GLOBAL CHANGE OPERATIONS AND CONCEPTUAL RESEARCH PLAN

FOR

OZARK HIGHLANDS BIOGEOGRAPHIC AREA

Recommended by:

Acting Biogeographic Area Coordinator

Thomas W. Griffith acting

Superintendent, Ozark National Scenic Riverways

Superintendent, Buffalo National River

Regional Director, Midwest Region

Regional Director, Southwest Region

Date Submitted 9/24/90

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Recommended By:

Chairman, Global Change Program Committee Date

Approved By:

Associate Director, Natural Resources Date

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Summary

A long-term research and monitoring effort to determine effects of global climate change in the Ozark Highlands (OZHI) cannot include every group of organisms for every parameter measurable. Staffing and fiscal resources dictate a focused approach. A majority of the completed and ongoing research at Ozark NSR (OZAR) and Buffalo NR (BUFF) is based on the hydrology, water quality, and biotas of the rivers. This Global Change Plan (GCP) outlines a program to detect climate change through enhanced aquatic ecosystem monitoring and study. Key biological, physical, and chemical parameters of both spring fed and precipitation fed Ozark aquatic systems were selected for their predictive value. Although the plan emphasizes aquatic studies, other resources potentially sensitive to climate change are possible and will be carried out. Among these are paleoclimate reconstructions from tree rings and cave formations, studies of glade/forest ecotones, and an assessment of the impacts of weather extremes on visitor recreation.

The initial research focus of the plan will be to describe past and present climatological and ecological conditions. Sufficient knowledge about the structure and function of ecosystems must be known to avoid false alarms due to natural variability and to be able to distinguish stress of anthropogenic origin from natural changes or shifts and episodic events. In order to determine if future changes are significant, research will quantify the range of expected variability of sensitive ecosystem components. Experimental research will follow as will modeling to predict responses to different climatic change scenarios. The general global climate change research hypothesis is that with global warming the OZHI will become warmer and drier with an accompanying increase in the frequency and intensity of storms and other extreme weather events (Hansen et al., 1988; Decker, 1990) (see Appendix A). Emphasis will be placed on documenting conditions of the drought period of the 1930's as climate then was similar to that predicted by GCC models. Research projects will be designed to test specific hypothesis concerning responses of sensitive components and processes of the OZHI ecosystem.

The OZHI Biogeographic Area Coordinator (BAC) will be stationed at the U.S. Fish and Wildlife Service Cooperative Fish and Wildlife Research Unit at the University of Missouri-Columbia (MCFWRU). The MCFWRU will provide office space, utilities, lab space and equipment and reduced overhead on research projects conducted through the Unit. If funding and FTE are provided above the base, a OZHI GIS Specialist position will be established at BUFF. A OZHI GCC advisory committee will be established for the purpose of providing advice and recommendations on program direction and research quality control. The OZHI BAC will be a member of the Ozark Highlands Biosphere Reserve Steering Committee.

Section I: Global Change Concept and Program Components

A. Research Statements and Hypotheses

The following ecological statements and hypotheses are designed to test potential effects of global climate changes in the OZHI. Each is followed by a brief explanation of resource sensitivity and overall research strategy. Priorities and phasing are included in Part B, Research Matrix.

Paleoecology

HYPOTHESIS 1: CAN LONGER RED CEDAR CHRONOLOGIES EXTEND THE HYDROLOGICAL APPLICATIONS OF TREE-RING DATA IN THE OZARK HIGHLANDS?

The OZHI region contains a substantial record of paleoenvironmental history of the Holocene and Pleistocene/Holocene transition. Paleoecological and archeological information from caves, rock shelters, and springs can be found in Mehringer et al. (1970) and King (1973). Additionally, tree-ring analysis of red cedar (Juniperus virginiana) has shown the potential for detailed climate reconstruction in Missouri for the last 500 years or more (Guyette et al. 1981). Also, McGinnes et al. (1983) found the spring and summer minimum discharge of Ozark streams is highly correlated with red cedar ring width. This relationship offers an opportunity to reconstruct the flow records of Ozark streams for the past 700 years.

HYPOTHESIS 2: CAN STABLE ISOTOPE RATIOS FROM CAVE SPELEOTHEMS PROVIDE LONG (>50,000 YEAR) PALEOTEMPERATURE RECORDS FOR THE OZARK HIGHLANDS?

A longer climate record than can be obtained from tree-rings and springs will be needed for complete coverage of the Holocene and the Pleistocene/Holocene transition. Caves provide unique and potentially valuable collections of time-sequence records of past and present climatic conditions. Both OZAR and BUFF are located in major cave regions of the Ozarks (Bretz, 1956; Lindsley, 1977). Cave temperatures approach the mean annual temperature of the area in which the cave is located. Cave temperatures, since they "damp out" most short-term fluctuations, may be uniquely indicative of temperature trends in continental areas.

Speleothems (cave formations) can be dated using uranium and thorium isotopes (Thompson, et al., 1975). Paleotemperature data can be obtained by measuring the ratio of $^{18}0/^{16}0$ in the calcium carbonate of speleothems (Hendz and Wilson, 1968).

Fluvial Geomorphology

HYPOTHESIS 3: PREHISTORIC ALLUVIAL DEPOSITS ALONG OZARK HIGHLANDS STREAMS ARE THE RESULT OF PALEOCLIMATICALLY DRIVEN CHANGES IN HYDROLOGY AND SEDIMENT SUPPLY. CAN AN ANALYSIS OF ALLUVIAL DEPOSITS INDICATE CHANGES IN HYDROLOGIC PROCESSES AND MAGNITUDES

THAT ACCOMPANY CLIMATE CHANGE?

HYPOTHESIS 4: HISTORICAL CHANNEL INSTABILITY AND AGGRADATION IN OZARK STREAMS HAS OCCURRED DUE TO SOME COMBINATION OF LAND USE, CLIMATE CHANGE, AND EXTREME HYDROMETEOROLOGICAL EVENTS. CAN AN ANALYSIS OF THE TIMING AND LOCATIONS OF THE INSTABILITY, COMPARED TO CLIMATIC AND FLOOD RECORDS, SHOW THE RELATIVE INFLUENCES OF THE THREE FACTORS, INDICATE PHYSICAL CONTROLS ON LOCATIONS OF INSTABILITY, AND ESTABLISH BASELINE INFORMATION FOR MONITORING FUTURE CHANGES?

HYPOTHESIS 5: HISTORICAL CHANNEL INSTABILITY AND AGGRADATION HAVE RESULTED IN SIGNIFICANTLY CHANGED AQUATIC HABITAT. CAN PHYSICALLY BASED, 2-DIMENSIONAL-PLUS FLOW MODELS PROVIDE A TOOL FOR PREDICTION OF FUTURE CHANNEL GEOMETRY CHANGES UNDER CONDITIONS OF CLIMATICALLY OR LAND-USE INDUCED VARIATION IN SEDIMENT SUPPLY AND HYDROLOGY?

Multiple terraces and recent severe gravel aggradation attest to profound, episodic changes in OZHI alluvial systems during the late Pleistocene to present (Saucier, 1987). Recent aggradation and instability have created extensive sand and gravel bars, long reaches of eroding cut banks, and thick accumulations of sandy overbank sediment (Barks, 1978). In the absence of significant tectonism, pre-historic alluvial changes probably resulted from climatically driven changes in runoff and (or) sediment supply in the contributing drainage basins. Historical aggradation and channel instability have been blamed on logging and grazing on steep uplands and in the riparian corridor; however, the background influences of climate change and cataclysmic flood events have not been assessed. Aggradation and instability have resulted in shallower channels, fewer deep pools, and unstable gravel substrate, which present a significant change in the availability of aquatic habitat compared to pre-historic conditions.

Paleohydrologic reconstructions from sedimentologic, isotopic, stratigraphic, archeologic, and pedologic analyses can describe paleoflow characteristics and document changes in processes of floodplain formation. Comparisons of the stratigraphic history with historic climate and landuse data, and paloeclimate and paleobotanical data, can be used to evaluate sensitivity of these basins to changes in climate and land use and establish past hydrologic analogs for hypothesized future climates. Processes and rates of recent channel instability can be evaluated from Government Land Office records and repeat photogrammetric mapping using aerial photography from 1938 to the present. The effects of individual recent flood events can be mapped and dated by dendrochronology. Combined with historic climate data, recent records of channel instability can be

used to evaluate spatial and temporal controls on channel instability and to detect trends during this time interval. The rates of present-day channel instability, and importance at a scale pertinent to aquatic habitat, can be established by monitoring channel geometry in representative reaches; predictions of future changes in channel geometry pertinent to aquatic habitat can be made by calibration of physically based flow models that predict velocity and boundary shear stress (Nelson and Smith, 1989). Once calibrated for Ozark streams, these models can be used to estimate changes in channel geometry under scenarios of changing sediment supply and hydrology.

Aquatic ecology

HYPOTHESIS 6: WILL STRUCTURE AND FUNCTION OF AQUATIC COMMUNITIES WITHIN THE CURRENT AND BUFFALO RIVER SYSTEMS BE ALTERED AS A RESULT OF CLIMATE INDUCED CHANGES IN TEMPERATURE AND STREAMFLOW?

HYPOTHESIS 7: WILL INCREASED CLIMATE VARIABILITY AFFECT FISH REPRODUCTION AND SURVIVAL IN OZARK STREAMS?

Ozark river systems contain a variety of stream segments and tributaries with different flow and temperature regimes within a single physiographic region. Many are influenced by groundwater springs others are precipitation fed (Barks, 1978; Dillard, 1977). Seasonal patterns and magnitude of discharge are major determinants of aquatic community composition, species abundance, and productivity in Ozark streams and springs (Barks, 1978).

The fish communities of OZAR and BUFF are some of the most diverse in North America (Cashner and Brown, 1977; Funk, 1970). The fauna has been well researched and monitored. Information is available on physiological tolerances, critical habitats, and other environmental requirements. Studies which focus on biodiversity in marginal habitats, e.g., tributaries and losing stream segments, can document the consequences of altered flow and temperature regimes. Species that exist in smaller, more variable water bodies are still fairly "intolerant" of change (Barks, 1978). Intensive examination of this faunal group should allow predictive models of the effects of global climate change to be made.

Benthic invertebrates in streams are known to be particularly sensitive in their life history patterns to alterations in thermal regimes and flow patterns (Barks, 1978), and would lend themselves well to a comprehensive modeling effort. The benthic invertebrates have been studied in relation to community diversity as well as for estimates of total secondary production (Geltz and Kenny, 1982; Livingstone and Rabeni, 1987). Thus, the groundwork has been laid for examining both structural and functional aspects of this important group.

HYPOTHESIS 8: ARE AQUATIC PLANTS, INVERTEBRATES AND FISH ENDEMIC TO COLD, CLEAR OZARK STREAMS AND SPRINGS SENSITIVE TO INCREASED UV-B EXPOSURE?

HYPOTHESIS 9: WILL INCREASED UV RADIATION AND ATMOSPHERIC CO_2 EXPOSURE INFLUENCE PRIMARY AND SECONDARY PRODUCTION IN OZARK STREAMS?

Increases in ultraviolet (UV) radiance due to ozone depletion and increases in water temperature due to gradual global warming can potentially have cumulative impacts on OZHI aquatic communities because of the characteristically clear water in which they reside and their often narrow thermal requirements. Most research emphasis on global climate change involves detecting and monitoring changes in biological variables over time. What is also required, however, is experimental evidence to predict responses of aquatic species at risk and critical ecological processes. Monitoring of existing conditions can then be interfaced with laboratory and field evaluations of changes in UV and temperatures to develop predictive models of changes in community structure and ecosystem function.

The effects of increased UV radiation and water temperature on aquatic species, communities, and ecosystem processes can be experimentally evaluated. Also survival and development rates of selected aquatic invertebrates and fish endemic to cold, clear-water Ozark springs and streams can be assessed in relation to increased water temperature and increased UV exposure. The UV-B wavelengths pose the greatest threat to aquatic biota and are expected to increase in intensity over the next several decades, as chloroflourocarbons, fossil fuel emissions, and other atmospheric emissions continue to degrade the ozone layer (Blumthaler and Ambach, 1990). Laboratory microcosms and onsite field enclosures can be used to experimentally evaluate how increased water temperature and UV exposure will influence aquatic primary and secondary production.

HYPOTHESIS 10: WILL COLD STENOTHERMAL PLANTS AND ANIMALS OF OZARK SPRINGS BE AFFECTED BY SMALL WATER TEMPERATURE CHANGES?

HYPOTHESIS 11: WILL VARIABILITY OF STORM EVENTS AS A RESULT OF GLOBAL-SCALE CLIMATE CHANGE INFLUENCE BIODIVERSITY AND ECOLOGICAL PROCESSES OF OZARK STREAMS AND SPRINGS?

Springs within OZAR and BUFF are unique point locations which integrate regionwide climatic, meteorologic, and watershed processes, thereby providing excellent sites to examine potential impacts of global climate change on aquatic biodiversity and community structure. They exhibit a distinctive flora and fauna characterized by evolutionary and physiological adaptation to cold water and a narrow range of temperature tolerance (Pflieger, 1982; Lipscomb, 1982). Over 40 species from springs and adjacent subterranean waters are endemic to the Ozark highlands region of Missouri and Arkansas (Pflieger, 1982). Of special interest are northern plants and

animals whose populations in Ozark springs are disjunct from the main body of the species more northerly range. These glacial relics will be particularly sensitive indicators of small temperature changes as a consequence of global climate change.

Long-term records of water temperatures exist for several Ozark springs. Precise monitoring can enhance this data base for modeling long-term trends. Also long-term population changes, biodiversity, and primary and secondary productivity of selected cold-water stenotherms and endemics of Ozark springs need to be defined. Furthermore, functional keystone species need to be identified and the dominant biogeochemical processes can then be tracked as part of a global climate change research program.

Terrestrial ecology

HYPOTHESIS 12: ARE THE INTERFACES BETWEEN GLADES AND FORESTS DYNAMIC SYSTEMS SENSITIVE TO PAST CHANGES IN TEMPERATURE AND PRECIPITATION?

HYPOTHESIS 13: ARE FIRE FREQUENCY AND SEVERITY AT THE FOREST/GLADE BORDER AFFECTED BY VARIATIONS IN CLIMATE?

HYPOTHESIS 14: WITH CLIMATE WARMING WILL UNFAVORABLE TEMPERATURE AND MOISTURE REGIMES ON GLADES MAKE TREE AND SHRUB SEEDLING ESTABLISHMENT MORE DIFFICULT?

The glades of OZAR and BUFF are unusual ecological systems embedded in a matrix of a more typical ecological character for the region, and the matrix (the forests) is much more extensive than are the glades themselves. The interfaces between the glades and the landscape matrix of forests are some of the most dynamic ecological systems in the region. Extensive background information exist for the glades of OZAR (Glenn-Lewin and Ver Hoef, 1989). Certain inventory work needs to be done at BUFF. The OZAR glades are of two major types, dolomite (and limestone) and igneous (rhyolite) (Nelson, 1985). The BUFF glades are primarily limestone (Keeland, 1978; Hinterthuer, 1977). Thus, comparisons of substrates within the region will identify any substrate effect on global change patterns. Comparisons of similar substrate types (limestone and dolomite) between OZAR and BUFF will sort out any regional (climate) differences at otherwise roughly similar latitudes. The glades of both areas share a few species, and exhibit similar species replacement. Thus, comparisons can be made for the same species at different sites, ecological replacements at different sites, and rare or sparse species at each site.

Spatial modeling of the glades over time will reveal both the changes at permanently marked points, and changes in ecological maps of species, combination of species, and environmental factors (Robertson, 1987). The second approach will use dendrochronological means to recover past events and monitor changes in the forest/glade border through time.

HYPOTHESIS 15: WILL CHANGES IN REGIONAL CLIMATE AFFECT MICROHABITATS AND POPULATION DEMOGRAPHICS OF RELICT BOREAL PLANTS OF THE OZARK HIGHLANDS?

Steyermark (1959) discusses 37 plant species with boreal distributions that have disjunct Ozark populations. Particularly notable relicts are Campanula rotundifolia, Galium boreale var. hyssopifolium, Trautvellavia caroliniensis, Zigadensis elegans and Waldsteinia fragarioides. The population centers of these species as listed in Fernald (1950), are far north of the Ozarks, extending southward only in the Rocky Mountains or Appalachians. Each is believed to be a relic survivor of a northern flora persisting in sheltered, favored localities of the Ozarks following the advances and retreat of one of the Pleistocene Ice sheets which drove species of the more boreal regions southward.

Climate change may be especially damaging to relict species whose habitats are restricted or fragmented. Global warming may cause a major rearrangement of life-zones. To survive, species may need to shift ranges considerable distances to keep up with the distribution of suitable habitat. This is unlikely for highly isolated relict surviving in precarious microclimates.

Socioeconomic

HYPOTHESIS 16: WILL INCREASED FREQUENCY AND DURATION OF WEATHER EXTREMES ASSOCIATED WITH GLOBAL CLIMATE CHANGE AFFECT RECREATIONAL LEVELS AND SEASONALITY OF USE?

HYPOTHESIS 17: WILL CHANGES IN OZARK HYDROLOGICAL SYSTEMS ASSOCIATED WITH GLOBAL CLIMATE CHANGE AFFECT RECREATIONAL LEVELS AND SEASONALITY OF USE?

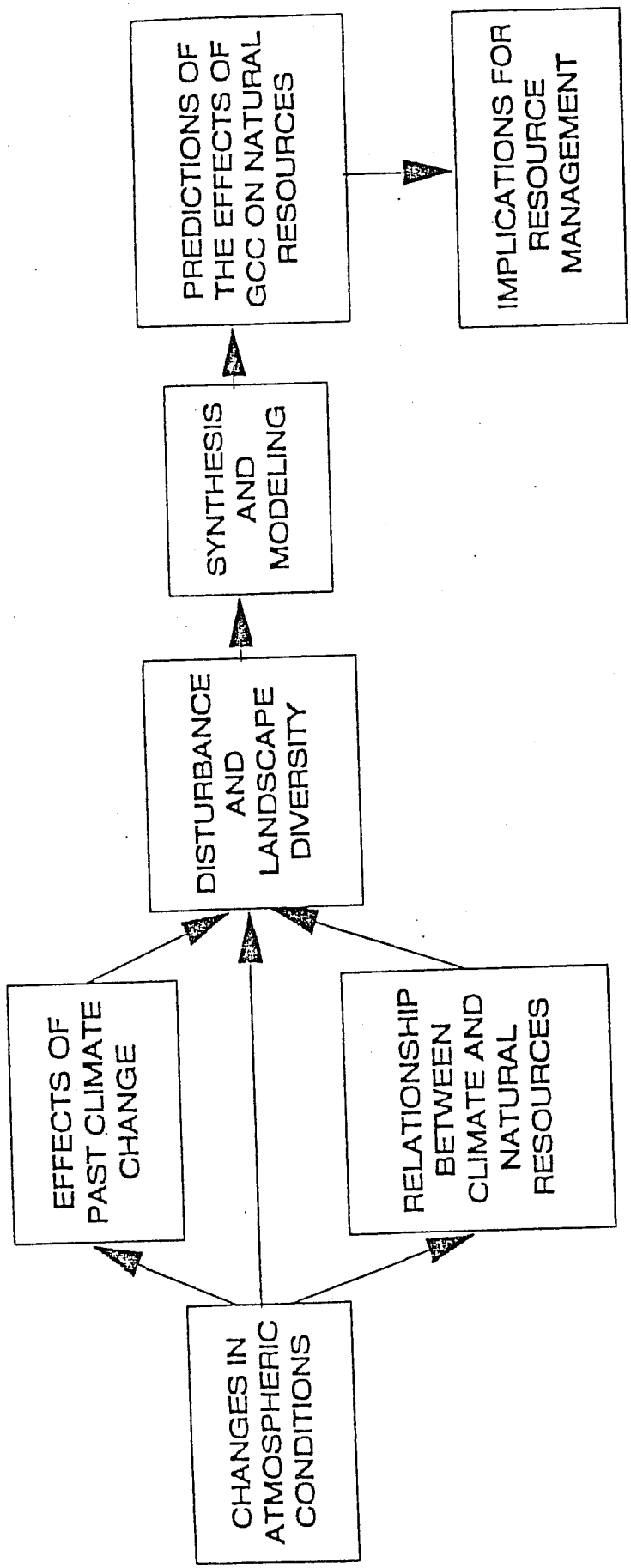
A river use monitoring system has been in place at OZAR since 1972 (Chilman and Everson, 1984). Rapidly increasing canoe use during the 1960's and 1970's necessitated determination of a recreational carrying capacity with related management objectives. The monitoring system measures canoeists' perceptions of quality aspects of their floating experiences and counts canoes rented by individual concessioners and privately-owned canoes for each of 10 designated management zones on the 140 miles of riverways.

Recreational canoeing in Ozark rivers is strongly keyed to seasonal river discharge and climate change may affect future recreation opportunities, demand, and patterns. An analyses of existing recreational use data collected under weather extremes may support predictive models of future recreational use under a more variable climate.

B. Research Matrix

Hypothesis Number	Hypothesis Priority	Project Phasing FY91	FY92	FY93	FY94	FY95	FY96
1	6	X	X	X	X	X	
2	17				X	X	
3	3	X	X	X	X	X	
4	4	X	X	X	X		
5	5	X	X	X	X		
6	1	X	X	X	X		
7	2	X	X	X	X		
8	7		X	X	X	X	X
9	8		X	X	X	X	X
10	9		X	X	X	X	X
11	10		X	X	X	X	X
12	11			X	X	X	X
13	12			X	X	X	X
14	13			X	X	X	X
15	14			X	X	X	X
16	15					X	X
17	16					X	X

C: Conceptual Overview



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Section II. Program Operation

A. Personnel Line and Functional Relationships: General supervision of the Biogeographic Area Coordinator (BAC) will be provided by the Regional Chief Scientist, Division of Natural Resources, Midwest Region. The BAC will supervise assigned program personnel, i.e., GIS Specialist and other disciplinary or clerical personnel, as needed to support strategic elements of the GCP. The WASO GCC coordinator will provide overall program guidance.

The BAC will maintain a strong functional liaison with park staffs, regional academic institutions, government agencies and other NPS Biogeographic Areas to coordinate the OZHI GCP and enhance program effectiveness and continuity. To assist in this effort, an interdisciplinary advisory committee will be established and each Park Superintendent will be asked to name a staff member to act as park GCP coordinator for on-going program guidance and support. The advisory committee membership will include park superintendents, park scientists and resource managers, academic disciplinary experts, and key representatives from other agencies involved in GCC research. The committee will provide advice and recommendations to the BAC on program direction, priorities, quality control and identifying linkages to the OZHI GCP.

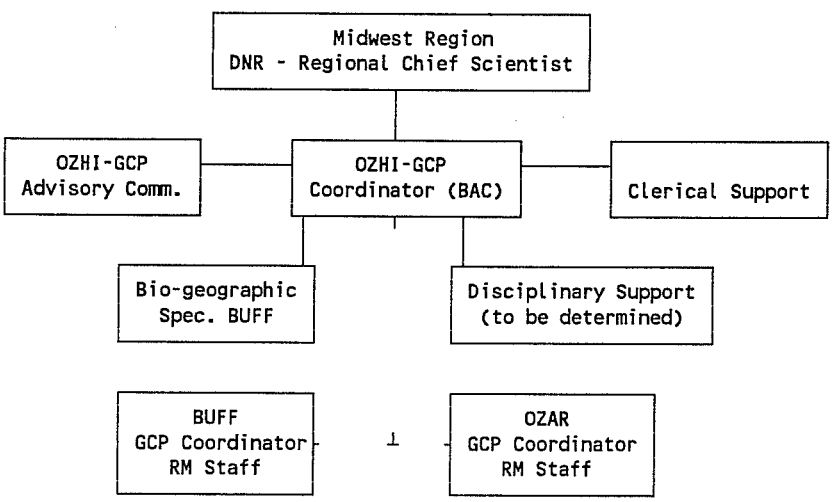

Figure 1. Proposed Organization Chart

B. Personnel Requirements and responsibilities: Initially, the minimum requirement will be the (BAC) position with adequate support funding to implement and administer the GCP. It would also be highly desirable to add a Geographic Information System (GIS) specialist at program inception to inventory existing databases, identify data voids, complete a plan for procurement of additional data and utilize the equipment available at OZAR and BUFF to support the OZHI GCP. Also, the Park GCP Coordinators are key program positions and should be budgeted part-time to facilitate field research activity in the parks. In the out-years, additional staff expertise may be

necessary to provide for long-term GCP emphasis and disciplinary support requirements.

1. BAC: This position will require a strong background of academic training and experience in ecology and considerable experience in research administration. This individual will be responsible for the overall administration of the OZHI GCP, i.e., coordinating the preparation and peer review of research proposals, preparing the annual work plan, documenting obligations of NPS program funds and "leveraging" funds from outside sources, developing annual program recommendations and budget justifications and defending them before the GCPC, updating the GCP at regular intervals, monitoring and documenting program accomplishments, assuring compliance with CEES and Departmental information and data management procedures and related quality control/quality assurance procedures. He/she will maintain communication with park(s) resource management and interpretation programs, coordinate NPS research with other agencies and institutions as well as other NPS Biogeographic Area Programs and encourage other scientists to use NPS areas for global change observations and research. In addition, the BAC will be responsible for the supervision of OZHI GCP staff positions, i.e., the GIS specialist and others as designated. He/she will work closely with both Regional Offices and the WASO GCP Coordinator to ensure that the Biogeographic Area Program meets NPS, Departmental, and CEES research goals and priorities. The BAC may also serve as a principal investigator or collaborator in global change research, although the primary duties involve the administration of the research program. The BAC will be stationed at the University of Missouri (see C. following).

2. GIS Specialist: This position will require a combined knowledge of biological and physical sciences such as ecology, botany, wildlife biology, hydrology, geology, physical geography, and remote sensing, etc. This individual would be responsible for assessing information needs, planning for data procurement, developing methodologies and producing digital databases to support program needs. Knowledge and skill in the application and operation of GIS equipment (computers, graphic terminals, plotters, digitizers) and operating systems (UNIX, GRASS, SAGIS, ELAS) would be required. This position would be located at BUFF.

3. Park Coordinators: These positions would serve as the primary link between the BAC and the field research program by providing for logistical and technical support for investigators, communication with park staff and on-site data management. At base funding levels, these duties will be assigned to existing staff as a collateral duty. We would recommend that these positions be funded on a part-time basis to enhance their effectiveness by expanding duties and responsibilities. Long-term planning should consider

the option of establishing full-time positions to meet this need.

4. Contributed NPS Staff: Logistical, technical and field project assistance will be provided by resource management staff at both parks and by the Research Coordinator at OZAR. The Chief of Interpretation at both parks will ensure that interpretation programs newsletters, brochures, etc. include information and educational material on the global climate change issues and the GCC Program.

C. Technical Requirements and Support Services: The BAC will be duty-stationed at the Missouri Cooperative Fish and Wildlife Research Unit (MCFWRU) at the University of Missouri-Columbia. The MCFWRU is located within the School of Natural Resources which is comprised of five departments (Fish and Wildlife, Soils, Forestry, and Parks, Recreation and Tourism). The MCFWRU is part of a network of Cooperative Fish and Wildlife Research Units that exist is 41 states including a new unit at the University of Arkansas - Fayetteville. The BAC will be provided office and laboratory space, equipment and secretarial support and a reduced overhead rate on research projects administered through the Unit. The BAC will have full faculty status and as such access to university facilities and services.

Staff at BUFF and OZAR and existing linkages with regional academic institutions and natural resource agencies provide an excellent base for technical support at the park level. BUFF has a five-person Resource Management staff which includes a hydrologist and fire management officer (FMO). OZAR has a four-person Resource Management staff which includes a aquatic ecologist, fishery biologist, wildlife biologist and FMO. Cooperative research relationships between OZAR and the University of Missouri - Columbia (UMC), Southern Illinois University (SIU) and Southwest Missouri State University (SMS) were established nearly twenty years ago and are continuing. Cooperative agreements are presently in effect with UMC, SIU, Lincoln University and Iowa State University. Interagency agreements with the U.S. Geological Survey (USGS), U.S. Fish and Wildlife Service (FWS) and Missouri Department of Conservation (MDC) are in place to facilitate cooperative research at OZAR and BUFF.

Facilities to support researchers are available at both parks. Approximately 3,300 square feet of building floor space has been dedicated to research use at OZAR. This includes sleeping quarters, a water quality laboratory, kitchen and additional space for field offices or other uses. The BUFF hydrologist maintains a small (200 sq ft) water quality lab. Small libraries exist at both parks. Computer modem connections are available with state university library systems at both parks.

Computer support is excellent at both parks which have on-line a variety of PC configurations to meet most standard needs such as word processing, spread sheets, database and graphics production. In addition, OZAR

has on-line a AutoCAD software/PC-386 platform for GIS and other applications. A GRASS software/UNIX platform will be on-line at BUFF in FY91 for additional GIS applications. This combined GIS capability is ideal for development of a variety of themes and construction of digital data bases.

Additional computing capability can be made available through linkage to mainframe facilities at the Universities of Arkansas and Missouri. Budget tracking, personnel and other administrative support will be provided buy the staff at BUFF or OZAR. Policy or other items that require regional action will be handled by the MWRO.

D. CEES Data Management Objectives: Information management mechanisms will be established that best serve the purpose for describing, gathering, transmitting, validating, processing, archiving and disseminating scientific data relating to the GCP. Minimum data standards will be established for each monitoring and research project to meet CEES and individual project requirements. Documenting accuracy and quality assurance will be the responsibility of each investigator and will be peer-reviewed. Establishing an OZHI-GCP archive center for data sets in a standardized format will be a high priority program objective. Where feasible, existing data sets will be converted, referenced and archived.

E. Internal Coordination: Coordination mechanisms within each park are in place so the principal effort will be placed on integrating the GCP into this structure and creating linkage between the two core parks. Emphasis will be placed on communication between parks and other NPS-GCP sites and generating awareness/support of park staffs and other constituents.

Coordination and communication will be promoted through on-going park staff meetings, periodic meetings of research and advisory groups, annual science meetings at core parks, publication of an annual report, periodic meetings of coordinators and other GCP participants and sharing of investigator publications/project proposals. Brochures and other awareness communication media will be produced cooperative with park interpretive staffs and GCP personnel or other technical support.

F. External Coordination: Established relationships with other agencies, institutions and private sector organizations will be emphasized with the objective of extending linkages on a regional/national/international scale. This will be a priority responsibility of the BAC in order to seek opportunities for cooperative efforts, leverage funds, encourage involvement in the GCP and care parks and preclude duplication in research programs.

The parks have a long history of cooperation with Federal agencies - USGS, USFS, USFWS, EPA; state agencies in Arkansas and Missouri; research and collaboration relationships with the Universities of Arkansas and Missouri, Southern Illinois University, Lincoln University, Southwest Missouri State University and John A. Logan College. The Research Scientist at OZAR was appointed as a Research Associate in 1980 at the University of Missouri and

participates on graduate student committees, etc. The advisory committee will enhance the external coordination effort through participation by many of the aforementioned entities.

The core parks are participating with the USFS, four state agencies and The Nature Conservancy to investigate the feasibility of establishing an Ozark Highlands Biosphere Reserve under the sponsorship of U.S. Man and the Biosphere (MAB) program. Since the MAB and GCP areas of consideration are one of the same, the BAC will become a member of the OZHI MAB Steering Committee to insure proper linkage of these programs.

G. Areas of Research: The following are possible topics of research that could become thematic initiatives in future years.

1. Freshwater streams and springs.
2. Cave formations.
3. Forest/grassland ecotones.

Section III. Project Proposals

Priority Number: OZHI-I-01

Project Title: An integrated approach to evaluate effects of global climate change on ecological structure and function of Ozark Highland streams.

Program Component: Integrated Studies of National Park Ecosystems Research.

Research Category: Research on Species and Ecological Communities.

CEES Science Element and Science Priority: Ecological Systems and Dynamics--long-term measurements of structure/function.

CEES Activity: Observe, Data systems, Understand, Predict

Preliminary Budget Estimates:

		Budget Year Estimates ($K)				
Science Elements	Activity Element	1	2	3	4	5
ESD	Observe	30	30	30	30	10
	Data systems	20	20	20	20	40
	Understand	30	50	60	60	30
	Predict	10	40	50	50	60
	TOTAL	90	140	160	160	130

Project Description: Climatic factors are important correlates of productivity in aquatic systems (Brylinsky 1980) and predicted global changes have potential to influence both streamflow and water temperatures. Physical stream variables, especially flow dynamics (average flow and storm-scale events) temperature regime, water depths, current velocity, and substrate characteristics are major determinants of aquatic community structure and function (Vannote et al. 1980, Brussock et al. 1985, Huryn and Wallace 1987). An understanding of the associations among organisms, ecological processes and those habitat features likely to change because of global warming will allow us to use models that simulate habitat availability as a function of physical stream variables to predict and monitor effects of global change.

This project will develop a fundamental understanding of the relationships between the in-stream physical and chemical variables, primarily flow and temperature characteristics, regulating habitat availability, and aquatic community structure and function in the OZAR and the BUFF. It will evaluate the spatial and temporal variation inherent in the existing ecosystem, how ecological processes and the biota respond to that variation, and will yield conceptual and simulation models and a monitoring strategy to predict alterations due to global change.

Objectives:

1. Establish detailed habitat descriptions in stream sections of both river systems representing headwater, midreach, and downstream sections.

2. Verify and calibrate existing flow models to predict how climate-induced changes in hydrology will influence channel geometry.

3. Quantity habitat conditions at various temperatures and flows (using U.S. FWS instream flow models; e.g., PHABSIM) at a spatial scale appropriate to an organism's microhabitat.

4. Choose several indicators (e.g., algae, invertebrates, fish guilds) and determine their microhabitat needs and temperature preferences in a field environment.

5. Quantity selected water chemistry variables, relative biomass of dominant plant and animal guilds, organic matter, and nutrient fractions, and community metabolism within dominant habitat types of stream reaches.

6. Relate biodiversity, community structure and functional processes to the multivariate influences of temperature, flow patterns, water depth, current velocity, and substrate type.

7. Link the habitat-flow/temperature model to ecological processes and to the distribution and abundance of biota to predict climate induced stream ecosystem change.

8. Utilize models developed to predict changes in the aquatic community beyond the measured parameters to long-term changes in temperature and flow.

External Linkages: This project, by design, directly incorporates principal investigators from three Federal agencies and two universities. The project relates to ongoing University of Missouri-Columbia (MU) Atmospheric Science projects on modeling global change in the Midwest, as well as a direct linkage for data collection and analysis with U.S. FWS's Global Change Project through their National Fisheries Contaminant Research Center. Linkages are established with the USGS's Ozark Streams Geomorphology Project, which is investigating climatic and land-use influenced changes in stream geomorphometry, the U.S. FWS's instream flow group from the National Ecology Research Center, and the Geographic information System, Archaeological Survey, University of Arkansas.

Internal Linkages: Park related antecedents for the project include 14 completed relevant research projects and 6 ongoing research projects which provide over 10 years of data on Ozark rivers structures and function. Most studies were jointly funded by a combination of NPS, USGS, U>S. FWS, Missouri Department of Conservation, and Arkansas Department of Game and Fish. Logistics, equipment, and facilities support for this project will be supplied by all the above named agencies.

Milestones:

Year 1 - Accomplish Objective #1; begin Objectives 2, 3, 4, and 5.

Year 2 - Continue Objectives 2, 3, 4, and 5; begin Objective 6.

Year 3 - Complete Objectives 2, 3, 4, and 5; initiate analysis process of Objectives 6 and 7.

Year 4 - Accomplish synthesis of Objectives 6 and 7.

Year 5 - Accomplish Objective 8 to establish monitoring program.

Data Management: All data will be archived in commonly accepted formats, readily transferable to users interested in statistical, GIS or IFIM analysis. Standard location data will be used for future GIS purposes, and data will conform to requisites for appropriate times series analysis. Quality Control guidelines from the Environmental Protection Agency or U.S. FWS will be used as appropriate. Appropriate data validation will occur at several steps in the project.

References:

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Meyer, R.L. and D.L. Galat. 1990. Predicting and monitoring effects of increased temperature on stenothermal algal assemblages in Ozark Highland springs. Preproposal submitted to NPS by Univ. of Arkansas and FWS.

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Smith, R.C. and K.S. Baker. 1979. Penetration of UV-B and biological effective dose-rates in natural waters. Photochem. Photobiol. 29:311-323.

Worrest, R.C. 1982. Review of literature concerning the impact of UV-B radiation upon marine organisms. Pages 429-458 in J. Calkins (ed.), The role of solar ultraviolet radiation in marine ecosystems. Plenum Press, New York.

Priority Number: OZHI-I-02

Project Title: Climatic and land-use effects on the fluvial geomorphology of Ozark streams

Program Component: Integrated Studies of National Park Ecosystems

Research Category: Ecological Research on Small Watersheds

CEES Science Element and Science Priority: Earth System History--paleoclimate; paleohydrology

CEES Activity: Observe, Data systems, Understand, Predict

Preliminary Budget Estimates:

		Budget Year Estimates ($K)				
Science Elements	Activity Element	1	2	3	4	5
ESH	Observe	69.7	46.3	23.2	19.7	19.7
	Data systems	5.6	5.6	5.6	1.5	1.5
	Understand	8.6	31.8	23.2	-	-
	Predict	___	___	23.2	19.7	19.7
	TOTAL	83.9	83.7	75.2	40.9	40.9

Project Description: This project is designed to develop a predictive model for stream-channel changes due to climate changes, extreme hydrometeorological events, and land-use changes. The project includes analysis of paleohydrology to test the hypothesis that climate changes over the past 10,000-20,000 years have had important influences on the hydrologic regime of Ozark streams (hypothesis 3; see, for example, Brakenridge, 1988; Knox, 1988). Documentation of periods of aggradation and erosion, and correlation to paleoclimatic records, will develop understanding of how late Pleistocene and Holocene climate changes affected OZAR streams, and provide a predictive model for how future climate changes will determine channel geometry and alluvial materials. Paleohydrologic analysis will include characterization of hydrologic regimes by evaluation of sedimentology and

stratigraphy of terrace remnants and modern alluvial sediments, dating of terrace sediments using isotopic analyses, archeological data, and dendrochronology, correlation of alluvial sediments using pedologic criteria, and mapping of discrete chronostratigraphic units by photogrammetry and field methods.

For the time interval mid-1800's to the present, historical aerial photography, government land office records, and dendrochronology will be used to test hypotheses concerning the effect of land-use changes, small-scale climate shifts, and extreme hydrometeorological events on channel instability (hypothesis 4). These data will serve to evaluate and separate the influences of climate change, extreme floods, basin-wide land use, riparian land use, valley geometry, and tributary sediment influxes on timing and location of recent channel instability and aggradation. Maps of channel positions, gravel deposits, and riparian vegetation from 1939 to the latest available aerial photographs (at approximately 10 y intervals) will be compiled by stereoplotter and recorded in a digital geographic information system that will be useful for monitoring and updating future alluvial changes.

To test the hypothesis that channel instability and aggradation has significantly changed fish habitat (hypothesis 5), 8-14 representative reaches of streams will be chosen for installation of monumented cross sections which will be periodically resurveyed to document present rates of gravel deposition and erosion; this network should be considered for monitoring channel-geometry changes beyond the time span of this project. Reaches will be chosen to represent the range of channel instability existing in the OZAR and cross sections will be spaced along the channel to resolve channel geometry features significant to fish habitat. In addition to channel geometry and bed roughness data, bedload transport and velocity will be measured to verify and calibrate a 2-dimensional-plus flow model (Nelson and Smith, 1989) to predict the distributions of velocity and boundary shear stress under changing hydrologic and sediment supply conditions. Once calibrated, this model will provide capability to predict how future changes in hydrology and sediment supply, induced by changes in either land use or climate, will change channel geometry and hydraulics at the fish-habitat scale.

External Linkages: This project will be carried out by the U.S. Geological Survey, Water Resources division, Missouri District Office. The U.S.G.S. currently houses the Ozarks Stream Geomorphology Project (OSGP), which will serve as the umbrella for the project. The OSGP is jointly funded by the U.S.G.S. and the Missouri Department of Conservation, with research links with the U.S. Forest Service and Soil Conservation Service. In addition to the work proposed here for the OZAR, the OSGP is studying streams in the more heavily agricultural areas of the northern Ozark Plateau. Expansion of the OSGP to the OZAR allows for evaluation of climatic and land-use influences over a broader range of land-use, physiography, and drainage-basin size. Involvement with the National Park Service Global Change Research Program will also provide opportunities for multi-disciplinary

interactions with terrestrial and aquatic ecologists. The U.S.G.S. will provide expertise in geographic information systems, photgrammetric mapping, hydrologic monitoring, geomorphology, stratigraphy, and sedimentology.

Internal Linkages: Data and results from this study will have direct application to fish habitat studies and stimulations proposed jointly by the National Park Service/Water Resources Division, Missouri Co-op Unit Fish and Wildlife, Arkansas Co-op Unit Fish and Wildlife, and University of Arkansas. Stream reaches used by both projects will be coordinated and data and results will be shared. Long-term climatic records generated by proposed research on tree rings, bat guano, and cave speleothems (University of Missouri Columbia, University of Arkansas, Ozark Underground Laboratory) will be compared with the stratigraphic record of alluvial changes.

Milestones:

Year 1 - Establish monumented cross sections.

Year 2 - Complete stratigraphic framework for late Pleistocene and Holocene, ONSR

Year 3 - Complete photogrammetric mapping, 1939 to 1984(?)

Complete data collection for monitoring studies, begin model calibration.

Year 5 - Results, completed GIS, flow model.

Data Management: Data collected for the project will be archived digitally in transferable format. Maps will all be compiled and stored as ARC/INFO coverages with dataset documentation standards of the U.S.G.S. Photogrammetric map accuracy will be evaluated and documented; precision and accuracy are largely dependent on quality of available historical aerial photography. Analytical laboratory data and associated estimates of accuracy will be archived as transferable ASCII data sets. Hydrologic monitoring data will be collected following established U.S.G.S. guidelines and will be archived in standardized National Water Information Service formats with provisions for translation to other systems and formats. All data will be published and available to the public and other workers. As much as practical, datasets will be published digitally.

References:

Brakenridge, G.R. 1988. River floods regime and floodplain stratigraphy, in, Baker, V.R., Kochel, R.C., and Patton, P.C., eds., Flood Geomorphology: Wiley-Interscience, New York, p. 139-156.

Knox, J.C. 1988. Climatic influence on upper Mississippi Valley floods, in, Baker, V.R., Kochel, R.C., and Patton, P.C., eds., Flood Geomorphology: Wiley-Interscience, New York, p. 279-300.

Nelson, J.M., and Smith, J.D. 1989. Evolution and stability of erodible channel beds, in, Ikeda, S., and Parker, G., eds., River Meandering, American Geophysical Union, Water Resources Monograph 12, p. 321-377.

Priority Number: OZHI-I-03

Project Title: High resolution climate and streamflow reconstructions for the Ozark Plateau using long-term tree-ring data.

Program Component: Integrated Studies of National Park Ecosystems

Research Category: Paleostudies

CEES Science Element and Science Priority: Earth Systems History--paleoclimate; paleohydrology

CEES Activity: Observe, Data Systems, Understand, Predict

Preliminary Budget Estimates:

		Budget Year Estimates ($K)				
Science Elements	Activity Element	1	2	3	4	5
ESH	Observe	23.2	25.6	11.6	-	-
	Data systems	23.2	25.6	23.2	11.8	-
	Understand	11.6	12.8	23.2	35.4	-
	Predict	-	-	-	-	-
	TOTAL	58	64	58	59	-

Project Description: This project will use long, climate sensitive tree-ring chronologies to reconstruct and analyze past climate and streamflow on the Ozark Plateau. Twenty new tree-ring chronologies will be developed, primarily in the drainage basins of the BUFF and the OZAR. These new tree-ring chronologies will be coupled with existing long chronologies on or near the Ozark Plateau (Stahle et al. 1985a) to develop quantitative reconstructions for a suite of hydrometeorlogical variables, including streamflow, spring discharge, precipitation, drought indices, cloud cover and temperature on a seasonal to annual basis for the past 300 to 800 years. Previous reconstructions of annual runoff for the White River Arkansas (Cleaveland and Stahle 1989), percent possible sunshine for the Ozark region (Stahle et al. in press), and long tree-ring estimates of precipitation and drought indices elsewhere in the southcentral USA demonstrate the feasibility of the proposed research (e.g., Blasing et al. 1988, Stahle et al. 1985b). An extensive geographic array of tree-ring chronologies has been developed for the USA but much of the Ozark Plateau and the BUFF and OZAR are poorly sampled at present. A more representative network of chronologies within each drainage basin will be necessary for the highest quality streamflow reconstructions. We propose to non-destructively sample a variety of tree species to ensure both the longest possible chronologies and the most accurate and detailed reconstructions of climate or streamflow. The preferred species will be baldcypress (Taxodium distichum) and red cedar (Juniperus virginiana) given their documented longevity and

climate sensitivity (Stahle et al. 1985b, Guyette 1981). Baldcypress is not native to the Ozark Plateau, but existing 800-year long chronologies flank the plateau to the east and south. These cypress chronologies are highly sensitive to the Ozark regional climate, and will be extremely valuable for the proposed paleoclimatic reconstructions. Because several long baldcypress chronologies are already available, the proposed collections will concentrate on Ozark red cedar sites. White oak (Quercus alba) and post oak (Q. stellata) will also be heavily sampled because old, climate sensitive oaks are abundant, and these trees contain the most detailed frost ring record of severe late-spring freeze events yet discovered (Figure 2, Stahle 1990).

Accurate information on long-term climate means, variability, and trend is essential to understanding of the ecosystem response to existing climate and will be necessary for detecting climate change in the future. However, the episodic occurrence of climate extremes such as multiyear drought or consecutive years with severe spring frosts may be more significant to the dynamics of terrestrial and aquatic ecosystems than a gradual shift in the climate mean or variance. An increase in the frequency of climate extremes could, in fact, become the most important agent of ecosystem change in the event of global climate changes over the next two centuries. We therefore, propose to document the long term climate mean and variance, and to thoroughly investigate the individual and joint frequency distributions of several hydrometeorlogical extremes using both modern instrumental records and long term tree-ring reconstructions (e.g., severe droughts, late spring frosts). We also propose to evaluate the consecutive and concurrent occurrence of various extremes, and to develop cumulative stress indices for observed and reconstructed climate and streamflow data. Thorough analyses of the available data on past extremes will be important because the terrestrial and stream ecosystems of the Ozarks have clearly adapted to these episodic events, and only substantial changes in the recurrence of extremes are likely to result in wholesale environmental changes.

Some of the climate extremes that punctuate the instrumental and proxy record of climate in the southcentral USA have been linked to equally unusual extremes of the El Nino-Southern Oscillation or ENSO (e.g., extremely wet and cloudy growing seasons; late spring freezes). If global warming occurs and amplifies the ENSO as predicted by some climate models (e.g., Graham 1990), then the frequency of teleconnected climate extremes over the southcentral USA could also increase. If the connections between certain Ozark climate extremes and the ENSO can be substantiated during the proposed work, they could provide a basis for predictive models linked to ENSO activity.

External Linkages: The proposed research will be conducted at the University of Arkansas Tree-Ring Laboratory (TRL). The TRL is presently conducting tree-ring and paleoclimatic research in the Southeastern USA, funded by

the Climate Dynamics Program of the National Science Foundation (NSF) and the National Oceanic and Atmospheric Administration (NOAA) under the Climate and Global Change program. Results of the proposed analyses will be relevant to most of the draft global change research hypotheses suggested for the Ozark Highlands, and will be an important contribution to global climate change research being conducted by several national and international science agencies.

Internal Linkages/Readiness: Reconstruction of past climate and streamflow in the OZHI are important in developing predictive models in all areas of research. This project will build on limited red cedar chronologies previously developed (Guyette, 1981).

Milestones:

Year 1 Non-destructively sample old-growth forests, develop tree-ring chronologies

Year 2 Continue Year 1 work, begin climate reconstructions and analyses

Year 3 Finish Year 1 work, continue Year 2 work

Year 4 Complete analyses of observed and reconstructed data

Data Management: The basic products of the proposed research will be exactly-dated, well-replicated annual ring width chronologies, and seasonal or annual reconstructions of several climate and streamflow variables covering the past several centuries. The dated and measured ring width data, and the derived site chronologies and regional climatic or streamflow reconstructions will be archived in digital format, and will be made available through the TRL and the National Geophysical Data Center, NOAA, Boulder, Colorado.

References:

Blasing, T.J., D.W. Stahle, D.N. Duvick, 1988 Water Resources Research. 24:163-171.

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Graham, N.E., 1990. Workshop on Paleoclimatic Aspects of El Nino/Southern Oscillation. NOAA, Boulder, CO.

Guyette, R.P., 1981. Thesis, University of Missouri, Columbia.

Stahle, D.W., 1990. Dissertation, Arizona State University, Tempe.

Stahle, D.W. et al., 1985a. Tree Ring Chronologies for the Southcentral United States, TRL, State Climatologists Office, University of Arkansas, Fayetteville.

Stahle, D.W., M.K. Cleaveland and J.G. Hehr, 1985b. Nature. 316:530-532.

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Priority Number: OZHI-I-04

Project Title: Predicting and monitoring effects of increased temperature on stenothermal algal assemblages in Ozark Highlands springs.

Program Component: Integrated Studies of National Park Ecosystems

Research Category: Research on Species and Ecological Communities.

CEES Science Element and Science Priority: Ecological Systems and Dynamics--long-term measurements of structure/function

CEES Activity: Observe, Data Systems, Understand, Predict.

Preliminary Budget Estimates:

		Budget Year Estimates ($K)					
Science Elements	Activity Element	1	2	3	4	5	6
ESD	Observe	32	23	23	22	20	20
	Data systems	3	3	3	4	5	5
	Understand	1	1	2	2	2	-
	Predict	-	1	1	2	2	2
	TOTAL	36	28	29	30	29	27

Project Description: The Ozark Highlands are characterized by karstic topography containing a complex network of underground drainage channels. Water in these channels typically emerges as springs and is a major source of discharge to Ozark rivers. The seasonal presence of certain algal taxa are closely related to water temperature and they are sensitive to minor temperature changes (Meyer 1975-78, Meyer and Rippey 1978, Lipscomb 1982). Springs consistently have these stenothermal species associated with their constant temperature outlets (Kawanishi 1988, Vinson and Rushforth 1989), but exhibit varying seasonal and longitudinal floras in their outflowing streams (spring branches) because the spring branch is influenced by large seasonal fluctuations in surrounding air temperature. The spring ecosystem, therefore, is well structured to test the hypothesis that measurable changes in global climate will result in changes in stenothermal aquatic populations. Temperature increase in the midwest as a result of global warming (Decker and Achutuni 1988) is anticipated to have a greater impact on this obligatory cold water community than on any other above-ground Ozark Highland aquatic habitat. Furthermore, earlier detection of small changes in water temperature, discharge and floral biodiversity may be possible than for other Ozark Highland aquatic ecosystems because of the lower long-term temporal and spatial thermal variance characteristic of spring outlets. Lastly, subtle temperature changes will be most evident in the algal primary

producers because of their short generation time before changes are detectable at higher trophic levels.

Springs and their spring branches provide two mechanisms to determine the impact of subtle changes in global climate: (1) A comparison of seasonal variation in temperature of the spring branch versus the spring outlet, and (2) the positional shift of algal assemblages along the spring branch. Vemal and autumnal season spring outlet and spring branch temperatures are equivalent because average air and ground temperatures are equivalent. During summer and winter when average air and ground temperatures differ, spring branch temperatures will be higher or lower, respectively, than temperatures of the spring outlet. Thus, there will be a thermal gradient in the spring branch during summer and winter having logitudinally distributed stenorthermal algal assemblages whose species composition differs from that of the spring outlet. The algal community in the spring branch corresponds to the community in the lutlet only during the vernal and autumnal seasons. The position of algal assemblages toward or away from the spring outlet along the spring branch will detect small changes in temperature thereby serving as bioindicators of the effects of regional climate change.

Three categories of cold stenothermal assemblages are represented in the annual cycle of the algal community. Category 1 are those species which occur in the winter when water temperatures are less than the ground water temperatures ($<10^{o}$). Category 2 species are those which have a maximum thermal tolerance at the present ground water temperature (ca. 12-15°). A third category (3) includes warm stenothermal species which are present in the summer. A reduction of the category 1 assemblage with an increase in occurrence of category 2 and/or 3 assemblage taxa would provide the redundancy necessary to predict the initial influences of climatic warming on aquatic communities.

We will sample several Ozark springs to define normal variation within these ecosystems and determine the importance of light and flow rate on community structure (Quinn and McFarlane 1989). Springs existing from the same and differing geologic strata will be included to evaluate effects of varying water retention time and chemical environment on algal community structure. Springs of varying discharge will also be sampled to test if spring size is a critical factor in detecting temperature induced climate change.

Research and monitoring will include a thorough analysis of the natural algal flora and associated chemical and physical parameters from selected Buffalo and Current River system springs, including Big Spring, currently under a National Park Service (NPS) funded study (Galst 1990). Physico-chemical parameters will include conductivity, temperature, light penetration, flow rate, pH, alkalinity, nitrogen and phosphorus. These parameters will be supplied for Big Spring as part of the present study. Additionally, we will reactivate the discharge gauge at big Spring and upgrade it to also provide daily temperature and conductivity monitoring. Historic Big Spring

discharge data (1921-mid 1970's) will be compiled and a time-series statistical analysis performed to identify long-term patterns and trends. Possible future climate induced changes in spring discharge can be compared with this long-term data set.

Artificial substrates may be introduced as standardized microhabitats. These substrates would augment the natural substrates. A statistical comparison between the two substrates will determine the applicability of the artificial substrate as a standardized long-term monitoring sampling device (Meyer 1980).

External Linkages: U.S. Geological Survey (USGS), Water Resources Division, Rolla, MO, will upgrade and maintain Big Spring gauge. The taxonomic/ecological data will be merged with an existing data base at the University of Arkansas Phycology Laboratory and Missouri Department of Conservation (MDC) Heritage Data Base. Chemical and physical parameters will be compared to known geohydrological data on spring water quality from the USGS, NPS, regional universities, and other information sources. Results can also be compared to information from spring systems at other Biosphere Reserve sites (e.g., Krienitz 1988).

Internal Linkages: The identification of indicator species from this study will provide information necessary to initiate the experimental studies proposed by Galat et al. (1990). Park related antecedents for the project include 14 completed relevant research projects and 6 ongoing relevant projects which provide over 10 years of data on Ozark rivers ecological structure and function. Most were funded jointly by the NPS, FWS, Missouri Department of Conservation and Arkansas Game and Fish. Logistics, equipment and facilities support for this project will be supplied by the FWS, MDC, UA and MU.

Milestones:

Year 1 - Identify research sites and protocol; determine annual characteristic algal community structure. Reactivate Big Spring stream gauge. Compile historic Big Spring flow records.

Year 2 - Analyze Year 1 data; extend sampling sites to short retention time sites. Complete time series analysis of historic Big Spring flow data.

Year 3 - Integrate year 1 and 2 data; select indicator species; extend sampling to differing geological substrata; develop predictive models.

Year 4 - Introduce artificial substrates at Year 1 and 2 sites; test predictive models on initial sites.

Year 5 - Introduce artificial substrates at additional substrate sites; test predictive models on all sites.

Year 6 - Test predictive models at all sites.

Data Management: Data collected will include verified algal taxa with appropriate literature citations and archived collections. These collections can be subdivided and shared with qualified workers and/or deposited in selected

herbaria. Collection techniques and analysis will follow approved methods and procedures. QA/QC guidelines from U.S. Environmental Protection Agency and USGS will be used as appropriate. All data will be recorded on magnetic media in ASCII files accessible by most word procession, spreadsheet, graphical, and statistical software. Hard copies of the original bench sheets, statistical data, graphical presentations, reports, and other annotations will be deposited in the Phycology Laboratory at the University of Arkansas. Regular reports of data and analysis will be provided to the NPS. Results of the research will be presented to scientific societies and published in refereed journals.

References:

Decker, W.L. and R. Achutuni. 1988. The use of statistical climate-crop models for simulating yield to project the impacts of CO_2 induced climate change. DOE/ER/60444-H1. U.S. Dept. Energy, Office of Energy Res., Washington.

Duncan, S.W. and D.W. Blinn. 1989. Importance of physical variables on the seasonal dynamics of epilithic algae in a highly shaded canyon stream. J. Phycol. 25:455-461.

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Priority Number: OZHI-I-05

Project Title: Experimental effects of increased temperature and UV-B exposure on species and communities of Ozark Highland streams and springs.

Program Component: Integrated Studies of National Park Ecosystems

Research Category: Research on Species and Ecological Communities.

CEES Science Element and Science Priority: Ecological Systems and Dynamics--long-term measurements of structure/function

CEES Activity: Observe, Data Systems, Understand, Predict.

Preliminary Budget Estimates:

		Budget Year Estimates ($K)				
Science Elements	Activity Element	1	2	3	4	5
ESH	Observe	-	32	22	12	12
	Data systems	-	5	10	10	15
	Understand	-	20	120	85	30
	Predict	-	0	0	20	25
	TOTAL	-	57	152	127	82

Project Description: Increases in UV-B wavelengths (280-320 nm) resulting from depletion in atmospheric ozone over the next several decades are predicted to have deleterious effects on primary producers and other organisms in natural waters (Worrest 1982, Bidigare 1989). Ozark Highland streams and springs are known for their clarity, and therefore biologically harmful dosages of UV-B radiation are anticipated to penetrate to the streambed (Smith and Baker 1979). Because the highest diversity and productivity of aquatic organisms in streams occurs here, exposed benthic communities of Ozark Highland streams should be particularly sensitive to increases in atmospheric UV-B.

Similarly, a projected doubling of atmospheric CO2 will result in global warming and produce increases in stream and spring water temperatures in a region characterized by assemblages of cool water flora and fauna containing a high percentage of glacial relicts and cold water stenotherms (pflieger 1982, 1989).

This research experimentally tests the hypothesis that individual species and intact communities of Ozark Highland streams and springs will be sensitive to increases in temperature and UV-B.

Objectives:

1. Characterize the present thermal structure and spectral absorbance of Ozark streams and springs.
2. Experimentally determine temperature and UV-B effects on representative species isolated from Ozark Highland streams and springs.
3. Experimentally determine temperature and UV-B effects on the structure and function of analog Ozark Highland stream communities.
4. Integrate observational and modeling results of Galat (1990), Annett et al. (1990), and Meyer and Galat (1990) with experimental results of this study to further develop predictive models of changes in structure and function of aquatic communities in Ozark Highland streams and springs.

We will survey UV-B absorption characteristics from the range of habitats outlined in the Annett et al. (1990) and Meyer and Galat (1990) preproposals to characterize contemporary spectral properties of Ozark streams and springs. Absorptive characteristics will be assessed in relation to varying seasonal and hydrological conditions and we will determine if biotic (e.g., organic carbon; Edwards and Cresser 1987) and abiotic (e.g., suspended sediment) variables influence UV-B absorption spectra. Thermal characteristics of Ozark Highland streams and springs will be defined as part of the Annett et al. (1990) and Meyer and Galat (1990) preproposals and Galat (1990) study.

Testing effects of temperature and UV-B, singly and in combination, will be accomplished by controlled laboratory exposures of representative Ozark Highland spring and stream organisms from three groups: plants

(attached algae and/or macrophytes), benthic invertebrates, and fish. Specific taxa will be selected using results of the Annett et al. (1990), Meyer and Galat (1990), and Galat (1990) projects. We will assess effects of temperature and UV-B on algal and/or macrophyte photosynthetic pigments, thermal preferenda, primary production, and selected physiological indicators of stress (e.g., C:N ratio, protein.lipid ratio). Effects of temperature and UV-B on representative benthic invertebrates will include changes in morphology, behavior, fecundity, survival, and development rate. Early life stages and adult fish will be exposed to different temperature regimes and intensities of UV-B to evaluate impacts on morphological and behavioral development, anatomical/histological changes, growth rate, thermal preferenda, and survival. Results will enable us to generate bioenergetic simulation models of larval fish development and growth in relation to projected increases in spring and stream water temperature (e.g., Shutter and Post 1990).

Replicated artificial streams will be constructed at an Ozark Highland stream site and representative natural communities established. The intact stream community will then be exposed to controlled temperature and UV-B manipulations. We will evaluate changes in community composition, species interactions, primary and secondary production, and nutrient and organic matter fluxes between treatment streams and controls, as well as compare results with field observations proposed by Annett et al. (1990).

External Linkages: This research will extend the NFCRC's, "Evaluation of Increased Ultraviolet Radiation on Freshwater and Coastal Ecosystems" project to Ozark Highland streams and springs. It will benefit from NFCRC's results and use their UV detection equipment at a cost savings of 20 $K. This project will also be integrated into the Environmental Protection Agency's (EPA) research to quantity effects of increased UV-B exposure on components of marine ecosystems and USDA's effects of UV-B on forest growth (CES 1989).

Internal Linkages: This research provides an experimental manipulation component to GCC research on Ozark Highland aquatic ecosystems. It links directly to a currently funded NPS study Galat (1990) and the proposed Annett et al. (1990) and Meyer and Galat (1990) studies. Additional NPS relevant antecedents for this project include 14 completed and 6 ongoing research projects which provide over 10 years of data on Ozark river systems. Most were funded jointly by NPS, FWS, and Missouri Department of Conservation (MDC), with contributions by MU and Missouri Department of Natural Resources. Logistics, equipment, and facilities support for this project will be supplied by FWS, MDC, and MU.

Milestones:

Year 1 - Identify stream sites and initiate light monitoring. Select species for laboratory tests and begin culturing.

Year 2 - Conduct laboratory exposures of representative aquatic taxa to increased temperature and UV-B. Design artificial streams.

Year 3 - Conclude laboratory testing. Begin development of predictive models. Construct artificial streams and run community response tests.

Year 4 - Conclude community response tests. Complete simulation models. Prepare temperature/UV-B long-term monitoring schedule. Prepare final report. Demonstrate model predictions and outline monitoring program to NPS biologists.

Data Management: Data will be archived in commonly accepted formats, readily transferable to other users. Standard location data will be used for field monitoring. Computer model and statistical analysis documentation will be provided. QA/QC guidelines from EPA or FWS will be used as appropriate. Standard Operating Procedures will be prepared for selected procedures. NFCRC will participate in meeting CEES data management requirements. Appropriate data validation will occur at several steps throughout the project.

References:

Brussock, P.P., A.V. Brown and J.C. Dixon. 1985. Channel form and stream ecosystem models. Water Resources Bulletin 21:859-866.

Brylinsky, M. 1980. Estimating the productivity of lakes and reservoirs. International Biological Programme 22:411-453.

Huryn, A.D. and J.B. Wallace. 1987. Local geomorphology as a determinant of macrofaunal production in a mountain stream. Ecology 68:1932-1942.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell and C.E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130-137.

Priority Number: OZHI-I-06

Project Title: Dynamics of the glade-forest border under the influence of global climate change.

Program Component: Integrated Studies of National Park Ecosystems.

Research Category: Research on Species and Ecological Communities.

CEES Science Element and Science Priority: Ecological Systems and Dynamics--long-term measurements of structure/function

CEES Activity: Observe, Data Systems, Understand, Predict.

Preliminary Budget Estimates:

Science Elements	Activity Element	Budget Year Estimates ($K) 1	2	3	4	5	6
ESD	Observe	15	20	16	-	-	-
	Data systems	6	8	9	7	8	-
	Understand	-	-	15	14	15	15
	Predict	-	-	8	13	20	20
	TOTAL	21	28	32	50	43	35

Project Description: The interface between glades and forests are dynamic systems sensitive to past changes in temperature and precipitation. With climate warming unfavorable temperature and moisture regime on glades make tree and shrub seedling establishment more difficult.

Influences of global climate change on ecosystems will be most quickly revealed at the most dynamic points. The portions that are relatively stable are those that are well buffered, and although change at such stable points will be dramatic when it occurs, it is not likely to be seen readily until the buffering capacity is overcome.

The most dynamic points in the terrestrial ecosystems of the Ozark National Scenic Riverways (OZAR) and the Buffalo National Riverway (BUFF) are the borders between the prevailing forests and the embedded glades with their prairie communities. It is at these borders that the forces of water stress, temperature differences, soil effects and fire influences are most sharply focused.

In the face of global change, one would expect several ecological changes in the glades and at the forest/glade border. Based on the widely held assumption that there will be a general warming trend in central North America (Hansen et al. 1988), we hypothesize that:

1) the position of the border will change, in particular, the glades should expand at the expense of the forest;

2) the process of invasion of the glades by woody species will change, in particular, there should be less immigration and less successful establishment of woody plants on the glades;

3) the spatial distribution of plants on the glades and at the glades/forest boundary will change.

One of the most difficult aspects of interpreting global change influences on terrestrial systems is to separate them from the normal dynamics of the systems. A design which provides a means for cross-comparison of dynamics will help to sort out global change from normal fluctuations. The glades of OZAR are on either of two types of substrate, igneous (rhyolite), or (modified) sedimentary (dolomite) (Nelson 1985). Those of BUFF are on sedimentary (limestone substrates) (Keeland 1978, Hinterthuer 1985). We will establish sites on both types at

OZAR and on limestone at BUFF, providing a check on substrate influences.

Furthermore, we will establish sites at Saint Croix National Scenic Riverway, Wisconsin and Minnesota, on the igneous (basalt) glades there (Glenn-Lewin and Ver Hoef 1988). These will provide a latitudinal check by comparing results on igneous substrates. Since it is unlikely that climate change will be the same everywhere, and it is unlikely that climate change will have the same effects on different substrates, it will be possible to sort out global change effects from normal dynamics, and to estimate the interaction between climate change and substrate type.

Several glades will be selected from each park. On each selected glade, a permanent gride will be established throughout the glade and well into the surrounding forest. Within each grid unit, species data and environmental measurements, such as soil depth, moisture conditions, selected soil physical and chemical conditions, etc., will be obtained. Regression techniques combined with spatial modeling (Cressie 1990) will allow us to express and understand the spatial distribution of the glade and glade/forest vegetation. This includes both changes at permanently marked points, and changes in ecological maps of species, combinations of species, and environmental factors (Robertson 1987). Changes in the models over time will be the analytical expression of vegetational changes. These model changes will then be partitioned into those likely to represent normal or usual changes, and those likely to be the result of global change. The field data will be used to calculated the parameters of the models. The models can then be used to predict species' population and vegetation changes, which can be confirmed or modified by continued monitoring.

External Linkages: The design has a specific link with Saint Croix National Scenic Riverway. The project will be linked also with the proposed grassland global change project within NPS, and with ongoing grassland research at Konza Prairie, a Long-Term Ecological Research site. It will become a significant part of ongoing, long-term research on spatial patterns and structure in grasslands being performed by the grassland research groups at Iowa State university, the University of Utrecht, The Netherlands, and the University of Munster, Germany.

Internal Linkages: We already have established grids on 14 selected glades at OZAR (Glenn-Lewin and Ver Hoef 1989), evenly distributed between dolomite and igneous glades. The grids are 10 x 10 matrices of 7m x 7m plots. In all cases they extend well into the surrounding forest. We know that this field procedure produces useful and revealing spatial models. Applying this system across substrates and geographical distances, and monitoring it through time, will be a powerful tool for revealing the influences of global climate change on terrestrial ecosystems. We expect that initial results from the field work and spatial modeling will be available at the end of 3 years, and model confirmation and prediction after 6.

Milestones:

Year 1 - Project design completed and implement, sites selected, all grids established and read for the first growing season.

Year 2 - Grids read for the second growing season. Data management system established.

Year 3 - Data analysis for first 2 years completed. Comparisons of first 2 years results completed (to check for inherent variation). Spatial models developed.

Year 4 - Grids read for fourth growing season. Spatial models refined and implemented.

Year 5 - Spatial models completed for existing data.

Year 6 - Predictions made of spatial vegetational changes and changes in woody invasion. Recommendations for continued monitoring develope. Final report submitted.

Data Management: The data will be stored and accessible in a standard data base management system. They can easily be made available to any investigator. They can also easily be transmitted to a centralized data base, including a GIS. The data from years one and two will provide a check on re-measurement, and an estimate of the variation in spatial models.

References:

Cressie, N. 1990. Spatial statistics. (A book to be published in 1991.)

Glenn-Lewin, D.C. and J.M. Ver Hoef. 1988. prairies and grasslands of the St. Croix National Scenic Riverway, Wisconsin and Minnesota. Prairie naturalist 20: 65-80.

Glenn-Lewin, D.C. and J.M. Ver Hoef. 1989. Glades at Ozark National Scenic Riverways. Progress report submitted to the National Park Service, Midwest Region, Omaha.

Hansen, J., I. Fung, Lacis, D. Rind, G. Russell, S. Lebedeff, R. Ruedy, and P. Stone. 1988. Global climate changes as forecast by the GISS 3-D model. Jour. Geophysical Research 93: 9341-9364.

Hinterthuer, B. 1977. A survey of the flora of selected glades in northwest Arkansas. M.S. thesis, Univ. Arkansas, Fayetteville.

Nelson, P.W. 1985. The terrestrial natural communities of Missouri. Missouri Natural Areas Committee, 197 pp.

Robertson, G.P. 1987. Geostatistics in ecology: Interpolation with known variance. Ecology 68: 744-748.

Priority Number: OZHI-I-07

Project Title: Habitat analysis and demographic monitoring of boreal relict plants at Jam Up Cave Natural Area, Ozark National Scenic Riverways

Program Component: Integrated Studies of National Park Ecosystems Research Category

Research Category: Observations on Species and Ecological Communities

CEES Science Element and Science Priority: Ecological Systems and Dynamics--long-term measurements of structure/function

CEES Activity: Observe; Data Systems

Preliminary Budget Estimates:

		Budget Year Estimates ($K)					
Science Elements	Activity Element	1	2	3	4	5	6
ESD	Observe	20	20	40	20	20	-
	Data systems	5	5	5	5	5	-
	TOTAL	25	25	45	25	25	-

Project Description: Ozark National Scenic Riverways (OZAR) has a rich and unique flora with 40 state-listed and 12 federal candidate plants occurring within or in the vicinity of the park (Hensold and Morgan, 1987). The greatest concentration of rare plants occurs along the Jack's Fork where moist, north-facing bluffs provide refugia for boreal relicts found nowhere else in Missouri (Steyermark, 1963). The most significant location is Jam Up Cave Natural Area (JUCNA). Particularly notable relict taxa occurring at JUCNA are Campanula rotundifolia, Galium boreale var. hyssopifolium, Trautvellavia caroliniensis, Zigadensis elegans and Waldsteinia fragarioides. Climate change may be especially damaging to relict species whose habitats are restricted or fragmented. Global warming may cause a major rearrangement of life-zones. To survive, species may need to shift ranges considerable distances to keep up with the distribution of suitable habitat. This is unlikely for highly isolated relicts surviving a precarious microclimates.

The objective of this study is to determine if populations of relict species are changing or remaining stable by measuring certain demographic characteristics and to correlate these characteristics with physical habitat data. Reproductive output and survivorship are the primary demographic characteristics to be measured. The habitat analysis will include population boundary and topographic mapping, soil depth, nutrients and moisture measurements and the development of air temperature profiles. An additional objective is to compare population vigor between OZAR and a boreal site. Isle Royale National Park (ISRO) located about 600 km north of OZAR will be the boreal site. Three of the five notable relicts at JUCNA are found at ISRO (Slavick and Janke, 1983). The results of the study will be used to develop future experimental studies for inferring casual mechanisms of population change and modeling population viability under different climate scenarios.

External Linkages: A natural features inventory of the counties in which OZAR occurs was completed by the Missouri Department of Conservation (MDOC) in 1987 (Nigh, 1988). In addition, the MDOC inventoried rare and endangered plants of OZAR in 1985 and 1986 (Hensold and Morgan, 1987). Since most sites were visited only during a single season the MDOC has expressed interest in conducting further investigations including the eventual development of site specific management plans for rare species (T. Nigh, per. comm.).

Internal Linkages/Readiness: The unique assemblage of plants at JUCNA has been known for a long time, as the earliest plant collections date from the late 1800's (Steyermark, 1963). Steyermark (1963) collected from the site in the 1930's. Redfearn et al. (1970) as part of an initial floristic survey of OZAR estimated abundance of species on bluffs and ledges throughout the park. Autry (1988) determined importance values of plants to compare differences and similarities in the communities of 56 bluffs including JUCNA. As previously stated a county-wide natural features inventory (Nigh 1988) which include JUCNA was completed in 1987. Data collected as part of the inventory is stored in the Missouri Natural Heritage Program (MNHP) database. This proposal is a cooperative study between the NPS and Missouri MDOC. In addition, the study would enhance ongoing NPS rare plant surveys scheduled for OZAR in 1991-92.

Milestones:

Year 1 - Delineate populations, establish plots, and sample JUCNA site

Year 2 - Sample JUCNA site

year 3 - Sample JUCNA site; delineate populations, establish plots, and sample ISRO site

Year 4 - Sample ISRO site

Year 5 - Analyze data, compare sites, formulate future experimental studies.

Data Management: Data collected for the project will be archived digitally with the MNHP integrated data management system. Map files, manual files, and computer files are accessible for a variety of uses. In addition, OZAR is exploring the possibility of establishing a park-based Heritage Data Center (HDC). A OZAR HDC could utilize data already collected by the MNHP databases and would share new data with a nationwide network.

References:

Autry, D.C. 1988. Plant communities on riparian limestone bluffs in Ozark National Scenic Riverways. Ph.D. Dissertation, Southern Illinois University, Carbondale, Illinois. 138p.

Hensold and Morgan. 1987. Rare Plants of the Ozark National Scenic Riverways. Mo. Dept. of Conservation, Jefferson City. 200p.

Nigh, T.A. 1988. Missouri Natural Features. Inventory of Carter, Oregon, Ripley and Shannon Counties. Mo. Dept. of Conservation. 286p.

Nigh, T.A. 1990. Personal communication. Mo. Dept. of Conservation.

Redfearn, P.L., G.L. Ryrah, W.R. Weber, and J.T. Witherspoon. 1970. Botanical survey of the Ozark National Scenic Riverways. Unpubl. report to Nat. Park Ser. 654 p.

Slavick, A.D. and R.A. Janke. 1983. Vascular plants of Isle Royale National Park, Michigan. Unpubl. report to Nat. Park Ser. 46p.

Steyermark, J.A. 1963. Flora of Missouri. The Iowa State Univ. Press, Ames. 1728p.

Priority Number: OZHI-I-08

Project Title: Summer recreational visitor populations on the Upper Jacks Fork River: factors that influence their visits

Program Component: Integrated Studies of National Park Ecosystems

Research Category: Resource ethnography

CEES Science Element and Science Priority: Human Interactions-database development

Cees Activity:

Preliminary Budget Estimates:

		Budget Year Estimates ($K)					
Science Elements	Activity Element	1	2	3	4	5	6
H1	Observe	20	20	20	-	-	-
	Data systems	5	5	5	-	-	-
	TOTAL	25	25	25	-	-	-

Project Description: This project is premised on the observation during several years of research at OZAR that various user populations, i.e., river floaters, fishermen, day users, campers, etc., utilize most portions of OZAR. The need is to know more about the nature and interrelationships of these populations, their use of the area, and factors that influence changes in their use of and impacts on the river systems. These factors would include effects of weather extremes and water levels.

Research to develop recreation user monitoring systems for management purposes has been underway at OZAR since 1972, one of very few places in the U.S. where this kind of research has been conducted and with consistent focus over a long period of time. From this research, methods of sampling and designing

measurements of user populations for large wildland areas have been developed. At OZAR, these measurements have primarily focused on canoe floater populations, with some work on fisherman and primitive campsite user populations.

These monitoring measurements were designed to gather minimum information for management decision-making. The opportunity now is to utilize this measurement framework, and conduct more in-depth measurements and analyses of the human ecosystem on a specific land area. The area selected for study is the Upper Jacks Fork River portion of OZAR. This area is approximately 20 miles in length, with known populations of canoeists, fishermen, day users, and primitive campsite campers. This area was selected because it is subject to lower water conditions during summer months (not subject to recharge by major springs as other portions of OZAR) and thus river users' reactions to weather-caused fluctuations in conditions should be more subject to measurement.

This proposed research would appear to especially address the "social processes" and the "human-induced changes" portions of the overall goal of the Global Change Research Program, and may be especially important because very little of this kind of research had been done to date. This research would appear to be part of the Science Priorities of Ecological Systems and Dynamics (Long-Term Measurements of Structure/Function and Response to Climate and Other Stresses) and Human Interactions (Data Base Development) as indicated in Figure 11 of the FY 1990 U.S. Global Change Research Plan.

External Linkages: This project relates to an increasing interest in social (recreational) monitoring systems by forest and park management agencies, including the U.S. Forest Service and Tennessee Valley Authority. Recreation monitoring research was featured at the National Wilderness Management Conference in Minneapolis in September 1989 and the Outdoor Recreation Trends Symposium III in Indianapolis in March 1990. Recreation monitoring was also discussed at the International Union of Forestry Research Organizations (Recreation Research Working Group) meeting in Montreal in August 1990. In response to specific requests by the Chief of the U.S. Forest Service, a research task force on recreation inventory and monitoring will be convened in Portland, Oregon in October 1990.

Internal Linkages: The proposal relates to 18 years of continuous recreational use monitoring at OZAR.

Milestones: Because of existing knowledge of the research site and recreation monitoring methods gained from 18 years of research at ONSR, it would be possible to get a detailed data collection effort in place on the Upper Jacks Fork during summer 1991. Data analysis would be conducted during the fall months. This same general schedule could be maintained during 1992 and 1993.

Data Management: Procedures used for research design, data collection, and data management on past recreation monitoring research and for this proposed research are outlined in the widely used reference text Research Methods in Social Relations (5th ed.), L. Kidder and C. Judd, 1986, New York: Holt, Rinehart and Winston.

References:

Chilman, Kenneth C. and Alan R. Everson. 1987. A Recreation Monitoring System for Individual Zones on the Jacks Fork River. Research report submitted to National Park Service, Ozark National Scenic Riverways, Van Buren, Missouri. 37 pp.

Chilman, Kenneth C., David Foster, and Alan Everson. 1990. Monitoring Systems for Measuring Trends in Wildland Social Conditions. Proceedings of Outdoor Recreation Trends Symposium III, Indianapolis, Indiana, March 29-31 (in press).

Kidder, Louise H. and Charles M. Judd. 1986. Research Methods in Social Relations (5th ed.) New York: Holt, Rinehart and Winston. 563 pp.

Stewart, William P. and Mark Ivy. 1990. A Sociological Study of Wintertime Backcountry Users at Everglades National Park. Technical Report No. 14, National Park Service Cooperative Park Studies Unit, Texas A and M University, College Station, Texas. 176 pp.

Section IV: Package Proposals for Biogeographic Area Program.

A. Budget spread sheet

Package Component	Science Element	Activity Element	Budget Year Estimates ($K) FY91	FY92	FY93	FY94	FY95	FY96
Base Program (FTE:1.0)	-	-	60	60	60	60	60	60
Increase Level I								
Base Program (FTE:1.0)	-	-	60	60	60	60	60	60
OZHI-I-01 Stream	ESD	OBS	30	30	30	30	10	-
Ecology		DAT	20	20	20	20	40	-
		UND	30	50	60	60	30	-
		PRE	10	40	50	50	60	-
	TOTAL		150	200	220	220	200	60
Increase Level II								
Base Program (FTE:2.0)	-	-	90	90	90	90	90	90
OZHI-I-01 Stream	ESD	OBS	30	30	30	30	10	-
Ecology		DAT	20	20	20	20	10	-
		UND	30	50	60	60	30	-
		PRE	10	40	50	50	60	-
OZHI-I-02 Fluvial	ESD	OBS	70	46	23	20	20	-
Geomorphology		DAT	6	6	6	2	2	-
		UND	9	32	23	-	-	-
		PRE	-	-	23	20	20	-
	TOTAL		235	284	272	262	242	90
Increase Level III								
Base Program (FTE:2.5)			105	105	105	105	105	105
OZHI-I-01 Stream	ESD	OBS	30	30	30	30	10	-
Ecology		DAT	20	20	20	20	40	-

		UND	30	50	60	60	30	-
		PRE	10	40	50	50	60	-
OZHI-I-0Z Fluvial Geomorphology	ESD	OBS	70	46	23	20	20	-
		DAT	6	6	6	2	2	-
		UND	9	32	23	-	-	-
		PRE	-	-	23	20	20	-
OZHI-I-03 High Resolution Climate	ESH	OBS	23	26	12	-	-	-
		DAT	23	26	23	12	-	-
		UND	12	13	23	35	-	-
		PRE	-	-	-	12	-	-
OZHI-I-06 Glade-forest Dynamics	ESD	OBS	15	20	-	16	-	-
		DAT	6	8	9	7	8	-
		UND	-	-	15	14	14	15
		PRE	-	-	8	13	20	20
OZHI-I-07 Boreal Relicts	ESD	OBS	20	20	40	20	20	-
		DAT	5	5	5	5	5	-
		UND	-	-	-	-	-	-
		PRE	-	-	-	-	-	-
OZHI-I-08 Weather Extremes and Recreation	HI	OBS	20	20	20	-	-	-
		DAT	5	5	5	-	-	-
		UND	-	-	-	-	-	-
		PRE	-	-	-	-	-	-
	TOTAL		409	472	500	441	355	140

Note: See Appendix C for a list of preproposals not included in the OZHI GCP because of space limitations.

B. Package Discussions

Base Program

The base program would provide salary and support for the BAC but no research funds. The BAC would serve as a member of the OZHI MAB Steering Committee and work with the committee to construct a database of existing OZHI studies. The BAC would also establish a OZHI advisory committee. The BAC would revise the GCP and prepare a data management plan.

Increase Level I

At this increase level a OZHI GIS specialist would be hired and stationed at BUFF. BUFF is scheduled to receive funding to purchase GIS hardware in FY91. The BAC and GIS specialist would jointly prepare the data management plan. At this level research funding would be adequate to fund only one project--a comprehensive assessment of the potential impacts of climate change on OZHI stream and spring ecology. This project is anticipated to be a cooperative study involving the NPS, USFWS, USGS, and states of Missouri and Arkansas. At this level no funding support would be provided for park GCC coordinators.

Increase Level II

Increased funding will provide for the expansion of an ongoing USGS project (fluvial geomorphology) to OZAR and possibly BUFF. This project will investigate climatic and land-use influenced changes in stream geomorphometry and is closely tried to the stream ecology project (OZHI-I-01). Funding levels will remain the same for the BAC and GIS specialist. Again, no funding would go to park GCC Coordinators.

Increase Level III

This level of support would provide for a comprehensive program of GCC investigations. Also, .25 FTE and funding would be provided to the parks for park-based GCC coordinators. Research would be expanded to terrestrial systems with the funding of the high resolution climate project (OZHI-I-03) and the glade-forest dynamics project (OZHI-I-06). Both would provide information on long-term climate means, variability and trends essential to understanding ecosystem response to existing and future climates. In addition, funding would provide for a study of relict boreal plants and possible changes in survival associated with climate change. Finally, an aspect of human response to climate change would be investigated with the addition of the recreational study correlating river use and weather extremes.

Section V: Cooperation And Consultation In Developing The Plan

A. Chronology of OZHI GCP development

February 27, 1990	NPS Director announces Global climate change program
March 11, 1990	Brainstorming session held at Ozark NSR
April 30, 1990	Capabilities and Interest Statement submitted to WASO
May 17, 1990	Oral presentation to Steering Committee
June 6, 1990	WASO selected 11 core research areas.
July 7, 1990	Peer review of C/I statement received
July ?, 1990	Draft guidelines on the preparation of Global Change Operations and Conceptual Research Plan received
September 10, 1990	OZHI GCC workshop held at BUFF
October 1, 1990	GCP due in WASO

B. Directory of Specialists (participates at GCP workshop)

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SUMMARY OF THE RATIO OF PROJECTED PRECIPITATION WITH DOUBLING CO_2 TO THE PRESENT PRECIPITATION FOR THE OZARK PLATEAU

	Atmospheric Models		
Month	GFDL	GISS	OSU
Jan	1.4	.9	.8
Feb	.9	1.2	1.1
Mar	1.0	1.0	.9
Apr	.8	1.0	1.1
May	1.4	1.2	.9
June	.8	1.0	1.0
July	.9	1.1	1.1
Aug	1.1	1.1	1.8
Sept	1.0	1.3	1.0
Oct	1.3	.8	1.0
Nov	1.1	.7	.6
Dec	1.1	.8	1.0

SUMMARY OF PROJECTED INCREASES IN TEMPERATURE (°C) FOR THE OZARK PLATEAU WITH DOUBLING OF ATMOSPHERIC CO_2

	Atmospheric Model		
Month	GFDL	GISS	OSU
Jan	4.8	4.9	4.5
Feb	4.7	4.2	3.0
Mar	5.3	5.9	3.5
Apr	3.8	5.2	3.4
May	3.5	3.2	2.4
June	4.7	3.4	3.5
July	3.8	4.1	3.8
Aug	3.8	4.4	3.4
Sept	5.5	5.2	3.5
Oct	5.3	5.5	3.5
Nov	2.8	5.8	2.0
Dec	2.1	5.9	3.4

Appendix B

Preproposal Authors

OZHI-I-01

Cynthia Annett and James Johnson Arkansas Cooperative Fish and Wildlife Research Unit, U.S. Fish and Wildlife Service, Fayetteville, AR; David Galat and Charles Rabeni, Missouri Cooperative Fish and Wildlife Research Unit, U.S. Fish and Wildlife Service, Columbia, MO; Terry Boyle and Nancy Hoefs, Water Resources Division, National Park Service, Fort Collins, CO; Richard Meyer, University of Arkansas, Fayetteville.

OZHI-I-02

Robert Jacobson, U.S. Geological Survey, Rolla, MO

OZHI-I-03

D.W. Stahle and M.K. Cleaveland, University of Arkansas, Fayetteville, AR; R.P. Guyette, University of Missouri, Columbia

OZHI-I-04

D. Galat and C. Rabeni, Missouri Cooperative Fish and Wildlife Research Unit, U.S. Fish and Wildlife Service, University of Missouri, Columbia; E. Little, National Fisheries Contaminant Research Center, USFWS, Columbia, MO; R. Meyer, University of Arkansas, Fayetteville

OZHI-I-05

R. Meyer, University of Arkansas, Fayetteville; D. Galat, Missouri Cooperative Fish and Wildlife Research Unit, University of Missouri, Columbia, MO

OZHI-I-06

David Glenn-Lewin, Iowa State University, Ames, IA

OZHI-I-07

G. Willson, Midwest Region, National Park Service, Omaha, NE; Tim Nigh, Missouri Department of Conservation, Jefferson City, MO

OZHI-I-08

Kenneth Chilman, Southern Illinois University, Carbondale, IL

Appendix C: Titles of preproposals not submitted for funding

Climatic effects on soil, nutrient uptake and wildfire in the Current and Buffalo River Watersheds by chemical analyses of tree-rings.

Baseline monitoring of cave temperature and water fluxes and preliminary testing of cave-specific paleotemperature and palynology approaches.

Analysis and modeling of forest growth in the Ozarks under global climate change.