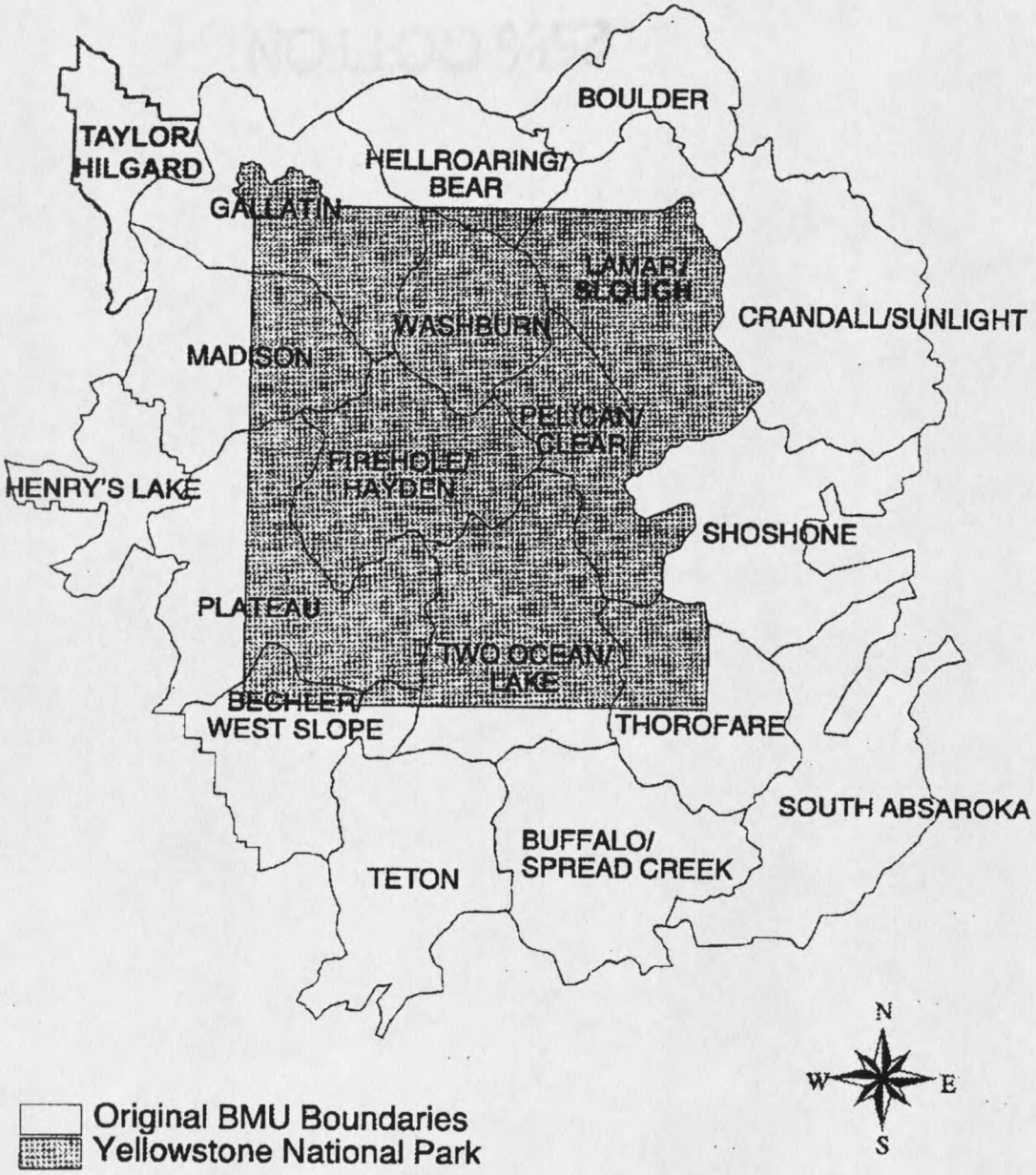

Figure 2: Original Bear Management Boundaries (BMU) developed in 1984.

Subsequent refinements were made to BMU boundaries as additional data became available. For example, the Taylor/Hilgard BMU that was added to the original 15 BMUs was initially a linear strip along the west edge of the ecosystem. Members of the technical committee, assisted by area biologists and managers with local knowledge, re-defined the internal boundaries of the Madison and Gallatin BMUs to adjust the Taylor/Hilgard Unit so that it more closely matched the seasonal bear use patterns attributed to the original BMUs (Puchlerz pers. comm.)

In 1988, the IGBST requested GYE agencies to provide written descriptions of BMU boundaries in order to create an accurate map for purposes of recording grizzly bear locations. From this information a map was created and distributed to the agencies for review. With agency revisions, a BMU base map was digitized and submitted to the Grizzly Bear Subcommittee for approval. Upon receiving Subcommittee sanctions, the first digital BMU map for the GYE was released in October 1989.

In conjunction with the revision of the Grizzly Bear Recovery Plan in 1993, it became apparent that the current BMU alignment would never allow achievement of stated grizzly bear recovery goals. This situation resulted from the original delineation of some BMUs based on a paucity of seasonal bear use. Therefore, the following changes to BMU boundaries were made: 1) part of the Madison BMU was included with the Henry's Lake and 2) part of the Lamar/Slough BMU was added to the Boulder. Figure 3 represents the current BMU boundaries as of October 1997.

BMUs are further divided into subunits to provide greater landscape resolution by accounting for additional seasonal heterogeneity of grizzly bear use patterns within a

Figure 3: Bear Management Unit (BMU) boundaries as of October 1997.

BMU. The typical subunit generally consists of a major drainage enclosed by portions of intervening ridges. The subunit represents the most energetically efficient area for a bear, and is correlated to the annual home range size of an adult female grizzly bear in the GYE (USDA 1985).

Subunits were delineated for the BMUs within Yellowstone National Park in 1984, again using primarily IGBST radio relocation data. Additional subunits were delineated for the BMUs on National Forest lands in 1989. Further refinement of subunits would occur in later years with additional review by local area biologists from state and federal agencies. See Figure 4 for subunit delineation as of October 1997.

Vegetative Habitat

This data layer contains information on landscape patterns based primarily on vegetation composition and structure. It also represents geologic and hydrologic features, as well as human developments on the landscape such as towns, airstrips and agricultural fields. Vegetation was mapped using the habitat type concept (Daubenmire 1966) according to manuals produced by Pfister et al. (1977) and Steele et al. (1983). The habitat type approach is an ecosystem classification method for describing forest communities. This method is used to identify vegetative potential on forested sites based on the geographic, physiographic, climatic and edaphic features of each type (Pfister et al. 1977). Since the habitat type approach represents the vegetative potential of a forested community under climax successional conditions, it primarily identifies the understory vegetative communities of various habitat types.

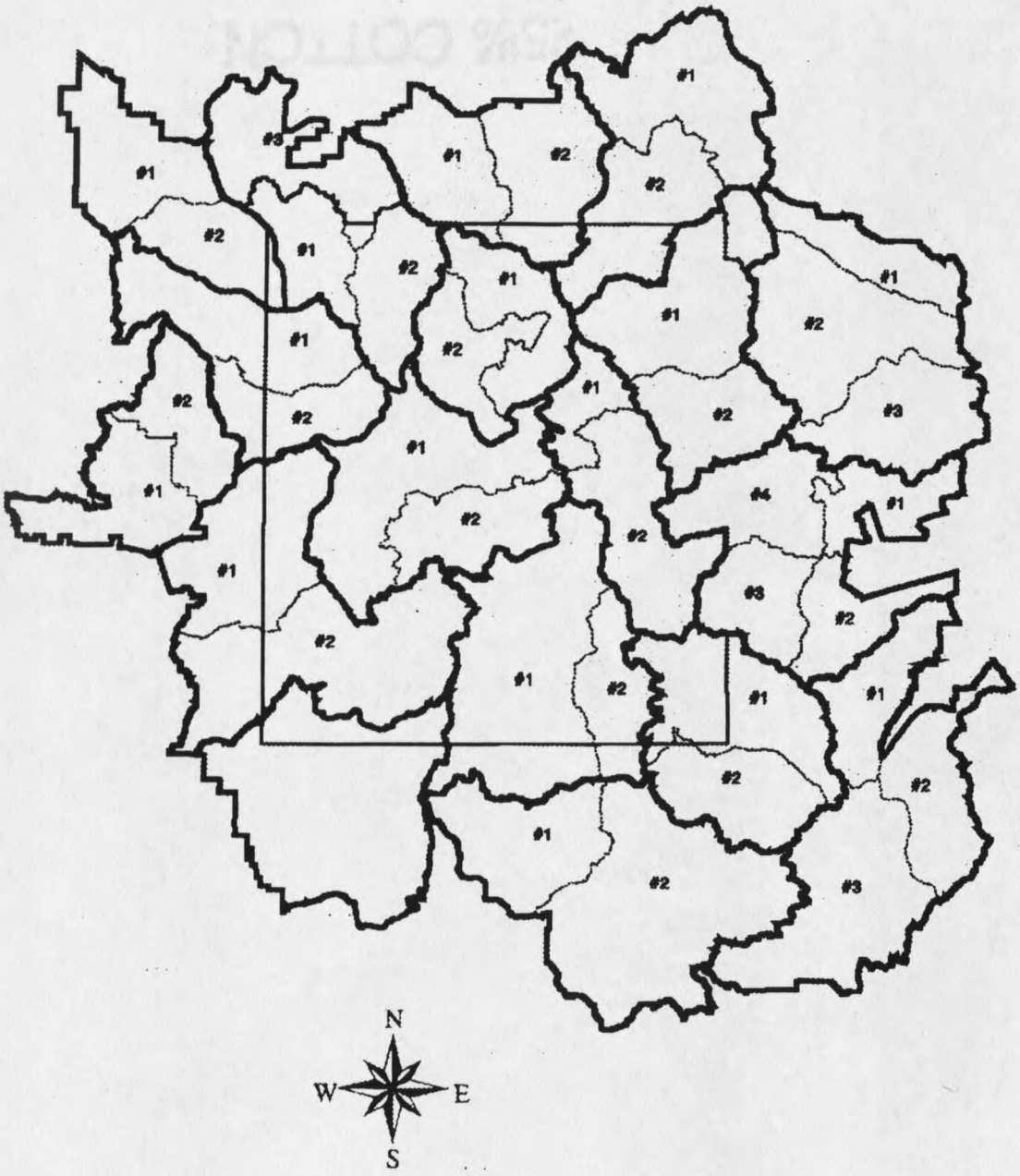

Figure 4: Bear Management Unit (BMU) and Subunit boundaries as of October 1997.

A complementary cover type coding scheme developed by Despain was used to represent the present overstory vegetation. Cover type codes indicate the predominant tree species in the forest canopy and current successional stage. This information is presented in the Grizzly Bear Habitat Component Mapping Handbook for the Yellowstone Ecosystem (Mattson and Despain 1985).

The habitat type approach was used to classify only forested habitat components. Nonforest habitat components such as meadows, shrublands, alpine tundra, rock and water, were coded using a more coarse definition of landscape units with less ecological resolution than the habitat type approach. This method was employed as the nonforest habitat types occurred at a much finer scale than could adequately be represented with a 5- to 10-acre minimum mapping resolution (Despain pers. comm.). The mapping handbook provides a description of the generalized nonforest habitat components as well as a key to mapping these vegetative types (Mattson and Despain 1985).

The ecological approach to recording vegetation structure and landscape patterning lends itself well to ecosystem management. The entire landscape was mapped to reflect successional patterns and disturbance regimes. Vegetative habitat mapping in the GYE was conducted using aerial photo interpretation and extensive ground truthing. This effort was initiated in the early 1970s with the purpose of producing the first vegetation map for Yellowstone National Park. Since this project was essentially completed prior to initiation of the CEM effort for grizzly bear habitat evaluation in the GYE, it provided the basis for vegetative habitat mapping of the surrounding National Forest and Park land. However, the procedure was refined somewhat so as to better meet

the needs of grizzly bear habitat assessment, and also to comply with mapping standards established for the National Forests. This refinement resulted in notable mapping discrepancies between Yellowstone National Park and the rest of the grizzly bear recovery zone. Specific mapping procedures employed by the various administrative units is described below.

Yellowstone National Park

In 1971, Yellowstone National Park initiated a project to produce a comprehensive vegetation map for the Park. The habitat type approach was chosen for the project, as this method produces an ecologically based classification system and would also be compatible with vegetative work being conducted on adjacent federal lands. At first, LANDSAT satellite imagery was considered for the project. It was later determined that the utility of LANDSAT data was limited to distinguishing coniferous forest from other vegetative types, and determining the density of forest cover (Root et al. 1974). As the project called for greater landscape resolution than LANDSAT data could provide, the satellite imagery concept was abandoned and a more labor-intensive aerial photography interpretation approach was adopted (Despain pers. comm.)

In 1973, transects were established for field sampling that would be representative of Yellowstone National Park vegetation types. The transects were mapped on 1969 to 1972 color aerial photography, at a scale of 1:15840. Sampling routes were based on known correlations between geology, climate and vegetation. The transects were carefully selected to ensure sampling that would cover the elevation range and geologic

parent materials present within the Park (Despain pers. comm.)

In 1974, field crews of botanists were hired and trained in habitat typing to improve their skills in identification of indicator species for GYE habitat types. The field crews visited transect locations on the ground, recording habitat types and percent cover of indicator species in forested habitat types, as well as listing all species found in nonforest types. As habitat typing manuals for Wyoming were not available in the early 1970s, the field crews mapped vegetation using Cooper's preliminary work (which would eventually be incorporated into Steele et al. 1983). Pfister's (1977) habitat types for Montana were also used when they became available (Despain pers. comm.)

While the field crews were out mapping habitat types along the transects, Despain was also out in the field with aerial photos training his eye to the correlations between habitat types on the ground and associated characteristics on the aerial photos. He then used this information, in addition to data collected by the field crews, to delineate habitat types and transitional ecotones on aerial photos. Schedule requirements for the project did not allow for delineation of "effective areas" on photos, so entire photos were mapped, using every other photo from each flight line to obtain full coverage of the Park (Despain pers. comm.)

Vegetative polygons were transferred from the aerial photos to 15 minute topographic quad maps (scale = 1:62500) using simple ocular transfer. These base maps were used because neither orthophoto base maps nor 7.5 minute topographic maps (scale = 1:24000) were available for Yellowstone National Park at that time. Habitat type units were recorded at a minimum mapping resolution of 10 acres. Inclusions of less than 20

percent of a mapped polygon were ignored unless they could clearly be broken into polygons at least 10 acres in size. The entire field mapping project took place in Yellowstone National Park between 1973 and 1979 (Despain pers. comm.)

Vegetative habitat type maps were sent to the National Park Service Regional Office in Denver, Colorado for digitizing. The first maps sent in were digitized by hand, and later maps were scanned when this technology became available. Digital maps were returned to Yellowstone Park for proofing and correction of errors (Despain pers. comm.)

As habitat typing was being completed in the late 1970s, the same aerial photos were used for cover type delineation of forested habitats. The cover type classification system developed for this project (Despain 1977) would later be incorporated into the mapping handbook for the rest of the GYE (Mattson and Despain 1985). Cover type classifications were based on species composition and successional stage of the overstory vegetation. Once cover types were mapped, the aerial photos were sent to the Denver Office where the delineations were transferred to 15 minute topographic quad maps using a zoom transfer scope and then digitally scanned (Despain pers. comm.)

These mapping efforts provided separate maps for habitat and cover types. When the surrounding administrative units later started mapping habitat and cover type combinations as a single map layer according to the mapping handbook (Mattson and Despain 1985), Yellowstone personnel used GIS technology to overlay and combine the two layers for the Park. This project initially resulted in a plethora of "slivers" between the newly created polygons. By reassembling the polygons into a 5-acre raster coverage, most of the "slivers" were eliminated (Despain pers. comm.)

Gallatin National Forest

Habitat mapping for most of the National Forests and Grand Teton National Park followed the procedures outlined in the mapping handbook (Mattson and Despain 1985). Following is a detailed description of this process as implemented on the Gallatin National Forest. Vegetative habitat component mapping occurred in three phases: pre field, field, and post field. The pre field phase consisted of aerial photo interpretation and delineation, and orthophoto base map preparation. Aerial photography used for the project was from an August 1981 flight, at a scale of 1:24000. First, effective areas were determined for the aerial photos to avoid delineation of habitat components at the outer edges of the photos where distortion can occur from the tilt of the aircraft and curvature of the earth's surface.

Within the effective areas habitat components were delineated directly onto aerial photos using a stereoscope to visualize topographic relief. Homogenous landform types (vegetative, rock and water) were identified by polygons on the aerial photos. Delineation of habitat polygons incorporated features such as aspect, elevation, slope, color, texture, density and size class of tree species, and topographic location (e.g. ridge top, side slope, valley bottom, flat land, etc.) Polygon size was constrained by a 5-acre minimum mapping resolution. In situations where multiple vegetative types were intermingled such that they could not be broken out into 5-acre or larger polygons, the combinations were mapped as a single habitat polygon and coded as "mosaics". (Coding of vegetation polygons will be described below.) An example of a mosaic would be a forested area interspersed with less than 5-acre meadow openings.

Once habitat polygons were delineated on aerial photos they were transferred by simple ocular method to mylar orthophoto base maps. USGS 7.5 minute orthophoto quads were used for base maps. Vintage of the base maps was generally 1976, and scale was again 1:24000. Care was taken to ensure that habitat polygons at the edge of base maps matched those on the adjoining quads. Parts or all of 57 quads were mapped to provide vegetative habitat component coverage for the Gallatin National Forest portion of the GYE grizzly bear recovery zone.

In preparation for the field phase of habitat component mapping, sample aerial photos were selected for field verification of habitat and cover types. Sample photo selection targeted every other photo from every other flight line for ground verification. This sampling scheme was utilized so that every unsampled photo would be adjacent to at least one field sampled photo. Figure 5 shows the sample photo selection strategy for field verification.

Once sample photos were selected, a process of "like-typing" was conducted to minimize the actual field time required to ground truth a photo. "Like-typing" was a process where each polygon on a photo was assigned a number based on physical attributes such as aspect, elevation, tree species present, structural and successional composition, and apparent moisture content of vegetation; e.g. wet, moist or dry. Polygons with similar attributes were given the same numerical identifier and field samplers were only required to visit one representative polygon of each number on a sample photo. Figure 6 shows an example of aerial photo delineation and "like-typing" for field samples.

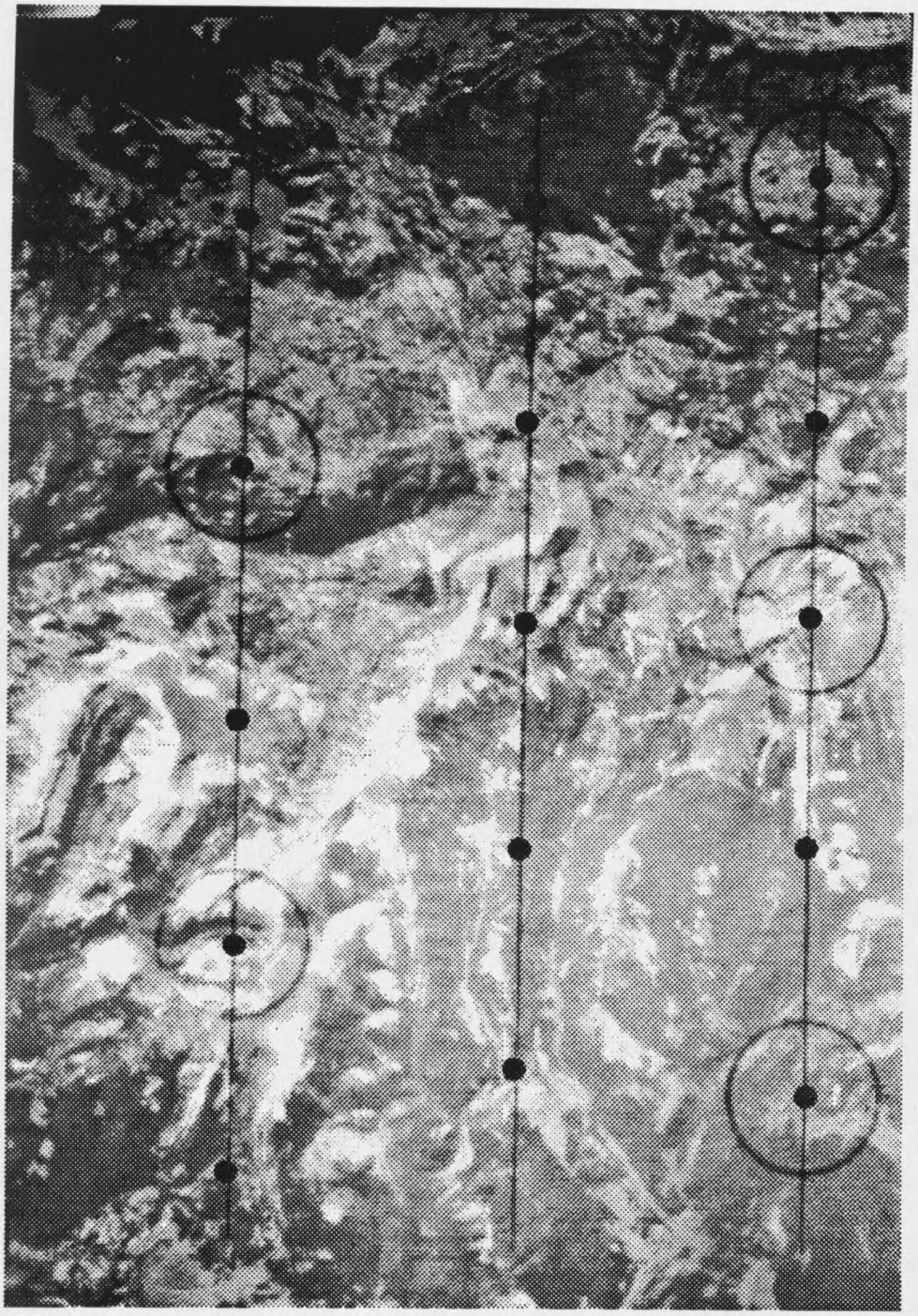

Figure 5: Field sample photo selection scheme. Every other photo (circled) from every other flight line visited on the ground.

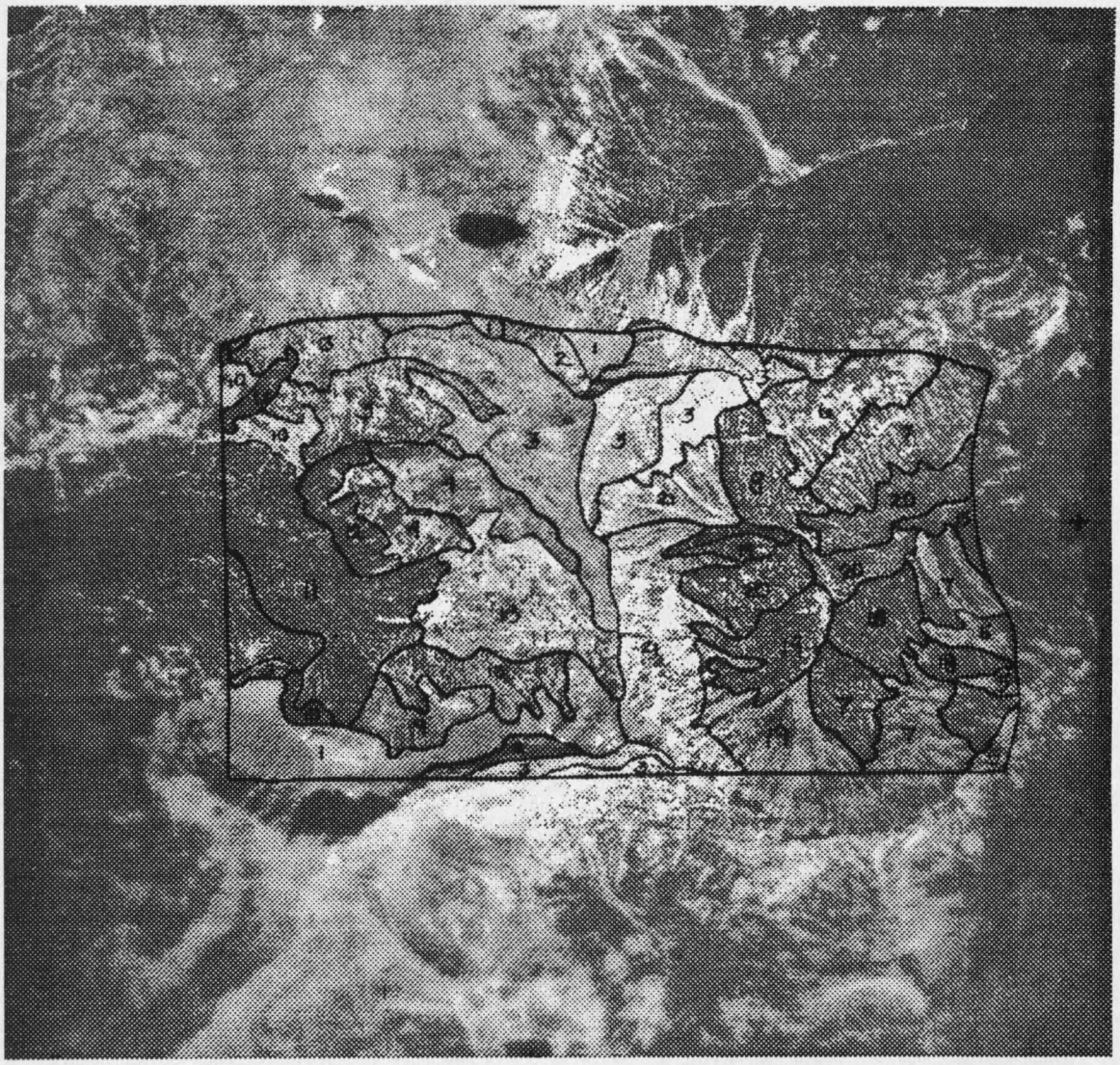

Figure 6: "Like-typing" on field sample photo. Only one polygon for each numeric identifier visited by field crews.

Mylar overlays were prepared for field sample photos with polygon delineations and "like-typing" identification in each polygon. Field coding forms accompanied the photos. These forms recorded the name(s) of field personnel, date sampled, quad on which the sample photo was located, and spaces for recording the habitat/cover type code(s) for each polygon visited.

A habitat component mapping workshop was held in Gardiner, Montana for GYE field mapping crews in June 1985. At this session, field crews were instructed in aerial photo interpretation, orienteering and habitat typing techniques. Gallatin Forest personnel followed procedures established at the workshop for field mapping of vegetative habitat components. Portions of the Gallatin Forest were field mapped from 1985 to 1987. In 1988 catastrophic fires in the GYE prevented any field mapping for that season. Field mapping did not occur until 1992 in order to allow time for habitat type indicator species to become fully re-established. The last of the field sampling phase for habitat component mapping on the Gallatin Forest occurred in 1995.

The post field mapping phase consisted of transferring field data to the orthophoto base maps. This data plus other existing information was used to extrapolate habitat component codes to those polygons that were not sampled in the field. Extrapolation was conducted by personnel trained in aerial photo interpretation and habitat typing techniques. Field sampled photos were compared with adjacent unsampled photos. Polygons in the unsampled areas were assigned the same vegetative habitat component codes as sampled areas with similar features. Additional information was gained from timber stand exam data, range allotment inventories, soils type maps and broad-scale

habitat type maps. Again, extra effort was made to ensure that adjoining polygons on adjacent quads had the same vegetative habitat component codes.

Once all polygons had been assigned codes, the final vegetative habitat maps were produced either on plain frosted mylar or mylar orthophoto prints. These maps were drafted in ink and labeled in preparation for digitizing. One of the tasks performed in this step was the elimination of lines separating polygons with the same vegetative component code. This procedure minimized the overall number of polygons and thus reduced digitizing costs and computer storage requirements. Final ink copies of the habitat component maps were carefully checked for drafting, coding and edge-matching errors prior to being sent off for digitizing.

Vegetative habitat maps that were completed prior to the 1988 fires (Madison, Gallatin, Hilgard, Lamar and Crandall/Sunlight BMUs) were sent to REDCON Data Consultants, a private firm in Bountiful, Utah, for digitizing under a GYE-wide contract. REDCON digitized the maps and returned them with check-plots and the digital information on 9 mm tapes, to the Gallatin National Forest. Check-plots and digital tapes were reviewed for errors, corrections were made, and the data were stored for future use with the CEM.

As mentioned earlier, the fires of 1988 resulted in suspension of habitat component mapping activities on the Gallatin Forest. Once this process resumed in 1992, the digitizing contract with REDCON had expired. Vegetative maps for the remainder of the Gallatin Forest were completed in 1997 (Hellroaring/Bear and Boulder/Slough BMUs). This mapping effort followed the same procedures as outlined above, with the exception

of digitizing. Instead of preparing a final manuscript complete with polygon delineations and labels, only the polygons were transferred to the final map. The blank polygons were then scanned at the Forest Service Regional Office in Missoula, Montana and the digital product was retrieved electronically. Gallatin Forest personnel edited the digital product for errors and completed the data entry necessary to assign the habitat component code attributes to the digital files.

Vegetative habitat component codes are 5-digit numeric labels that represent the habitat/cover type combinations for forested components, and the generic descriptions developed for nonforest types. Forested habitat type codes developed by Pfister et al. (1977) and Steele et al. (1983) are 3-digit codes. Cover type codes for forested components are 2-digit codes that represent the overstory species composition and successional stage. Nonforest types were assigned general 5-digit codes that begin with three leading zeros. The last two digits of nonforest type codes typically indicate the dominant vegetation present; e.g. grass, forb or shrub, and the relative moisture content; e.g. wet, moist, or dry and are also used to represent rock and water (Mattson and Despain 1985). Appendix B lists vegetation codes and coefficients used with ICE9 CEM software as of October 1997.

Mosaics (vegetative polygons with more than one type that could not be broken out in 5-acre or greater sections) were labeled with multiple codes, with habitat types listed in order of proportion. Figure 7 shows a sample of a Gallatin Forest vegetative habitat component map.

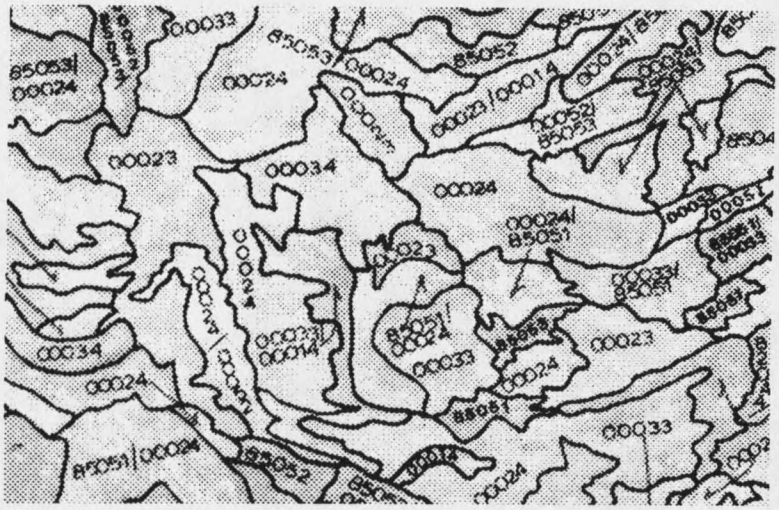

Figure 7: Vegetative habitat component mapping polygons and labels.

Shoshone National Forest

The Shoshone National Forest took a slightly different approach to vegetative habitat mapping than outlined in the mapping handbook (Mattson and Despain 1985) and described above for the Gallatin National Forest. This divergence from the standard was justified for two reasons. First, there was considerably more existing vegetation data available for the Shoshone than for other National Forests. Secondly, the Shoshone contracted out the vegetative habitat mapping to K. Houston, who had several years of prior experience in vegetative analyses and mapping on the Shoshone National Forest, including preparation of a "Grizzly Habitat Map" in 1978 (undated memo).

Pre-existing data available to the Shoshone for this project included Forest Plan habitat type maps, geology maps, North Absaroka fire plan habitat type maps, soil survey maps, habitat type mapping conducted by Mealey and Mattson in the 1970s.

In an undated memo from the Shoshone National Forest files, Houston described his methodology, which is summarized as follows. Available data (listed above) were assembled and field work was concentrated in those areas lacking information. Data regarding slope, elevation, aspect, parent material, habitat type and ecotones were recorded in the field. From this information "target diagrams" were developed to extrapolate forest habitat type information (the "target diagram" concept was not described in the memo, only referred to as a method). Nonforest types were identified through previous mapping efforts and from color infra-red aerial photography.

Although Shoshone personnel used a slightly different mapping technique, the final product was similar to that produced by other forests. With the abundance of pre-existing data, they did not feel it necessary to conduct the same degree of field sampling as required in other areas of the ecosystem. Consequently, the Shoshone was able to produce a similar product at less cost than the other National Forests and Parks.

The remaining National Forests (Beaverhead, Custer, Bridger-Teton and Targhee) and Grand Teton National Park, were mapped using methods consistent with those outlined in the mapping handbook (Mattson and Despain 1985) and described above for the Gallatin National Forest. Vegetation mapping efforts for these remaining administrative units will therefore not be discussed further.

Fire Update

The catastrophic fire event of 1988 burned well over a million acres in the GYE. This phenomenon dramatically changed the character of grizzly bear habitat as mapped for

the GYE CEM. Obviously, updating the vegetative habitat mapping to reflect cover type modifications resulting from the fires would be an undertaking of significant magnitude. Fortunately, the ecologically-based coding scheme utilized for this data lends itself to a disturbance-related update, since habitat types are unlikely to change due to the fires and cover type conversion is logically predictable based on habitat type and pre-existing cover type. Satellite imagery was immediately a mechanism considered by the Yellowstone Modeling Team for this project. The National Park Service Washington Office had contracted with EROS Data Center to obtain LANDSAT Thematic Mapping (TM) imagery of the Yellowstone area fires in October 1988 (Despain pers. comm.)

EROS personnel initially conducted an unsupervised classification of the imagery which resulted in 30+ classes of spectral data representing the burned and unburned areas. They then used GIS technology to "mask out" everything but the burned classes, and performed another unsupervised classification in an attempt to identify different classes of burn intensity. Color aerial photography was used in conjunction with the second satellite imagery classification to produce seven final burn intensity classes. These classes were based on fire intensity; e.g. crown fires where all trees were killed vs. mixed crown/ground fires that resulted in a combination of burned, scorched and green trees, and burns that occurred in nonforest areas. The final burn intensity categories are as follows: 1) crown fire in dense forest canopy 2) crown fire in medium forest canopy 3) crown fire in sparse forest canopy 4) mixed fire in dense forest canopy 5) mixed fire in medium forest canopy 6) mixed fire in sparse forest canopy and 7) burned nonforest areas; e.g. meadows (Despain pers. comm.)

A new map of the seven fire intensity classifications was produced and taken to the field in Yellowstone National Park for ground verification. This field exercise indicated that the resulting fire map was fairly accurate, except that it could not be used to detect surface fires where trees were not killed, nor to distinguish between conifer canopy burns and sagebrush canopy burns. The cover type map for Yellowstone Park was used to distinguish the sagebrush types and a final, post fire vegetation map was produced for Yellowstone National Park in 1989. The post fire map was created by overlaying the vegetative habitat map with the fire intensity map. The basic rule set for coding changes was to convert all forested components that had sustained any degree of burn (canopy or mixed) back to a recently disturbed cover type (Despain pers. comm.)

The Yellowstone Park prototype of a post fire vegetation map indicated that the method used was effective and could be used for updating the entire GYE vegetative habitat database and was thus adopted by the modeling team in September 1989. However, the argument was made that not all trees would die in the mixed burns, and therefore the post fire code for those stands influenced by a mixed burn would be coded as a mosaic of burned (early successional, recently disturbed) and unburned (retained the pre fire cover type code).

Initially the modeling team thought it would also be appropriate to convert the codes for burned shrub lands (e.g. willow and sagebrush communities) to grass or forb meadows, depending on the nature and geographic location of the site. However, it was later decided that these types would likely revert back to shrub communities in a matter of a few years, so all nonforest types were left coded as they were pre fire.

With the rule set for modifying the vegetative habitat data in place, the modeling team agreed to pursue a fire update using the burn intensity map developed by EROS and Yellowstone National Park. Utah State University (USU) was awarded a contract through the Forest Service National Grizzly Bear Habitat Coordinator and the Regional Office in Ogden, Utah. Prior to conducting the fire update, the contract with USU required the consolidation of all the vegetation data for the GYE into a single map; an endeavor that had yet to be undertaken.

All administrative units sent existing vegetative habitat digital data to the Forest Service Regional Office in Ogden where data were assembled and checked for gross errors before being forwarded on to USU. The Hellroaring and Boulder BMUs were not included at the time of the initial data consolidation as field mapping was disrupted due to the fires. In order to maintain consistency in the database, these units were subsequently mapped using pre fire (1981) aerial photography. With the exception of field-checked polygons, vegetation was mapped as though it had not been impacted by the fires. Once completed in 1997, these units were sent to the database coordinator in Ogden to be run through the same process for fire update as documented by USU (Ramsey 1991).

The final product delivered by USU in 1992 was a GYE-wide vegetative habitat coverage, in ArcInfo format, complete with attributes for pre fire vegetation, burn intensity, and post fire vegetation. As the fire update process had already been completed for Yellowstone National Park, the post fire coverage was sent to USU for inclusion in the GYE vegetation data consolidation and fire update. Consequently, the pre fire codes are the same as the post fire codes for Yellowstone Park data in the resulting GYE coverage.

The ecosystem-wide coverage is now maintained by the GYE CEM database coordinator in Ogden.

Supplemental habitat

This data layer includes information on environmental factors that are not evident in the vegetative habitat layer. Originally termed the "protein" layer, this data set currently includes information on distribution of ungulate seasonal ranges, fish spawning streams and insect aggregation sites; i.e. habitat features that supply critical energy sources to GYE grizzly bears. The name was later changed to "supplemental habitat" in recognition of some additional features that we may eventually want to include in the CEM, but as of yet lack sufficient data to do so. Examples of these types of features include potential denning areas, security core areas, and travel corridors.

Nine supplemental component types were initially identified for the GYE including moose (*Alces alces*) winter range, bison (*Bison bison*) winter range, high elevation elk (*Cervus elaphus*) winter range, low elevation elk winter range, geothermally influenced elk winter range, carrion concentration areas, traditional ungulate calving grounds, summer-fall ungulate concentrations, and fish spawning areas. Specific definitions and mapping instructions for these types are outlined in the mapping handbook (Mattson and Despain 1985). Insect aggregation sites, primarily army cutworm moths (*Euxoa auxillaris*), were discovered in 1993 and included as important supplemental habitat components for grizzly bears in the GYE and mapped later (Mattson 1993b). Figure 8 represents a supplemental habitat map.

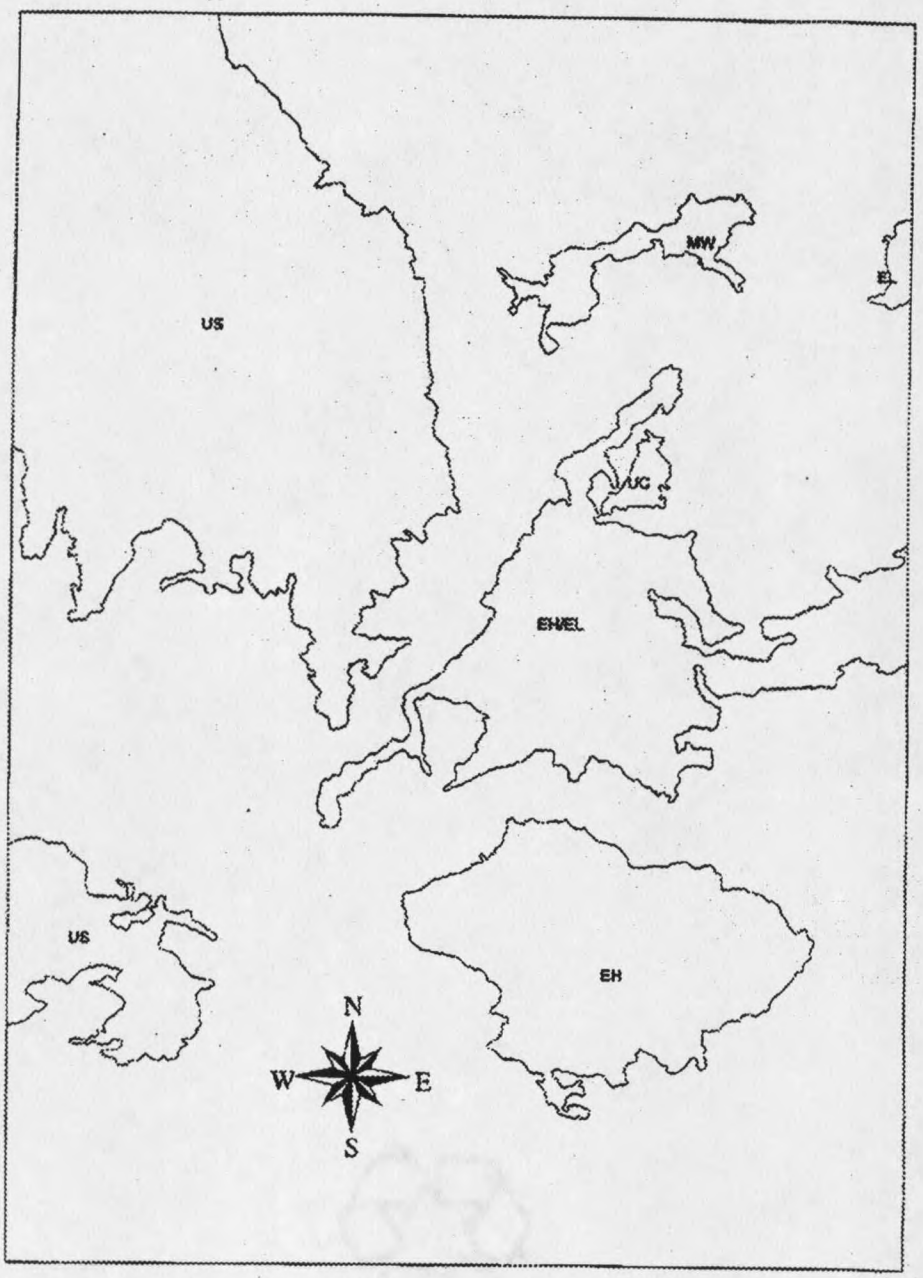

Figure 8: Supplemental habitat component features.

Supplemental habitat components with high energy food sources were mapped independently by GYE administrative units. In 1994 the Greater Yellowstone Coordinating Committee (GYCC), a group of GYE managers with membership that largely overlaps with the GYE grizzly bear subcommittee, approved an elk habitat mapping project for the GYE. Since several types of elk habitat (listed above) had already been mapped for use with the CEM, this data was identified for use as a starting point for the elk habitat mapping project.

The GYCC project was the first serious effort to consolidate any of the supplemental habitat data for the CEM. As this project proceeded it was soon apparent that there were considerable discrepancies in the mapping of elk habitat between the various administrative units. Some edge-matching of supplemental habitat polygons occurred with the elk habitat mapping project, but further review of the database revealed some major differences in the way the rest of the supplemental habitat components were mapped by different administrative units.

At a modeling team meeting in June 1997, Mattson, now with the Fish and Wildlife Resources Department at the University of Idaho, presented a GYE-wide map of supplemental food sources that he had developed for research he was conducting, unrelated to the CEM. As Mattson was the original author of the animal food source definitions included in the mapping handbook (Mattson and Despain 1985) and also developed the coefficients assigned by the model to these map units (USDA 1985), the modeling team decided to adopt his map as a new base for the official supplemental habitat map for the GYE CEM. This new map will be augmented with additional

information from existing supplemental habitat maps (Barber 1997). This process will result in a much more consistent, uniform map of supplemental habitat data for the GYE.

Human Activities

Human land uses were mapped and categorized in very general terms to avoid the complexity and size requirements for a database that incorporates descriptions of all possible human activities on the landscape. Activities are therefore classified according to their potential to disrupt grizzly bear use patterns. A combination of map overlays with corresponding attribute files identify human activities in grizzly bear habitat. The map overlays represent spatial relationships by identifying the geographic location of activities. Attribute files serve to further define the mapped features. These files contain information regarding temporal aspects of activities such as seasonal variations in use, and distinctions between daytime-only or 24-hour use patterns. Attribute files are also used to indicate the intensity of human uses by differentiating between motorized and non-motorized activities and classifying the relative level of use; e.g. high, low or incidental (USDA 1990).

Activities are classified by their nature as being point, linear or dispersed. Point activities are those that occur at a specific location on the landscape and can be identified with an "x" on a map. Examples include campgrounds, outfitter camps, picnic areas and home sites. Linear activity features include roads, trails and other regularly traveled routes (e.g. fishing activity along a stream course) which are represented on maps as line segments. Dispersed activities are those which are not confined to a specific location or linear route, and are displayed as closed polygons on a map. Examples include hunting,

cross-country hiking and snowmobile play areas.

Motorized activities are those that produce loud mechanical noises such as automobile engines, chainsaws and generators. Non-motorized activities obviously have no such loud noises associated with them. Explosives; e.g. road construction and seismic exploration, have their own designation. Duration of an activity is indicated by records of the actual period of use; e.g. a trail may be used only during the summer months (7/1 - 9/30), whereas a paved road may be used on a year-round basis (1/1 - 12/31). Point activities are further refined by differentiation between day-use; e.g. picnic areas and 24-hour use; e.g. back country camp sites (USDA 1990).

Levels of use are generally recorded in relative terms of high and low. An exception was made for closed roads and trails that are known to receive occasional administrative and/or illegal use, but these occasions were not considered significant enough to constitute a "low use" designation. Activity classifications as currently defined for use with the GYE CEM are described in the "Green Book" (USDA 1990).

The broad, general activity classification system developed for the GYE CEM provided for efficiency in mapping the multitude of human activity sources found in this area. However, it also rendered a considerable amount of subjectivity into the mapping task, which resulted in notable discrepancies between (and even within) the maps produced by various administrative units. Early in the project, Yellowstone National Park personnel developed a diagram to key out the different types of activities (USDI 1986). This flowchart was distributed to the other agencies which significantly helped to standardize the classification and mapping of some human activities. However, since the

diagram was developed specifically for Yellowstone Park, it did not address many of the multiple uses associated with National Forest lands such as timber harvest, mining and livestock operations.

Linear features (roads, trails and corridors) were the best matched activities across administrative boundaries as numeric parameters could more readily be attached to these types of features and most agencies had some sort of monitoring system in place to track use levels. The activity diagram developed for Yellowstone Park defined high use for motorized linear activities as receiving use "more than once per daylight hour" and low use as anything less than this. For non-motorized linear features, high use was defined as "used by more than 3 parties per day" and low use was anything less (USDI 1986).

With the "unification" of the CEM across the grizzly bear ecosystems, numeric parameters attached to linear features changed slightly. High use for motorized features was re-defined as "averaging 20 or more vehicular disturbances per week". "Vehicular disturbances" was the terminology adopted to account for multi-vehicle parties traveling through an area together, and thus treated as only one disturbance. Low motorized use was defined as "averaging between 3 and 19 vehicular disturbances per week", and a new category of *incidental* motorized use was developed to account for seldom used but open roads and trails as well as periodic administrative and/or illegal motorized use on closed roads. The use level for this category was defined as "averaging 2 or less vehicular disturbances per week" (USDA 1990).

Obviously, we do not have enough data on transportation systems within the ecosystem to accurately classify all roads and trails precisely into these categories. The

majority of the classification was based on mappers' intuition. However, agency personnel with the best knowledge of road and trail use were consulted during the mapping process, and numeric parameters greatly facilitated interpretation efforts.

Standardization of linear features across administrative boundaries was further facilitated by a modeling project that parallels the CEM effort. The linear portion of the CEM database was pulled out for a separate analysis of human access into grizzly bear habitat for the purpose of evaluating high density access areas as well as identifying potential security core areas (USDA/USDI 1994). The "Access" project calculates road and trail densities in grizzly bear habitat regardless of habitat quality or other types of activities; e.g. point and dispersed. This project resulted in the first attempt to edge match any of the human activities data on an ecosystem-wide scale and required close scrutiny of linear features that cross administrative boundaries.

Point activities were a bit more difficult to fit into standardized categories than linear activities. However, they do not generally cross administrative boundaries so there is no need to edge-match for geographic location of these features. The major discrepancies in methods used to categorize point activities occurred in the distinction between motorized and non-motorized point sources, and in the mapping and classification of concentrations of point sources.

Early mapping efforts, and associated descriptions outlined in the Yellowstone Park diagram for mapping activities (USDI 1986) considered most "developed" point activities; i.e. those in close proximity to road networks, to be "motorized point sources". Examples include developed campgrounds, houses and businesses such as hotels, stores

and gas stations. With the "unification" of the different grizzly bear models, it was jointly decided by all modeling teams that the road systems associated with these types of point sources represented the motorized activities, and that the point sources themselves should be coded as non-motorized. The only types of point activities that were considered motorized under the "unified" definitions were those that emitted large equipment noises; e.g. timber harvest activities, oil and gas drilling, mining and mill site activities (USDA 1990). Very few of the GYE agencies that had completed the activities mapping prior to establishment of the new definitions went back and revised their data.

The second major source of confusion with the mapping and classification of point activities was regarding concentrations of point sources; e.g. large developed campgrounds, ranch and lodge complexes, subdivisions and actual town sites. These types of point clusters did not fit well into the standard definitions. Obviously, it did not make sense to map every single residential and business structure in the city of West Yellowstone, but it was difficult to determine how many "points" were needed to simulate the impact of such an environment.

The mapping of major developments such as communities within the grizzly bear recovery zone had been addressed in various modeling team discussions and a recommendation was made to map these features as a single "point" and assign a large zone of influence and a high-impact disturbance coefficient to the site (zones of influence and disturbance coefficients will be discussed later in this document). In fact it has been noted by Mattson that evidence supporting the treatment of major developments as single point sources with large zones of influence comes from the most thorough data sets