From the Frontier to the Biosphere

A brief history of the USIBP Grasslands Biome program and its impacts on scientific research in North America.

By David C. Coleman, David M. Swift and John E. Mitchell

The Grasslands Biome, part of the U.S. International Biological Program (IBP), the largest, most successful program of its kind, had its early beginnings in Great Britain. Building from the success of the International Geophysical Year, which occurred in 1957, a group of ecologists and environmental scientists in Europe proposed an international program on the environment, which they called the International Biological Programme, or IBP (18).

The program was interpreted broadly to include all aspects of biological productivity in relation to human welfare. Numerous governmental agencies in Europe provided funding for studies that began in the early 1960s. There was considerable interest in the United States for the IBP concept, but no significant funding mechanism existed for such a program. Regardless, with the assistance of senior scientists in the biological community, including W. Frank Blair from the University of Texas, George M. Woodwell from the Brookhaven National Laboratory, and Arthur D. Hasler from the University of Wisconsin, a series of planning meetings were held during 1966, including a pivotal one in August, held in Williamstown, Massachusetts, chaired by Eugene Odum. An action plan was created to establish a series of IBP sites in each of the major biomes of North America, beginning with a Grasslands Biome, followed by several others, including forests and deserts (1).

In the final months of the Lyndon Johnson administration, several million dollars were authorized and appropriated by Congress, enabling an Ecosystems Studies program office to be established in the National Science Foundation (NSF). As planned, biome research programs were begun, with the Grasslands Biome being established first at Colorado State University (CSU), Fort Collins. This was truly an example of preparation meeting opportunity, because the principal investigator, Dr. George M. Van Dyne, was primed and ready for this large program. A brief history of Van Dyne follows. His life encompassed the transition from the old frontier to the current era of concerns about global biology as epitomized by the term, biosphere.

A Biosphere Pioneer

George M. Van Dyne grew up on a ranch south of Trinidad, Colorado, almost on the New Mexican border. George, an accomplished horseman who worked on the ranch as a hand, was enamored about all aspects of the West. George earned his B.S. degree in Animal Science at CSU, and then went on for his Master's degree in Range Science at South Dakota State University under Mr. James K. (Tex) Lewis, undertaking a total system study of rangeland ecology. Van Dyne then received his Ph.D. degree from the University of California at Davis, working with Dr. Harold Heady, developing mathematical models of rangeland systems.

George looked carefully for somewhere to launch his career, and settled on Oak Ridge National Laboratory (ORNL), Tennessee, where Stan Auerbach led the Environmental Sciences Section. Jerry Olson and Bernard Patten had already formed a Systems Ecology group there. George joined them in 1963, and the three of them taught the first Systems Ecology course in the USA at the University of Tennessee in Knoxville. At that time, Oak Ridge was one of the few places in the world that had computers capable of solving the complex differential equation and matrix models being formulated by George and his two colleagues. They were the first to use both analog and digital computers to model natural systems.

Because the three scientists worked full-time at Oak Ridge, they drove to Knoxville in a van on Saturdays, taking turns offering one-hour lectures each, with diverse ideas and methods for studying ecological systems. George Van Dyne, being junior and serving in a "clean-up" role, would follow Drs. Patten and Olson during the noon hour, writing on the chalk board with his right hand, eating a sandwich with the left, and talking in his soft, but intense bass voice about many exciting developments in ecosystem modeling (D.A. Crossley, Jr. pers. comm.). Students who took the course were unanimous in their praise of the creativity and the dedication of these young instructors.

George was equally respected in the Environmental Sciences Division at Oak Ridge for his high research productivity. He suggested to a delighted Stan Auerbach that two scientific papers per person per month be considered the norm for full-time scientists in a research group. George then proceeded to author up to four papers per month in the 18 months he was at Oak Ridge, drawing upon many data sets he had accumulated throughout his Master's and Ph.D. research. Many of his more than 120 refereed scientific publications were written during his Oak Ridge days.

Drs. Olson, Patten, and Van Dyne were instrumental in developing the concept of systems ecology, a quantitative approach for studying and integrating entire ecosystems, together with their biotic and abiotic components. Bernie Patten went on to a distinguished career at the University of Georgia where he developed new theories on modeling ecosystem self-organization, nutrient cycling, and energy transformation. Jerry Olson remained at Oak Ridge, and became widely recognized for his pioneering work on global carbon dynamics.

George Van Dyne moved to Colorado State University in the fall of 1967, establishing the Natural Resource Ecology Laboratory (NREL) as his vehicle to pursue the Grassland Biome studies.

Fig. 1. ***George M. Van Dyne at the ALE (Arid Lands Ecology) Pacific Northwest Bunchgrass site near Richland, Washington. Norman French is on the right in the two-tone sweater facing Van Dyne.***

He began with a secretary and two graduate students (L. J. "Sam" Bledsoe and R. Gerald Wright), along with an initial seed grant from the Ford Foundation until funds from the NSF Ecosystem Studies office began arriving. Van Dyne (Fig. 1) followed the initial plans agreed to in the 1966 action plan on how to set up a Biome program, although other Biomes were more decentralized. He established a central headquarters at the NREL and an intensive study site (the Pawnee Site) near Nunn, Colorado, located on the shortgrass steppe northeast of Fort Collins on the Central Plains Experimental Range, a research station administered by USDA Agricultural Research Service (Fig. 2).

George Van Dyne's grasp of ecosystem science led him to produce and edit a book entitled, *The Ecosystem Concept in Natural Resource Management*. The book (15) contained chapters by various authors, all colleagues of George, that had led advances in systems ecology; scientists like Herb Bormann, Chuck Cooper, Gene Likens, Jack Major, Stephen Spurr, and Fred Wagner.

Developing A Collaborative Program

Within two years, George had a burgeoning program in place. He brought Dr. Don Jameson into the program as assistant director over research at the Pawnee Site. Ray Souther was hired as Pawnee site manager. Numerous graduate students worked on a

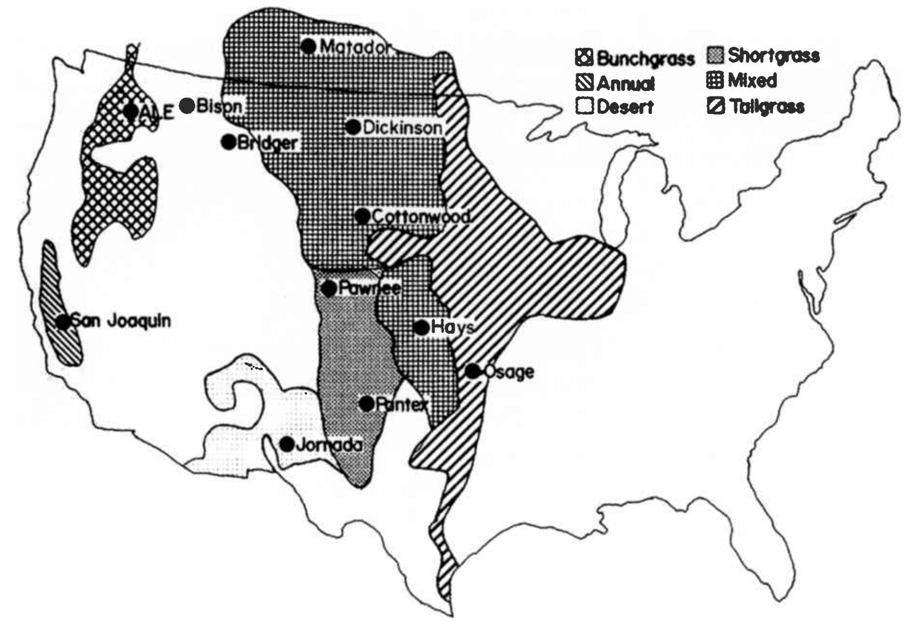

Fig. 2. ***IBP Grassland Biome sites, encompassing tallgrass, mixed grass, shortgrass, Northwest bunchgrass, and annual grasslands (from French 1979).***

diverse and extensive series of studies designed to understand and parameterize various grassland ecosystem processes. These included such subjects as feeding and assimilation studies of animals ranging in size from arthropods to bison, effects of grazing on both above-ground and below-ground productivity, and plant-water-nutrient relationships on both species and entire plant communities.

A series of extensive, or satellite, study sites, were established from the Osage tallgrass prairie in Oklahoma on the east, to the annual grassland in California in the Sierra foothills above Fresno (Fig. 2). In all, over one dozen sites were established and started generating data in 1969 for the modeling effort. Dr. Norman French joined the Grassland Biome to supervise this extensive network of field sites spanning three time zones.

All data, including those from the outlying network sites, were sent to the NREL for archiving and analysis. The Biome's statistical design was to collect adequate field data to estimate population means within 20 percent and with 80 percent reliability. Another protocol required all sites to use the same plot size for estimating plant biomass. The NREL provided each site with screening statistics of submitted data, including the sample size necessary to achieve the above-mentioned sampling adequacy. Dr. Rex Pieper, Director of the Jornada Site near Las Cruces, NM, recalls with some humor reading the regular printouts coming back from the NREL stating that his crews would have to clip literally hundreds of plots in each treatment because of the high spatial variation in desert vegetation biomass. He was never encouraged to change the plot shape, however (R. Pieper, personal communication).

Dr. George Innis, a mathematical modeler (Fig. 3) joined the Grassland Biome in 1970, and shortly thereafter assembled a cadre of postdoctoral fellows from a variety of disciplines. Several of these postdocs, including William Parton, William Hunt, and Robert Woodmansee, remained at CSU and established distinguished careers as senior scientists in the NREL. They continue to participate in large international programs in East Africa, Asia, and South America. Dr. Woodmansee served as the third Director of NREL between 1984 and 1992.

An anecdote about Van Dyne epitomizes his fabled chutzpah. At one point, he proposed to a CSU Vice President that he needed to acquire a building off campus to provide several thousand more square feet of floor space. The official insisted that only a Dean could make such a decision, not a faculty

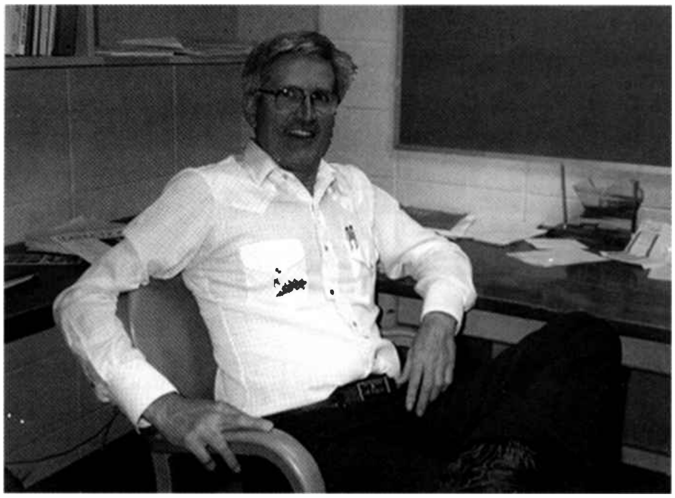

Fig. 3. ***George S. Innis, leader of the ELM modeling group.***

member, influential though George was. George immediately shot back with: "So, make me a Dean!"

By late 1971, it was apparent to both George Van Dyne and NSF that the program's rapid growth had reached a point at which not even George could provide all of the scientific direction and leadership required to make the Biome study a success. To coordinate the numerous ongoing data gathering and modeling activities, four more persons were hired to serve as "integrators" of the project. The initial persons hired were: Freeman Smith, abiotic factors; John Marshall, primary producers; Jim Ellis, consumers; and David Coleman, decomposers. The integrators' principal job was to conduct and encourage synthesis in the form of internal "gray literature" publications, called Technical Reports, of which over 200 were produced in just four years' time, and also as refereed journal and book articles. While several of the modeling postdocs stayed on with the NREL, only Jim Ellis of the original four integrators remained to lead the Lab into major international research projects in the 1990's and beyond. Dr. Ellis' tragic death in an avalanche in March 2002 caused his many colleagues around the world to reflect upon his preeminent work on understanding interactions between natural processes and human societies. Jim's ability to conceptualize and synthesize large, complex systems was second to none, with the possible exception of George Van Dyne.

Dr. Coleman's first contact with the IBP/Grassland Biome happened while attending a U.S./Canada grassland ecology symposium at Saskatoon, Saskatchewan, in 1969. Robert Coupland and several colleagues at the University of Saskatchewan had directed a large-scale Canadian IBP study of grassland ecology on a former cattle ranch, the Matador site in Kyle, southwestern Saskatchewan. George chartered a DC-3 airplane to fly two dozen scientists from around the west from Denver to Saskatoon to participate in the symposium. The ride up there was incredibly rough, and the ashen-faced participants were uncharacteristically quiet the first day of the meeting. By the time we moved out to the Matador site, interests and volume of discussions had intensified, as had our collective thirst, which was slaked by many cases of good Canadian lager over the course of the three days of presentations and discussions.

The Grassland Biome's "crown jewel" was the development of a total system model, called ELM (Fig. 4), an acronym for "Ecosystem Level Model." It took George Innis, many postdoctoral fellows and research associates, including Gordon Swartzman, George W. Cole and others working long hours to produce a very detailed model that had 4400 lines of code, 180 state variables and 500 parameters. It required roughly 7 minutes to compile and run a two-year simulation with a two-day time step on a CDC 6400 mainframe computer. Roughly 20 man-years of effort went directly into its development and reporting (6,16).

The structure of the model was probably overly elaborate, including, for a variety of reasons, ecosystem components that might, in retrospect, have been omitted. Further, its stated objectives were somewhat vague, and we can probably infer that its real objective was to prove that it could be built. In other words, Van Dyne wanted to demonstrate that ecologists knew enough about grassland processes, mathematics, and systems analysis that a mathematical construct that acted like a grassland system could be developed. In his view, such a construct could be used to examine grassland dynamics in place of, or as a complement to, field experimentation. The issue of the feasibility of developing such a model was very much an open question at that time (8).

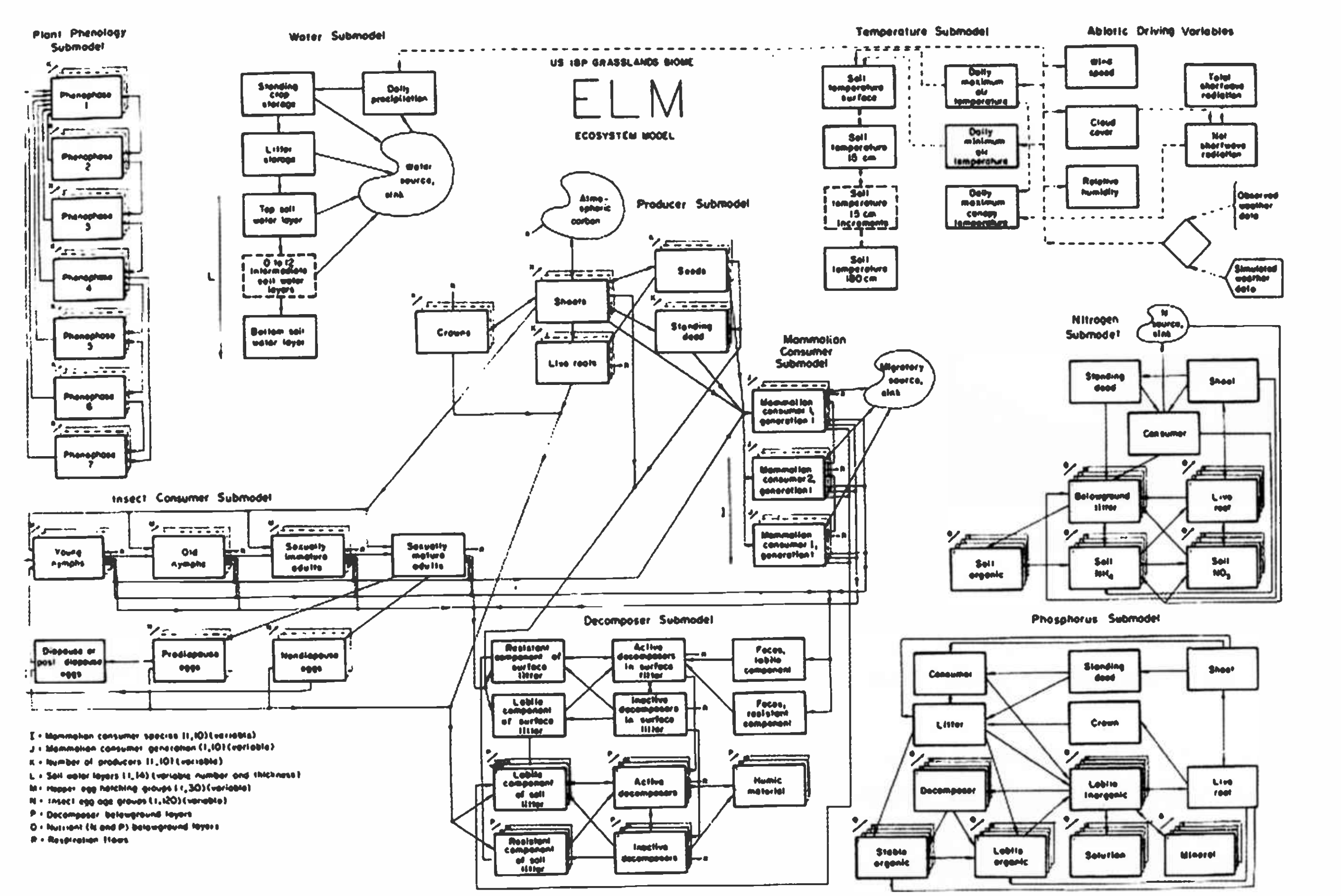

Fig. 4. ***Schematic diagram of the ELM model, US/IBP Grassland Biome (from French 1979).***

It seems to us that the model itself was never much of a success in terms of being used to answer questions about grasslands, but that it was a necessary precondition for the development of simulation modeling in ecology. In that sense it was quite successful. Much more useful simulation models quickly followed the development of ELM, and modeling was no longer considered to be aberrant behavior among ecologists. Most of the large-scale, long-term, multi-variable questions now being addressed by those interested in the ecology of our planet would be largely unapproachable in the absence of the modeling capabilities developed and proven in the IBP.

The Grassland Biome years were short and intense, lasting from late 1967 until 1974, one year after George Van Dyne stepped down as NREL Director. They were characterized by many planning meetings and extensive travel; in essence, an experiment in "top down" Biology. The travel included numerous site visits by those in leadership positions (Table 1), and trips to Fort Collins and other central locations for synthesis activities by participating scientists. This interaction and synthesis were, perhaps, the Biome program's strongest contribution to science. Under the leadership of George Van Dyne and other pioneers in systems ecology, the IBP provided the first broad forum in history to integrate the various disciplines in ecology, soil science, climatology, etc. into a comprehensive representation of grassland ecosystems. Synthesis and collaboration extended to numerous international meetings and symposia (Table 2).

The Grassland Biome's weak points were the same! A detailed cost-benefit analysis was never done comprehensively, but an evaluation of the three senior biome programs, including the Grassland biome (13) published in Science was generally critical of the approach, claiming that it was not cost-effective and the scientific findings

Table 1. IBP Grassland Biome site visits in 1972 and 1973

Location	Lead investigator(s)
Osage Site, Ponca City, OK	Paul Risser, et al.
Pantex Site, Amarillo, TX.	Ellis Huddleston, Russ Pettit, et al.
Jornada Site, Las Cruces, NM	Rex Pieper, et al.
Bridger Site, Bozeman, MT.	Theodore Weaver, et al.
Cottonwood site, Phillip, SD.	James K. Lewis, Jerry Dodd, et al.
ALE site, Richland, WA	William Rickard, et al.
Annual grassland, Coarsegold, CA.	Donald Duncan, et al.
Pawnee, shortgrass prairie, Nunn, CO	George Van Dyne & Don Jameson

were not very significant. Interestingly, however, a series of papers published on Grassland biome studies one to two years after the aforementioned critique were widely cited by other researchers in ecosystem science (5,10,14,17). The lattermost paper has been cited more than 100 times (ISI Web of Science). Two synthesis volumes were produced in the late 1970's as well. Norman French edited a volume (7) reviewing the major findings of the U.S./IBP Grassland Biome study. By 1978, a major international compendium on grassland ecology was assembled, based on several synthesis meetings in the early and mid-1970's, and published two years later (2).

One must put any criticism of the efficiency of the use of funds by the Grasslands Biome program, as well as other IBP studies, in perspective. The summed U.S. IBP budgets easily doubled NSF's support of ecological science. Examples abound in industry, government, and the military that show the extreme difficulty of wisely expending funds under a rapidly expanding budget. This was complicated by the fact that in any really new undertaking such as the IBP – there is a certain amount of experimentation with approaches; some of which work and some of which don't. When viewed in retrospect, failed approaches look wasteful, but they are an unavoidable outcome of searching for the successful ones.

With most Biome programs exceeding the $1M level (the Grassland Biome's budget in 1972 and 1973 was about $2.1 million), the National Science Board (NSB) had to approve each Biome program's budget and its continuation every year. Several years after the Biome program came to an end, Frederick E. Smith, one of the strongest supporters of IBP, and a member of the NSB, confided to us in the NREL that the NSB usually voted by a narrow margin of 8 to 7 in favor of continuing the Biome programs. This reflected the strong divergence of opinion about the merit of the Biome programs.

The initial assessment by Mitchell et al. (13), together with pressure from the NSB, probably caused NSF to pursue a post-IBP model of medium-sized grants for ecosystems studies, currently in the Long-term Ecological Research (LTER) Network (3). This model is being followed today, with the average annual grant to an LTER site equaling no more than $800,000, which would have equaled less than $250,000 in early 1970s dollars, roughly one-tenth of the Biome budgets at their peak. Of course, the total number of personnel supported by an LTER grant seldom reaches 50, with

Table 2. International Biological Program Workshops, meetings during 1972-1974, a partial listing.

1. International microbiology/decomposition workshop, Åbisko, Sweden, May 1972
2. International decomposition and soil fauna workshop, Louvain, Belgium, June 1972.
3. Grassland-Tundra International workshop, Fort Collins, August, 1972
4. International symposium on the International Biological Program, Seattle, WA, September 1972.
5. Grassland-Desert process studies workshop, Logan, UT, January 1973
6. Grassland Biome decomposition workshop, Fort Collins, March 1973
7. International workshop on grassland processes, Dziekanow, Poland, July, 1973.
8. International workshop on belowground processes, CSU, Ft. Collins, October, 1973
9. International workshop on tropical grasslands, Banaras Hindu University, Varanasi, India, January, 1974.
10. International workshop on decomposition and nutrient cycling, UNM, Albuquerque, May, 1974.

many of the senior scientists drawing no salary or at most a month of summer funding. In contrast, each Biome program had more than two dozen full-time scientists, programmers and support staff, and supported numerous graduate students as well. Most Biome programs encouraged the participation of colleagues from cooperating federal agencies, such as USDA Forest Service and Agricultural Research Service and U.S. Geological Survey, a successful practice that continues today at a majority of the LTER sites.

The Biome programs were hotbeds of ideas and concepts that led into post-IBP and early LTER studies. For example, projects developed at the NREL became comprehensive studies addressing belowground ecosystem foodwebs (D. Coleman, H.W. Hunt); N, P, and C cycling and their interactions (R. Woodmansee, C.V. Cole, W.J. Parton); ecological hierarchies and spatial variability (D. Anderson, R. Heil, R. Woodmansee); plant/animal interactions (J. Detling, M. Dyer); and humans in ecosystems (J. Ellis, D. Swift, K. Galvin).

Knowledge For the Future

The direct contribution of the IBP to future scientific research was more in terms of personnel and mode of conducting research, and less in terms of program emphasis (4). The IBP showed that teams of scientists could work together fruitfully and enjoyably, investigating complex problems involving many variables, across many sites. The IBP approach included both conceptual and mathematical modeling, marking the coming of age of this useful research tool.

By way of contrast, the LTER model, which began in 1980, six years after the demise of the IBP, initially pursued a set of questions in five core areas across multiple sites, and across decades in time span (11,12). Successors to the Grassland Biome sites include the shortgrass steppe LTER at the old Pawnee IBP site, Jornada LTER in southern New Mexico, and the Konza Prairie LTER in eastern Kansas. Although each of the 24 sites in the LTER network focuses on questions that are unique to their ecosystem, there is a commonality of approaches in the five core areas, including primary production, decomposition, nutrient cycling and disturbance phenomena. Comparative studies and syntheses are encouraged by supplemental small grants to encourage this activity (9).

In summary, we conclude that there have been many contributions, intellectually and by example, through which the IBP programs of previous decades have expanded research from local or site scales involving one or two disciplines ("the old frontier") to broad-scale networks of entire ecosystems, as embodied by the LTER program and other programs investigating global ecological issues ("the biosphere").

George Van Dyne's untimely death at the age of 48 years in 1981 cut short a phenomenal life. Including the Grassland Biome project, he brought more than $25 million in research dollars to CSU. During his short career of 25 years, he authored or co-authored nine books and 125 scientific papers (He had 35 manuscripts in press or preparation at the time of his death). [In 1983 he was the recipient of the Frederic G. Renner Award by the Society for Range Management. (Editor)]. George spread his vision of systems ecology widely, delivering at least 150 invited lectures and presentations at more than 40 universities.

We look forward to future decades of collaborative research, perhaps in more of an international context, as we benefit from the many contributions of our colleagues and predecessors in the U.S. IBP. Their studies led the way towards our expanding understanding of ecosystems, and the socio-economic systems embedded within them.

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