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INTERNATIONAL BIOLOGICAL PROGRAM

Analysis of Ecosystems

CONIFEROUS FOREST BIOME

YEAR 2 PROPOSAL

Volume 1

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UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON 98105

TO: NATIONAL SCIENCE FOUNDATION

TYPE OF SUPPORT REQUESTED: Research Grant

TITLE OF RESEARCH PROJECT: "Western Coniferous Forest Biome"

PRINCIPAL INVESTIGATOR:

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AMOUNT REQUESTED: $1,791,984

DESIRED GRANT PERIOD: One year, beginning January 1, 1972

UNIVERSITY OFFICIAL TO BE CONTACTED REGARDING GRANT OR CONTRACT NEGOTIATION:

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ABSTRACT

Introduction

This proposal by the Coniferous Biome investigators requests support for the second year of a highly integrated series of investigations within the Analysis of Ecosystem program of the United States effort under the International Biological Program. The program for the Coniferous Forest Biome has been approved by the U.S. Executive Committee for the IBP as an integrated research program in cooperation with other programs in progress or under development for the Analysis of Ecosystems. The proposed study is one of six which will collectively form a reference modeling system to cover the important ecosystems of North America.

Coniferous forests occupy about one-third of the land area of the western United States, including Alaska. The products from this land area, such as wood, water, forage, fish, and wildlife, are most important to the physical and economic well-being of the nation. In addition, large areas are used as recreational sites by increasing numbers of people.

The capacity of the land to produce various goods and services varies greatly from area to area. Arguments about the management of these lands have been prominent in the literature of land management sciences (such as forestry and fisheries) and ecology for many years. These highlight problems such as single- vs. multiple-purpose use, the balance between various uses, the land's basic productive capacity, and management procedures best suited to maintaining and increasing it. More recently fundamental questions have been raised about the impact of widespread and previously accepted practices, such as clearcutting, on environmental quality and long-term productive potential of the land. We know that some of the lands are more vulnerable to ill-considered use than others and many areas are being subjected to extreme modification by urban developments.

We believe that a better understanding of the forest ecosystem, which is the goal of this proposal, will provide a basis for more intelligent management and use of these lands and thereby will have important social consequences. In light of the seriousness of the questions raised, the research proposed can therefore claim an urgency as well as scientific and practical values.

Objectives

We seek a basic understanding of coniferous forest ecosystems, including both terrestrial and aquatic components, so that ecological limitations on management and opportunities for increasing production of fiber, food, water, and wildlife are recognized and defined. The overall strategy includes identification of the major components and processes, both physical and organic, and definition of how they are interrelated. The definitional interrelationships will be accomplished through a systems analysis and modeling program. As an overall guide for this and future Biome proposals we have identified the following general objectives for our research work:

1. To determine major factors, both components and processes, that control the productivity and distribution of organisms in coniferous forest ecosystems.

2. To examine terrestrial and aquatic linkages in coniferous forest ecosystems with respect to water, elements, and energy.

3. To determine how manipulations influence the structure and function of coniferous forest ecosystems.

4. To understand population dynamics of major components of each trophic level which apparently influence the sustained productivity and stability of various ecosystems within the Biome.

5. To produce models of temporal and spatial variation in coniferous forest ecosystem components, which will include factors affecting system productivity and stability and the land-water linkages, and will predict the behavior of these systems after various manipulations.

6. To apply specific models in the solution of major use problems in the Biome area and assist other groups or agencies to do likewise.

Specific objectives or tasks for the year-2 research program have been formulated as follows:

1. Complete general ecosystem descriptions on the two intensive sites at the specific locations and with the degree of resolution required to support the modeling and research work.

2. Develop the necessary additional data and functional models for transfer mechanisms and pathways of nutrients, particulate matter, water, and energy in selected intensive site ecosystems. Terrestrial-aquatic interfaces will be emphasized. Furthermore, the relative importance of different energy and nutrient sources for production in aquatic systems and structure and function of decomposer subsystems will be given special attention.

3. Model assembled information from past and ongoing research on consumptive and disruptive influences of terrestrial consumers and on environmental influences on terrestrial primary productivity, and investigate strategies for whole-ecosystem modeling.

4. Develop further the total Biome strategy of ecosystem study particularly the role and a specific operating plan for the coordinating research program.

Rationale

This second-year proposal plans to focus considerable research effort on the development of coordinated submodels with assembled information from the baseline Douglas-fir ecosystem conditions of the two intensive sites. Whole-ecosystem models will be developed simultaneously by the modeling group.

Future years will see more effort shifted to model validation and manipulation studies in similar and different ecosystem conditions, involving considerable coordination with the then-well-developed coordinating sites program.

Proposed Research

The necessary research has been defined according to the specific year-2 objectives by the subject matter research committees and focused on specific study sites by the site directors. New field research is concentrated on process studies critical to model development, with a few descriptive studies needed to fill in information gaps.

Continual interaction and mutual education of subject matter groups and subsystem modelers from the modeling group will ensure a realistic approach to modeling. Integration of submodels and simultaneous total-model development will be the responsibility of the modeling group.

The major function of the Biome director and his staff will be direction and supervision of the research efforts, facilitation of communication among all participants, and provision of necessary operational services.

Study Sites

It has been decided to develop the intensive study at two sites, the Cedar River-Lake Washington drainage basin and the H. J. Andrews Experimental Forest. Both are located in the dense coniferous forests of the coastal Northwest, specifically the Douglas-fir-western hemlock forests which are the most productive in the Biome. Each contributes unique features of past research programs, facilities, involved personnel, and principal natural resources which we have combined into a single comprehensive investigation of a conifer forest ecosystem. The considerable institutional contributions in manpower, existing facilities, maintenance, and new developments at these locations will enable the research programs to develop rapidly and produce results rather quickly.

Cedar River-Lake Washington drainage extends from the Cascade crest in northern Washington to salt water on Puget Sound. It includes, therefore, a variety of aquatic and forest environments. The major aquatic system is Lake Washington and the major drainage into it is the Cedar River. A major part of the Cedar River is administered by the City of Seattle. Biome study sites and proposals will include both aquatic and terrestrial habitats, with emphasis on young-growth forests (1 to 100 years) originating from past harvests of old growth. The maritime climate has rainfall ranging from 102 to 254 cm over the drainage area.

H. J. Andrews Experimental Forest is a 608-ha drainage in the western Oregon Cascades, administered for research by the U.S. Forest Service Pacific Northwest Forest and Range Experiment Station. Old-growth (450-year-old) Douglas-fir-western hemlock forests dominate although younger forests (1 to 130 years) are also present. Streams provide most of the aquatic habitat. The mature mountainous topography ranges from 457 to 1615 meters in elevation and 229 to 254 cm of rainfall is characteristic.

Current and proposed studies at these sites are designed to complement each other and capitalize to the maximum extent possible on past research. At Andrews Forest the research work will concentrate on older forests and cycling in unit watersheds. At the Cedar River-Lake Washington site studies will emphasize young forests, detailed process studies, and lake systems.

The coordinating-site investigators will be developing a cooperative research program and strategy oriented to the validation of models developed by the intensive-site scientists. Already considerable input from investigators studying aspects of modeling and site-independent process studies elsewhere in the Biome have been incorporated in the present proposal for year 2, including work by visiting scientists on the two intensive sites.

Collaboration

This proposal will involve nearly 130 professional participants at 25 institutions in 11 states. A list of the institutions by states follows:

State	Institution
Alaska	University of Alaska
California	University of California at Davis University of California at Berkeley Chico State College
Colorado	Colorado State University
Germany	University of Munich
Idaho	University of Idaho
Illinois	Argonne National Laboratory
Montana	University of Montana
Oregon	Oregon State University U.S. Forest Service, Pacific Northwest Forest and Range Experiment Station University of Oregon George Fox College U.S. Soil Conservation Service
Pennsylvania	Swarthmore College
Utah	Utah State University University of Utah Brigham Young University
Washington	University of Washington Western Washington State College City of Seattle, Water Department Municipality of Metropolitan Seattle Washington State Department of Natural Resources Battelle Memorial Institution

Federal, state, and municipal agencies will be involved in the research program both through participation of personnel and through use of major land areas for the research. For instance, the H. J. Andrews Forest is a dedicated experimental forest in the U.S. Forest Service; many of its research programs are being adapted to the Biome program. The upper Cedar River watershed is either owned or controlled by the City of Seattle and includes a research area dedicated to Biome research. A number of proposed coordinating sites are owned by federal or state agencies and, as work at these centers is developed, further collaboration with the respective agencies will take place. Scientists from these agencies will participate in the planning and execution of the proposed research.

Scientists from private forest companies are also involved in the Biome organization and research development, especially the Forest Research Center of Weyerhaeuser Company at Centralia, Washington. As the Biome research develops, the contributions of these individuals and organizations will take on added significance.

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BUDGET SUMMARY IN SUBJECT MATTER GROUPS

Services	$ 310,594
Modeling	182,777
Terrestrial Producers-Processes	159,392
Terrestrial Producers-Biomass and Structure	143,455
Genetics	24,031
Terrestrial Consumers	133,187
Decomposer-Aquatic	80,397
Decomposer-Terrestrial	144,963
Aquatic	268,369
Interface-Nutrient Cycling	132,789
Interface-Hydrology	105,127
Interface-Meteorology	106,903
TOTAL BUDGET	$1,791,984

Key for abbreviations on the following pages:

U of W	University of Washington
OSU	Oregon State University
U of I	University of Idaho
ANL	Argonne National Laboratory
WWSC	Western Washington State College
USU	Utah State University
U of C	University of California
U of O	University of Oregon
BNW	Battelle Northwest
CSC	Chico State College
CSU	Colorado State University
U of U	University of Utah
USFS	U.S. Forest Service
BTI	Boyce Thompson Institute
SCS	U.S. Soil Conservation Service

ND CATEGORY, IBP CONIFEROUS FOREST BIOME F. Y. 1972

	WWSC	USU	U of C Berkeley	U of O	BNW	CSC	CSU	U of U
	$ 1,200	$ 4,730	$	$ 2,525	$1,660	$	$ 1,700	$ 1,800
·00		4,000				800		
	7,200	13,200		5,600		690		2,600
		4,000	7,728					
	597			3,400				1,100
00	8,997	25,930	7,728	11,525	1,660	1,490	1,700	5,500
00	558	2,852	773	1,210	166	149	144	550
	7,520		6,700	3,517				
00	900	1,650	1,167	900	400		500	600
00	450	3,200		750	200		13,000	600
		500		200	250			50
		4,200			400			
	500				630			200
)0	$18,925	$38,332	$16,368	$18,102	$3,706	$1,639	$15,344	$ 7,500
--	3,181	14,934	3,632	3,760	1,401	376	935	3,360
)0	$22,106	$53,266	$20,000	$21,862	$5,107	$2,015	$16,279	$10,860

TOTAL: $1,791,984

IBP-CONIFEROUS FOREST BIOME F. Y. 1972, *SUMMARY OF INSTITUTIONAL CONTRIBUTIONS

Category	U of W	OSU	USFS	U of C (Davis)	U of I	ANL (AEC)	BTI	WWSC	USU	BNW (AEC)	U of C (Berkeley)	U of O	SCS	CSC	U of U
Salaries	$ 75,629	$52,380	$ 46,178	$43,725	$ 8,175	$ *	$1,200	$2,400	$1,460		$1,226	$ 762	$2,600	$1,200	$1,800
Benefits	7,564	5,238		4,373	649	*	120	305	160		159	80		120	180
Equipment		2,350		5,200	1,900	*	600	700						50	
Supplies		750				*	1,400	400							
Travel		2,400			300		300								
Other		6,013	69,267 1/		500			800					2,600 1/	50	
Direct Costs	$ 83,193	$69,131	$	$53,298	$11,524	$	$3,620	$4,605	$1,620		$1,385	$ 842		$1,420	$1,980
Indirect Costs	35,603	25,228		20,551	4,989		564	849	840		576	249		303	1,100
Total Contribution	$118,796	$94,359	$115,445	$73,849	$16,513	$50,000 2/	$3,620	$5,454	$2,460	$10,000 2/	$1,961	$1,091	$5,200	$1,723	$3,080

1/ Detailed breakdown of direct and indirect costs for federal agencies, excluding salary, not available.

2/ Detailed breakdowns of the AEC contributions through Argonne National Laboratory and Battelle Northwest at Hanford are not available. Salaries, equipment, supplies, and indirect costs are some of the items included.

* The Grantees will cost-share in accordance with current Foundation policy. The detailed presentation concerning the anticipated Grantees' contribution is shown for information purposes only.

I. INTRODUCTION

A new public awareness of natural resource use problems and environmental changes has had major influence on the political and scientific communities. Public interest in and support of environmental improvement has caused research scientists and research funding groups to examine means for environmental improvement through more problem-oriented research. An era of relevance of research and teaching is upon us; new goals and new concepts have emerged, and research objectives have changed. A general reappraisal of what the scientific community is doing is resulting in a redirection of effort at all levels of government and education.

The International Biological Program and especially the Analysis of Ecosystems program has a unique opportunity to aid in this redirection and demonstrate how sound biological information can be synthesized and used in assessing alternatives. The Analysis of Ecosystems research has previously received support on the basis of understanding ecosystems to predict functions, especially those relating to productivity. This general goal is still valid for we critically need to understand forest and other natural ecosystems productivity as our impact upon these systems increases. In addition we must strive to understand how natural systems may be maintained and where increased productivity may be detrimental. At the same time research must address itself to major problems in the social and political field of resource use as well as to the biological problems.

Among the principal resource problems of the Western Coniferous Forest Biome the following have been identified as areas where specific contributions can be made by IBP research:

1. allocation of land, forest, water, and other resources for various uses;
2. productivity and productivity maintenance on forest lands,
3. productivity of surface waters;
4. role of land and vegetation management in water quality and quantity;
5. the impact of management practices on forest lands, e.g., clear-cutting of Douglas-fir forests, slash burning, and road construction;
6. spread of suburbia throughout forested areas and the ecological impact of this spread;
7. interaction of animal populations in forest areas;
8. impact of recreation seekers on western forests,
9. the potential for using forest land to control and absorb some suburban and agricultural pollutants.

The Western Coniferous Forest Biome researchers have developed a program of coordinated and interdisciplinary research aimed at providing answers to some of these specific problems. The original proposal established the basic organization of the Biome and set certain goals for research and data analysis within the context of the U.S. International Biological Program. The present proposal extends these programs and develops more specific objectives for this and subsequent years of Biome research geared to major problems of ecology and society within the Biome area.

The fact that local and regional researchers and research administrators are supporting this interdisciplinary effort is evidenced by contributions of funds, land areas, and other forms of support to the program. The city of Seattle is contributing the land area for the intensive site on the Cedar River watershed and a considerable amount of developmental work, in addition to protection of expensive equipment installations. The participating educational institutions are contributing time of a large number of research scientists along with certain facilities such as computers. The Pacific Northwest Forest and Range Experiment Station of the United States Forest Service is contributing land and facilities for the other intensive site, the H. J. Andrews Experimental Forest. The Forest Service has also integrated ongoing research projects in the amount of about $115,000 into the Biome program, and is, in addition, providing at least another $115,000 in salaries and support of regular research staff who are involved in several research projects and the Biome administration. All of the organizations mentioned already have made sizable financial contributions in the form of salaries and expenses involved in development of Biome organization and preparation of proposals. We believe these contributions are direct evidence of the enthusiasm with which the Biome research program is being received and of the potential for securing answers which can be applied to specific resource problems within the Biome area.

An additional direct educational impact of Coniferous Biome and IBP research is now apparent. Even in a limited first year activity new concepts of ecosystem analysis and modeling are entering into both undergraduate and graduate education at instititions throughout the Biome. Students are among the most enthusiastic supporters and originators of new approaches to forest ecosystem studies and their use in decision making. The participation of these students in IBP and the Coniferous Biome research may by itself lead to the most long-range benefits of the program.

In the research field, the present controversy over the practice of clear-cutting coniferous forests is an excellent example of possible IBP and especially Coniferous Forest Biome research input to management and political decisions. Clear-cutting can be defended as ecologically sound in certain environments and with certain management objectives. There are many other situations in which the practice can be criticized as ecologically unwise. Obviously, generalized statements covering the entire forest areas of the United States are of no value in attempting to decide management practices for local areas.

Specific information is needed for each set of forest parameters and an integrated research effort with the ultimate goal of a working ecosystem model for the forest parameters is the best answer.

The research details and the organization needed to achieve these research and educational goals are presented in the text of the proposal which follows. A great deal of detail is presented and much supporting information. However the success of the total program will revolve on three key points:

1. Integration of research efforts. Scientists from different institutions and disciplines must work together, sharing concepts, information, and progress.

2. Continuous development of modeling concepts among all research workers. Each researcher must be a modeler and have the relationship of his effort to others firmly in view.

3. Adequate communication at all levels of Biome research and management, not only within the Biome but with other national and international programs.

General and specific Biome objectives follow.

1.1. General Biome Objectives

The goal of our Coniferous Biome research studies is a basic understanding of coniferous forest ecosystems, including both terrestrial and aquatic components, so that ecological limitations for increasing productions of fiber, food, water, and wildlife are recognized, as well as the opportunities. The overall strategy includes identification of the major components and processes, both physical and organic, and definition will be accomplished through a systems analysis and modeling program. As an overall guide for this and future Biome proposals we have identified the following objectives for our work:

1. To determine the major factors, both components and processes, that control the productivity and distribution of organisms in coniferous forest ecosystems. Here we include: (a) an analysis of the structure and distribution of the principal resources; (b) definition of the functional relationships between abiotic, decomposer, consumer, and producer components of the systems; and (c) analysis of the forms and degrees of stability in these systems.

2. To examine the linkage of terrestrial and aquatic components in coniferous forest ecosystems, including; (a) water, energy, and transport of chemicals (including pesticides); (b) direct transport of terrestrial products into the aquatic system (e.g., through litter fall and surface erosion); and (3) return of organic and inorganic material from the aquatic to the terrestrial environment through movements of fish, birds, and insects.

3. To determine how various manipulations influence the structure and function of coniferous forest ecosystems. This will be accomplished by using both unit watersheds and plot studies. Special attention is directed to the influence of manipulation on (a) stability and productivity of these systems, and (b) the linkages between terrestrial and aquatic components of the systems.

4. To understand population dynamics of those major components of each trophic level which appear to influence significantly the sustained productivity and stability of various coniferous forest ecosystems within the Biome.

5. To produce models of temporal and spatial variation in coniferous forest ecosystems or system components. These models will include factors affecting productivity and stability of the systems and the linkages between terrestrial and aquatic environments and will forecast the behavior of these systems and their relationships to human manipulation.

6. To apply specific models in the solution of major use problems in the Biome area and assist other groups or agencies to do likewise.

1.2. Specific Annual Objectives

The general Biome objectives provide broad guidelines for Biome research. For more specific direction in planning and integrating the research program, the Planning and Program and Executive Committees have developed annual objectives. These objectives have been used as the basis for soliciting research proposals, determining priorities, and integrating large units of work. As a device for focusing the Biome's research, the annual objectives have worked well and we plan to continue and expand the use of specific objectives in the future.

In the following section the specific annual objectives used in planning the year-1 and year-2 proposals, and those we expect to adopt in the future, have been broadly outlined. The year-2 objectives are discussed in considerable detail in section 7.1.2. The objectives listed for future years are tentative and will, of course, be refined and revised in the light of program developments being used as a basis for planning future proposals.

In year 1 we planned a minimum of new research and emphasized utilization of existing data, collected over many years, for preliminary modeling objectives. Our specific objectives were: (1) development of models based on existing data from past or current studies with special emphasis on the terrestrial-aquatic interface; (2) initiation of process studies to elucidate functional relationships between and within terrestrial and aquatic components of the ecosystems under a range of conditions, including natural and manipulated; and (3) initiation of process and validation studies at the intensive sites. Development of the program around these objectives has provided a broad base for moving into a full-scale effort in the second year of the program, our first year of full-scale funding. Progress reports for the first six months of year 1 are given under each subject in section 7.

Research efforts in year 2 will be directed toward the terrestrial-aquatic interface with an emphasis on the understanding of mechanisms maintaining ecosystem productivity and the definition of limiting factors. Specific objectives to be accomplished include:

1. Carry out general ecosystem inventories at the intensive sites at the specific locations and degree of resolution required to support the modeling and research work outlined below.

2. Develop the necessary additional data and conceptual models for modeling transfer mechanisms and pathways of nutrients, particulate matter, water, and energy in selected intensive site ecosystems, specifically including:

   a. interfaced terrestrial-aquatic systems, i.e., rates, pathways, and controls on nutrients and water cycling in stable terrestrial-aquatic systems (on unit watersheds or drainages) and energy transfers between the terrestrial and aquatic parts of the systems;

   b. interfaced terrestrial-groundwater systems; i.e., energy, water, and nutrient budgets including transfer mechanisms, rates, and pathways in a second-growth Douglas-fir stand (Thompson Research Center;

   c. determination of the relative importance of various energy and nutrient sources for production in higher trophic levels (e.g., fish) in aquatic systems (including primary production, direct transfers from terrestrial systems, and fish carcasses); and

   d. acquisition of data and conceptual framework for determining the degree of resolution of models of the detritus or decomposer segment of terrestrial and aquatic systems.

3. Model information on the other important facets of coniferous ecosystems.

4. Further develop the total Biome strategy of ecosystem study particularly the role and specific operating plan for the coordinating site research program.

Specific objectives to guide research work in subsequent years will be formulated as research from year 1 is completed and the proposal for year 3 is developed. However, certain general guidelines can be stated at this time. During year 3 transitions will be made from inventory and process studies of undisturbed ecosystem conditions to (a) validation studies of ecosystem sub-models, (b) studies of manipulative effects on ecosystem model parameters, (c) application of information to specific systems, and (d) testing of the robustness and predictive power of the models. Many of the necessary studies will be combined with the coordinating sites research program. Specific types of changing research emphasis will be:

1. reduction of investment in intensive site unaltered ecosystem studies;

2. initiation of submodel validations with mobile equipment on different localities with (a) similar ecosystems, (b) dissimilar ecosystems, and (c) different age systems or individuals;

3. initiation of ecosystem disturbance (manipulative) studies with an emphasis on the effects on the terrestrial-aquatic interface: (a) historical (e.g., fire, erosion); (b) recent (natural disruptive influences due to pests, fire, landslides, floods; artificial disturbances by unit watershed and habitat treatments, such as clear-cutting, partial cutting, fertilizing, and pesticides; and low-level chronic disturbances);

4. examination of disruptive influences due to organism interactions (population dynamics, biological control);

5. relationship of application or manipulation to productivity in both terrestrial and aquatic systems;

6. publication and discussion of Biome research (presently plans are being made for a one-half day symposium at the Northwest Scientific Association meeting for 1972).

In years 4 and 5 Coniferous Biome research will be further devoted to generalization of models by extension to different coniferous ecosystems. Validation models on undisturbed and manipulated ecoystems will be further refined. This will mean greater activity at one or more coordinating sites. A definite effort will also be made to apply results to more pressing resource management problems throughout the Biome through workshops and scientific public meetings. Publication of results will also proceed rapidly during this research year.

1.3. Modeling Approach

1.3.1. Introduction

In this section the modeling approach and philosophy of the Coniferous Biome is reviewed. In the proposal for the research of the first year a rather full treatment was given of the general ideas of system modeling as well as of the major classes of models. The appropriate section from that proposal is included in section 8.4 of this proposal for 1972, and can be referred to for amplification of some aspects of the more summarized treatment given here. In addition, the experience of the first year of the research efforts has brought out some new concepts and approaches which are discussed in the following sections.

It needs to be emphasized that almost every scientific study beyond simple observation involves some type of model. For most biological studies in the past these have been verbal or graphical models and often have been limited to very simple parts of the system. However, attempts have been made to make some models much more comprehensive--for example the work on stability and diversity. Also there have been some powerful and useful mathematical models, e.g., the Lotha-Volterra competition models and their various extensions.

Another class of mathematical models deals with the population dynamics of an exploited fisheries population. These include both interpolatory or empirical models such as that of Schaefer, and functional or structural models (Beverton-Holt, for example). A useful review of population dynamics models of both these types, comparing their advantages and disadvantages, is to be found in Schaefer and Beverton (1963).

While these models are mathematical, they are still extremely simple, dealing for the most part with a single species essentially isolated from and abstracted from its environment. What is new in recent research is the availability of the computer to perform tasks of synthesis and analysis as well as data compilation previously beyond our capabilities. Because biological relationships are so complex and biological variables so numerous, the computer is needed to store the data collected, analyze it efficiently, and perform the mathematical operations required for predicting the response and interreactions in complex systems. The computer provides a new and powerful tool to science that encourages a scope and complexity of research previously impossible.

1.3.2. Approach

The analysis of an ecosystem should begin by construction of models from existing data and from our understanding of the functions and processes involved. The second step is the collection and analysis of data for testing and refining the first models. As the kinds of additional data that are needed are identified, scientists will be able to conduct specific field tests to further improve the models.

While ideally the research design would involve a sequential process of the type indicated in the previous process, the time limitations on the Biome studies preclude this approach. Many gaps in our knowledge are apparent now and fieldwork is in progress to fill these gaps. The modeling and fieldwork thus will progress simultaneously.

Modeling and fieldwork are not proceeding completely independently, however. The Modeling Committee attempts to work closely with the scientists engaged in field and laboratory research. The steps to accomplish this and to maximize the needed interactions of the modelers and other scientists are outlined in section 8.3.1.

Before discussing the major aspects of the modeling process as developed by the Modeling Committee of the Biome we recall that models may focus on different aspects of the system and may have different levels of resolution. After Klir (1964, p. 55), we can identify several ways in which the ecosystem can be defined: (1) as a collection of subsystems with a specified pattern of coupling, (2) as a set of states with a specified pattern of transition, and (3) as a "black box" with a specified set of external variables. The first and third definitions may be considered two levels of resolution, as the subsystems are typically treated as black boxes, and of course may again be structured into a collection of subsystems so that several levels of organizational resolution can be recognized. Models under definitions (1) and (2) are typically called <u>structural</u> models and those under definition (3) <u>functional</u>

models. Thus the level of organizational resolution of an ecosystem model is determined by the level of organization at which functional (black-box) submodels are defined. It is apparent that the level of resolution need not be uniform over the entire model.

The term level of resolution is also used in several other ways, all useful to ecosystem modeling. We will refer to these by the names variable, temporal, and spatial. Variable resolution specifies the degree of fineness of the system variables, or the precision to which quantities will be measured and parameters will be defined. Temporal resolution refers to the temporal frequency at which variables are defined and observations are made, while spatial resolution specifies the size of the area to which the model relates.

There are other properties of models that need to be considered; generality, realism, and precision are obvious aspects. In section 8 some of these properties are considered for the models of the Coniferous Biome. In addition we can refer to models as being robust and sufficient. A robust model yields valid results even though the assumptions may be violated to some degree. A model is sufficient if the population is adequately described by the parameters of the model.

We recall also the distinction between associational and causal models. Other terms for associational models are interpolatory or empirical while causal models are also referred to as structural or process models. These terms were used earlier in citing some examples from the field of population dynamics of exploited populations. The aim of most modeling is to proceed from associational to causal models. Further, it is the aim of modeling to use these causal models to predict the effect on the system of natural or man-induced changes.

1.3.3. Component models

An ecosystem is made up of a great many components, and part of the understanding of the ecosystem is an understanding of the functioning of the many components. Such research is quite traditional in ecology. However it has not been customary to carry the research on the components to the point of building mathematical models, though here too many important exceptions exist. What the focus of the IBP program implies is that the development of the mathematical model is an integral part of the research. Since it is unreasonable to expect most primary investigators who are not mathematicians to develop these mathematical models, the research plan postulates a team approach that involves modelers with expertise in quantitative disciplines and scientists with a background in the substantive field (chemistry, physics, biology, microbiology, etc.) required for the research in point.

How does such a team proceed? Often a verbal or better still a graphical model is a starting point of a series of meetings, at which the basic variables are set down and the known functional relationships are expressed, first in words, then in some mathematical format.

Next, provisional parameter estimates are supplied by the research scientists from existing data, or by reasoned estimates where data are lacking. A set of plausible initial conditions is agreed on; the system of equations is converted to Fortran or Basic statements; and a computer run of the simulated subsystem is obtained, usually in the form of plots in which time is the independent variable, and exhibited to the research scientists for their comments.

This point in the procedure is usually a convenient one at which to reassess much more critically the assumptions on which the entire submodel was constructed. Usually, the first computer output is not a very good representation of the real subsystem. It is possible, of course, that parameters have been badly estimated, but it is more likely that the form of certain relationships is faulty. Modelers and scientists continue to modify until satisfactory results are obtained. At this time assumptions are carefully formulated, the resulting equations are written down, parameter estimates are recorded (together with source of experimental data), and final computer output is attached.

In this development of a submodel participation by research scientists is critical; modelers function essentially as the translators of their concepts into mathematical language, but the creation and evaluation of the model is the work of the research scientist. We have found in practice that, unless the research scientist is adept at mathematics, involving him at all stages of the modeling practice may be inefficient and even frustrating for all involved. It is possible, however, to enlarge the role of the modeler and reduce that of the research scientist to mutually satisfactory levels at which work proceeds rapidly, but in which the suggestions and critical comments of the research scientists are crucial to the development of the model.

1.3.4. Ecosystem model

The component models are important to our understanding of the processes that are involved in the system but, as has been clearly stated in the Analysis of Ecosystems part of the International Biological Program, the ultimate and important goal is the development of a model for the whole system so that a holistic view of the system is attained. The process of model development for ecosystem models will follow much the same pattern as that outlined above for the component models, though in the development stages modelers will be involved more and research scientists less. The total contribution of all the research scientists to the model must ultimately be very great, however, for this is the value of the interdisciplinary team. At the stages of refining and testing there will be a series of further workshop meetings at each university associated with the intensive sites, as well as intra- and inter-Biome meetings.

The modelers can and will begin with some overall ecosystem models of rather low resolution, focusing perhaps on one aspect (e.g., water). Much more meaningful results will be obtained when component functional models have been developed to a reasonable degree of sophistication and when the necessary parameter estimates have been refined.

Both the submodels and the ecosystem model will require testing and will suggest further research that must be undertaken to answer new questions or replace inadequate parts of the models already derived. Often the parameter estimates available may be too crude: it will be necessary to test the sensitivity of the model to the possible errors of estimation. This will usually be possible through computer simulations varying the range of estimate input over the possible range suggested by the data. If the output is largely unaffected, the model may proceed. If the output is significantly affected, additional observations and research are required.

Some simple graphical models which are being used as the first step of ecosystem models were exhibited in the discussion on system modeling in the proposal for the first year of the Biome and these are included in section 8.4.

1.3.5. Applications of the model

The aim of the ecosystem model is to guide the further research and to provide answers to specific questions. A variety of manipulations will occur because of outside events or will be proposed for experimental evaluation. The model should be useful to predict the outcomes of such manipulations, though of course in the early stages such predictions and their checking will serve as critical checks of the model also.

One of the manipulations of great interest is that of timber harvesting; e.g., there are choices between clear-cutting over wide areas or over restricted areas with strips of uncut forest, or between either of these procedures and selective logging. There are also choices in the treatment of the residue from the logging operation: Should it be left to recycle to the soil and, if so, should it be treated in any way? Should it be burnt and, if so, under what conditions? The decisions between these choices involve economic inputs of the different types of operations beyond the scope of our ecosystem models at this time. But the biological and physical consequences of timber harvesting are within the objective of the Biome research.

Timber harvest is only one of many manipulations that now occur in the terrestrial and aquatic systems of the Coniferous Forest Biome. Further, there is interest not only in evaluation of alternatives from the point of view of the part of the system directly involved, but also with regard to the other parts of the system. For example, timber harvest alternatives can be evaluated with regard to aquatic productivity. The model will be expected to provide precise answers, and in particular to point out effects and interactions that might otherwise be overlooked.

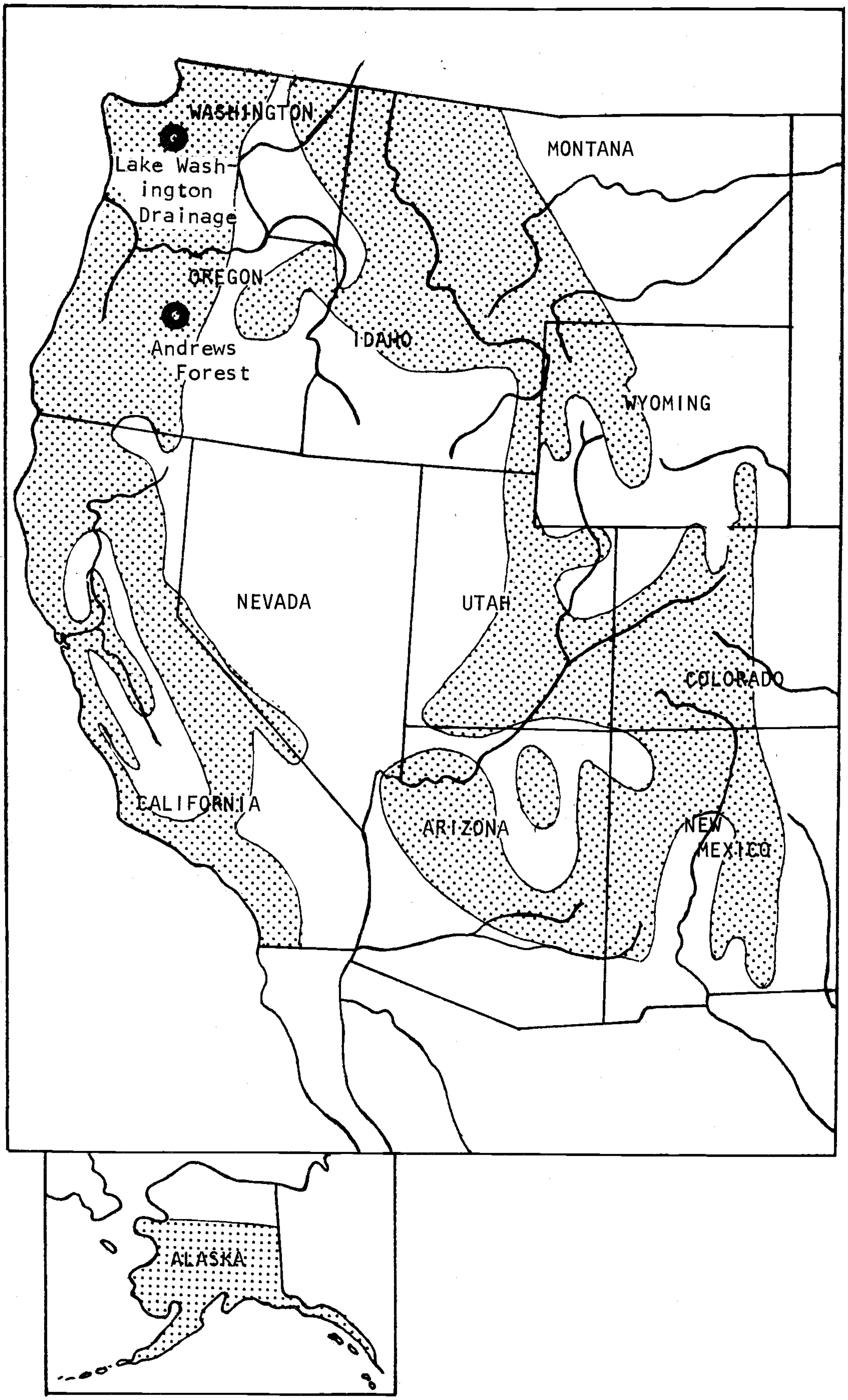
2. DESCRIPTION OF THE BIOME

Forests dominated by coniferous trees are widespread in western North America from Alaska to Guatemala and Honduras. Although broadleafed trees, such as birches, poplars, alders, oaks, and subtropical hardwoods, are not uncommon in this conifer belt, they emerge into dominance in conditions which are unusual in much of the western half of the continent. Conifers hold sway where mean annual temperatures are low, in dry forests bordering grasslands and desert scrub (where they often share dominance with oaks), and in regions where the seasonal distribution of precipitation appears not to favor the development of many kinds of broadleafed trees. Figure 2.1 roughly indicates the land area covered by the Coniferous Biome.

The commercially important coniferous forests of the western United States--those which comprise the Western Coniferous Biome--occur very largely in mountainous country. Four main divisions may be distinguished: (1) In temperate coastal and low-altitude mountain forests of California, Oregon, Washington, British Columbia, and Alaska, the maritime coastal climates are characterized by heavy winter precipitation, summer dry seasons moderated by frequent fogs or cloudy weather, and small seasonal variation in temperature. Important species include coast redwood, Douglas-fir, Sitka spruce, western hemlock, and western red cedar, all giant trees attaining 80 meters or more in height. (2) In forests of the Sierra Nevada of California and the adjacent Cascades of southern Oregon, climates are characterized by heavy winter precipitation and dry summers. Important species include ponderosa and sugar pines, incense cedar, California red fir, and Douglas-fir, as well as evergreen hardwoods such as tanoak, chinquapin, and madrone. (3) Coniferous forests of the Rocky Mountains are characterized in the north by severely cold winters with precipitation largely concentrated in the summer months, during which long dry periods often occur. Dominant trees include ponderosa pine, Douglas-fir, grand fir, western white pine, and large tracts of lodgepole pine, especially on poor soils and burned-over areas. Here occur the driest coniferous ecosystems, the pinyon-juniper woodlands, which extend from the central Rockies into the arid uplands of central Mexico. (4) Subalpine forests, the montane counterparts of the boreal forests of Canada, have cool, short growing seasons and often heavy snowfall in winter. Characteristic species include subalpine fir, Engelmann spruce, mountain hemlock, and limber and bristlecone pines. (5) In Alaska, as in Canada, the taiga forests, of lesser commercial value, cover broad expanses of lowland and grade into the Arctic tundra. Characteristic species include white and black spruce intermixed with birch and other deciduous forms.

Fire plays an important role in determining the floristic composition and hence the physiognomy of the vegetation of the Western Coniferous Forest Biome. In the temperate coastal forests of western Washington and Oregon, Douglas-fir, which reproduces itself poorly in heavy shade, would be replaced in the natural course of events by the somewhat smaller western hemlock and western red cedar. Infrequent major forest fires have provided the relatively open sites required by this species. Similarly, lodgepole pine in the Rocky Mountains and many of the several species of pines which occur in the mountainous dry interior of Mexico and Central America (notably *Pinus oocarpa*) are aided by fire in their competition with broadleafed trees and other conifers.

Figure 2.1 Coniferous Forest Biome Region .:: and Intensive Sites ● (Coniferous Region After U. S. Department of the Interior, Geological Survey (1970))



The Biome contains a great diversity of aquatic habitats, intimately linked with adjacent terrestrial communities. In the high mountains are nearly sterile alpine cirque lakes and shallow subalpine ponds. Important oligotrophic lakes of intermediate and large size are found in the lowland areas of Alaska and Washington and at higher elevations to the south and east. In the lowlands are oxbows and, to the south, warm eutrophic lakes. Snow-fed streams of swift water and high gradient feed into broad meandering rivers supporting endemic organisms as well as functioning as pathways for anadromous fish such as salmon and steelhead.

In western North America man's existence is intimately linked with the natural resources of the Coniferous Forest Biome--the forest and interspersed rangelands, the waterways and the seas, and the mountains and valleys themselves. From the vast forests come wood products, and forage for domestic livestock and wildlife. Snow-capped peaks provide the pure water for the salmon streams, irrigation, and thirsty cities. Not only do these resources provide man's livelihood but they are the key to a high quality of life exemplified by clear air and water and extensive outdoor recreation. Unfortunately, as the human population has increased, competing pressures upon the Biome's resources have multiplied and serious conflicts in use are frequent.

Important decisions affecting the prosperity and welfare of future generations are being made today. Which lands should be set aside for wilderness, intensive forest management, damsites, ski slopes, municipal development? Which uses are incompatible and which areas can be managed for more than one use? What restrictions and options await the next generation of Americans and how can we conserve for them the ecological alternatives needed for survival?

Many of these decisions are being made in a haphazard or piecemeal fashion and usually without sufficient knowledge. Wise land-management decisions must be based upon consideration of economic, social, and ecological consequences. Knowledge of ecological constraint upon manipulation of the land is critical but rarely available. We can often estimate how various manipulations will affect wood production, number of blacktail deer, or water yield, but we do not really understand the various interactions or processes, and we are unable to predict side effects. We must understand how the ecosystems function if we are to avoid more problems in the future, some of disastrous proportions.

The Western Coniferous Forest Biome thus encompasses a wide range of forest ecosystems varying markedly in environment, composition, structure, and productivity. Their resources are valued differently and, consequently, these ecosystems are managed differently. A general model of coniferous forest ecosystems must reflect reality by encompassing this variability in intrinsic character and manipulative practice. For this reason, research will be carried out at more than one study site, rather than being concentrated on a single, intensive site. Further, a requirement for data quantitatively relating one process to another and for linking the terrestrial and aquatic components of the ecosystems makes it essential that these representative sites have a history of research development and sufficient interested scientific manpower to focus and carry the initial thrust of the research.

Fortunately, a group of such sites is available for International Biological Program use in the Coniferous Forest Biome. Sustained support for research relevant to our program, particularly by the United States Forest Service and state land-grant universities, has been typical rather than exceptional. On the other hand, the research effort at different locations typically has not been coordinated. Difficulties have resulted not only because techniques of data collection and analysis are often not comparable but, more often, because information could not easily be interpolated between areas with different histories and/or environments. Also, the tools and scientific manpower have been lacking to accomplish a well-integrated research effort. The IBP Analysis of Ecosystems program is providing a mechanism for attaining these goals.

3. RESEARCH SITE DESCRIPTION

3.1. General

In order to meet the objectives of this Biome proposal, a single intensive study conducted at two locations will be developed. As a basic understanding is acquired and models are developed from the intensive program, research will be extended to other coordinating sites where validation studies will be initiated.

The criteria for determining intensive study sites were postulated as follows: (1) possibility of coordinated research on terrestrial and aquatic components, (2) continuity of ownership and assurance of possibilities for site manipulation, (3) accessibility to researchers and visitors, (4) commitment of facilities appropriate to program, (5) institutional commitment of manpower (25 major investigators or more), (6) representation of important western coniferous forest habitats, (7) security level satisfaction, (8) sufficient area for present and future studies, including the basis for at least one terrestrial-aquatic ecosystem model, (9) variation in local site conditions, including drainage catenas and differences in elevation, (10) representation of the economically important ecosystems, (11) location for interrelationship to the marine environment, including water, biota, and chemical interchange studies.

On the basis of these criteria it was decided to develop the intensive study at two sites, the Cedar River-Lake Washington drainage basin and the H. J. Andrews Experimental Forest.

Although both of the locations are in the dense conifer forests of the coastal Northwest, each contributes unique features of past research programs, facilities, involved personnel, and principal natural resources to the intensive study. Each site has a long history of research relevant to the IBP Analysis of Ecosystems program. At the H. J. Andrews Forest the work has focused on hydrologic and nutrient cycles in unit watersheds and has been concerned with the mature and old-growth Douglas-fir stands which dominate the experimental forest. Related aquatic research has dealt with stream systems.

In contrast but complementary, the research within the Lake Washington drainage basin has been focused on comparative studies of primary production within the lake systems, the population dynamics of resident and migratory fishes, and the transfer of water and nutrient elements between components of the terrestrial ecosystem. Terrestrial studies have been conducted primarily within the extensive areas of second-growth Douglas-fir which dominate much of the lower elevations at the Cedar River watershed.

The types of research facilities developed at the two locations are also complementary. At the H. J. Andrews Forest the most important facilities are the eight, smaller (101 to 1018 km^2) gaged unit watersheds in three matched sets, including two sets which have not yet undergone any manipulation.

Within the Cedar River watershed, a field research station has been developed, specifically designed to examine processes of nutrient and water transfer between the vegetative and soil components of the ecosystem. This facility includes two permanent buildings for laboratory use, storage, and data recording.

The principal natural resources at the two locations again combine to provide examples of the important conditions in the coastal conifer forests essential to a complete intensive study. Major study areas in the Cedar River watershed are occupied by young-growth Douglas-fir forest. These combine with the mature and old-growth Douglas-fir—hemlock forests dominating the H. J. Andrews site to provide a full array of age classes. The Cedar River site has topography and soils typical of a heavily glaciated drainage basin. Mature mountainous topography and volcanic-derived residual and colluvial soils characterize the H. J. Andrews Forest. Lakes are a major feature of the Cedar River drainage and have a sizable migratory salmon population. Stream systems are characteristic of the H. J. Andrews Forest; native trout are the major fish resource.

Radiation load is, of course, lighter at Cedar River, the more northerly site, and precipitation is heavier. At the H. J. Andrews site, local variations in moisture and temperature regimes account for most of the variation in productivity and composition of communities. At Cedar River nutrient regime is relatively more important than moisture in patterns of variation.

Our intensive study program will capitalize on the natural resources, facilities, research history, and personnel of each of the locations and combine them in a comprehensive investigation of a conifer forest ecosystem. It would be difficult, or at least inordinately expensive, to attain our objectives at either location alone. By combining the resources and integrating the research, a satisfactory intensive study of coastal conifer forest ecosystems is possible.

In line with this coordinated effort the research proposed for the H. J. Andrews Experimental Forest will focus on mature and old-growth forests and the gaged unit watersheds. Research on these stable old-growth stands is especially timely in view of their rapid disappearance at man's hand and their importance in ecological theory, and will strongly complement the young-growth studies at Cedar River. The unit watersheds also provide an opportunity for us to proceed quickly toward large-scale manipulative research. Aquatic research will be on stream systems.

On the other hand, research at the Cedar River—Lake Washington site will concentrate on studies in younger age forests and on the detail of elemental cycling, water cycling, and other process studies within a unit forest community. Aquatic research will be on lake systems.

3.2. Intensive Sites

3.2.1. H. J. Andrews Experimental Forest

The H. J. Andrews Experimental Forest occupies a complete 6000-ha drainage basin in the western Cascade Range of Oregon about 128.7 km southeast of Corvallis (Fig. 3.1). This tract has been dedicated exclusively for research and education under the administration of the U.S. Forest Service's Pacific Northwest Forest and Range Experiment Station. Outstanding attributes that led to the selection of the site include: (1) a long history of research

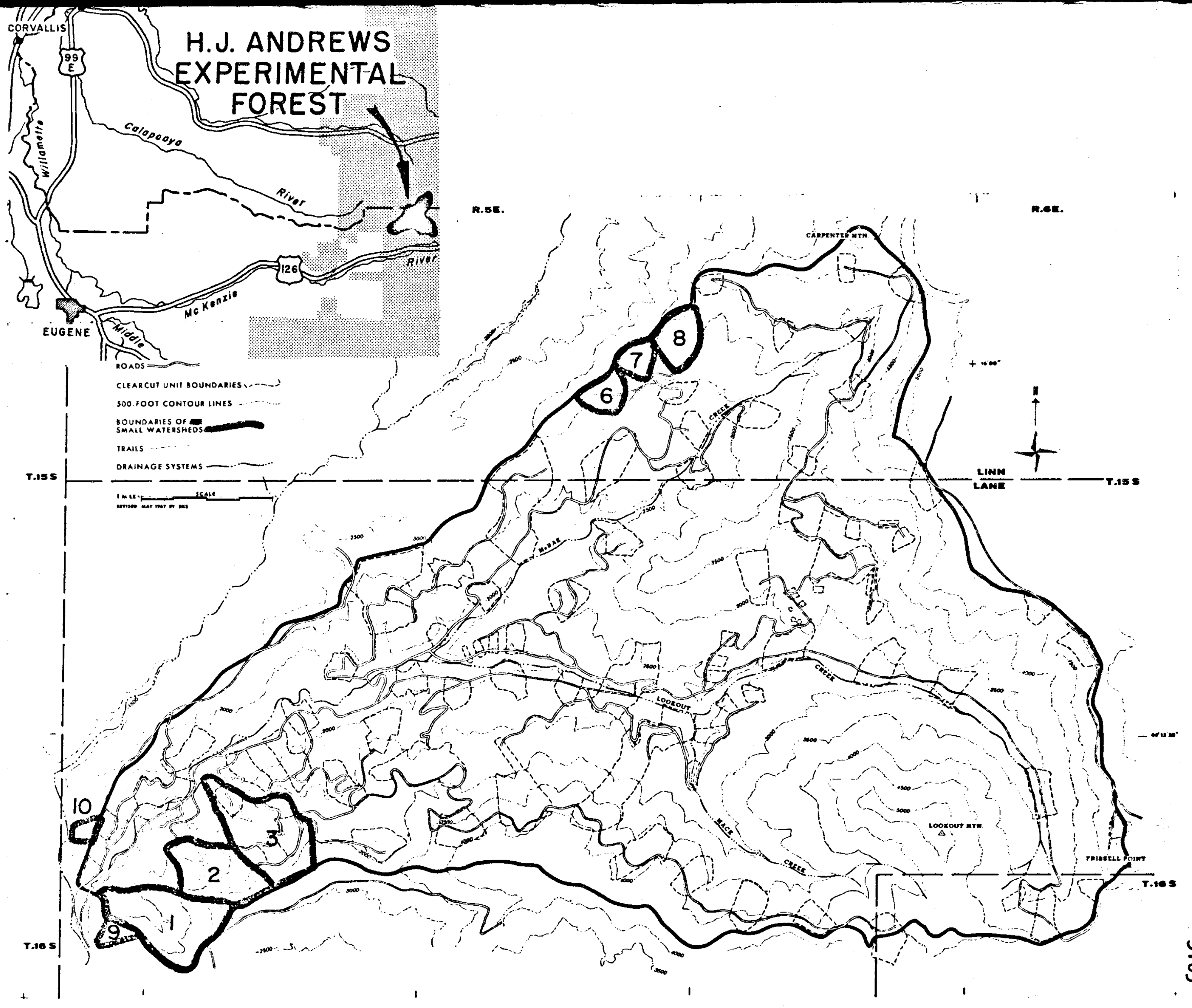


Figure 3.1 Map of the H. J. Andrews Experimental Forest Showing the Location of the Eight Gaged Unit Watersheds.

relevant to the IBP Analysis of Ecosystems project; (2) availability of extensive natural and coniferous ecosystems including streams; (3) presence of eight gaged unit watersheds; and (4) the area's complete ownership and control by a federal research agency.

The experimental forest occupies the mountainous drainage of Lookout Creek, a tributary of the McKenzie River, and spans an elevational range from 450 to 1600 meters. The topography is geologically mature, developed upon volcanic tuffs, breccias, and basalts at the lower elevations and andesite on the ridges. Deep colluvial soils classified as reddish brown lateritics and brown podzolics dominate at lower elevations while soils from volcanic ash are found on the high ridges. Climatic stations maintained at various places within the drainage indicate the average precipitation is 2380 mm annually with 90 percent falling from October through April. Evapotranspiration is estimated at 533 mm annually. Snow accumulation may exceed 1.5 meters at elevations above 1000 meters. A permanent snowpack seldom accumulates at lower elevations. Annual streamflow is about 65 percent of the precipitation and peak winter flows are often 1000 times that observed in summer. Streamflow and water quality data from the main stream, Lookout Creek, and from the eight gaged watersheds shown in Fig. 3.1 have been summarized from records going back to 1947. The gaged watersheds range from 10 to 102 ha. Two were logged using contrasting techniques after a calibration period, and provided excellent data for modeling. Some information on groundwater is available from the Willamette Basin Snow Laboratory conducted in an adjacent basin. The eight unit watersheds are characterized by forest age class, gaging history, and cutting treatment in Table 3.1.

Dense coniferous forest of massive proportions are the outstanding biotic feature of the Andrews Forest. Vegetation-soil studies suggest the occurrence of two major zones, each of which can be denoted by the dominants in the climax forest. A Western Hemlock Zone occupies the drainage from 400 to about 1050 meters elevation. Within this zone the major forest cover type is Douglas-fir with varying mixtures of western hemlock and western red cedar. Incense cedar, red alder, bigleaf maple, and grand fir are also present in certain habitats. The majority of stands are from 350 to 450 years old, but a considerable area is in younger 125- to 175-year age classes. Over the last 20 years approximately 20 percent of this zone has been clearcut in small blocks so that younger stages in forest development are available for study. At elevations about 1050 meters the Pacific Silver Fir Zone begins. The major cover types include noble fir, western white pine with some Douglas-fir, and western hemlock. Age classes are similar to those in the Western Hemlock Zone. At the highest elevations in the drainage forests of mountain hemlock, Pacific silver fir, Alaska cedar, and subalpine fir occur along with rock outcrop habitats and subalpine meadows. The vegetation has been analyzed and classified into 23 units which can be interpreted along measured moisture and temperature gradients.

The main streams and tributaries within the Andrews Forest support a native fishery of cutthroat and rainbow trout and sculpin. Columbia black-tailed deer and black bear commonly occur within the drainage. Some beaver, coyote, bobcat, and an occasional cougar have been seen, and a small herd of elk is sometimes present on the forest. The small mammal and ground-feeding bird populations are distributed by habitat preference as documented through extensive research.

Table 3.1. Characteristics of Gaged Unit Watersheds Developed for Experimental Purposes at the H. J. Andrews Experimental Forest

Watershed no.	Size (hectares)	Gaging began	Planned treatment type and date
Old-growth (450-year-old) Douglas-fir forest, treatment accomplished:			
1	97	1953	Completely clearcut by skyline crane (without roads) in 1962-66, burned 1966
2	60	1953	Control
3	102	1953	One-third clearcut by three conventional patch clearcuts with roads in 1962, burned 1963
Second-growth (125-year-old) Douglas-fir forest:			
6	13	1963	Clearcut 1971
7	15	1963	Shelterwood cutting, 40% volume in 1971
8	21	1963	Control
Old-growth Douglas-fir forest:			
9	8	1968	Control
10	10	1968	Clearcut for study of mineral losses in 1971

Since 1948, about 64 km of high standard forest roads have been constructed giving good access to the entire drainage. A trail system is being expanded to provide controlled access to certain watersheds. The construction and maintenance of all roads, administration of any required logging operations, and fire protection are provided without cost to IBP. The value of these services alone is estimated at more than $20 million. The Willamette National Forest District Office, located 8 km away at the Experimental Forest headquarters in Blue River, has permitted IBP to place its trailers within the Forest Service trailer court, providing at this time facilities for 13 researchers. No budgeting for extending power, phone, or water service was necessary. In addition, a field laboratory of the U.S. Forest Experiment Station is located there. Facilities are adequate for preparation and preliminary analysis of soil, water, and plant samples. Field installations on the forest include 12 recording, standard, and storage rain gages, two snow courses, a standard climatic station, 10 continuous recording streamflow installations with water-temperature and automatic water samplers for chemical and physical properties at six stations. Solar radiation is recorded continuously and more than a dozen recording thermographs monitor environmental variation under various forest environments.

Greatly supporting the studies on aquatic ecology and aquatic-terrestrial interface conducted in the Andrews Forest are the staff and facilities at the Berry Creek Experimental Stream and Oak Creek Laboratory Stream, part of Oregon State University's research program located near Corvallis. The experimental stream is a 457-meter section of Berry Creek under complete flow control within a mixed woodland where the stream leaves the foothills of the Coast Range. Experimental units along the stream contain screen boxes and enriching facilities. Some laboratory facilities are available, but the nearby Oak Creek Research Center has more elaborate facilities. There 24 artificial streams have been constructed for studies on the effects of environmental manipulation, particularly introduction of pollutants, upon aquatic communities. The experience gained by research at these two facilities permitted IBP to begin immediately to model aquatic systems similar to those which past graduate studies have characterized as typical of the Andrews Forest. The Oak Creek and Berry Creek facilities have been in operation over 14 years and represent an investment in physical facilities of more than $230,000. Much of the research conducted at these two aquatic research areas have recently been summarized in the book Biology and Water Pollution Control by Charles Warren. More than fifty graduate students have been involved in the research.

No less impressive is the research effort at the H. J. Andrews Experimental Forest. The U.S. Forest Service supports research there at $200,000 per year. Their scientists devote collectively about four to five man-years of professional time and about two man-years of technician time to the research program there. Active projects by the U.S. Forest Service include: nutrient cycling of small watershed; mineralogy of major volcanic rock types, and of the soils derived from Cascade tuffs and breccias; soil moisture relationships under different vegetative cover; physical, chemical, and hydrologic characteristics of indigenous soils; identification of the flora and characterization of major vegetation types and plant succession following logging and burning; productivity indexes in high-elevation conifer forests through stem analysis; streamflow and water temperature; effect of logging old-growth forests on streamflow and stream sedimentation; effect of logging on chemical quality of water; changes in stream characteristics following shelterwood logging; additions of DDT to ecosystems in rainfall; fluctuations in small-mammal populations; and feeding habits of small mammals and ground-feeding birds.

The IBP during the first year has supplemented the Forest Service effort by conducting additional studies concerning rates of mineral release by lichens growing on tree trunks and microbiological activity in the litter and soil, nutrient capital and biomass estimates of old-growth trees, characterization of aquatic environments, and an environmental analysis of the major plant communities in relation to their distribution and productivity.

In year 2, studies are proposed to model the hydrologic and nutrient-cycling data gathered from an undisturbed watershed. More emphasis is planned on factors controlling decomposition and release of nutrients and energy in both terrestrial and adjacent stream systems. New procedures for estimating biomass and transpiration are being tested in the hope that in the future nondestructive sampling may be possible. Both vertebrate and invertebrate animal populations will be estimated and related to ecosystem dynamics and environmental changes.

Following the completion of well-structured models of relatively stable systems, research will attempt in years 3 and 4 to evaluate unstable systems that have been manipulated or will soon be modified through carefully coordinated effort by the staffs of the Willamette National Forest and the Pacific Northwest Forest and Range Experiment Station.

The experimental and artificial stream facilities, along with the H. J. Andrews Experimental Forest, will allow IBP scientists to pursue coordination modeling studies of aquatic biology and, especially, aquatic-terrestrial relationships at many levels of organization and complexity.

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3.2.2. Cedar River—Lake Washington drainage

3.2.2.1. General

The Lake Washington drainage basin includes the Lake Sammamish—Sammamish Slough branch, which primarily drains industrial, agricultural, and urban areas, and the Cedar River—Morse Lake branch, which drains the Cedar River watershed. These two branches converge at Lake Washington and drain through the ship canal into Puget Sound (Fig. 3.2). Thesetwo drainage systems are very different in both physiography and the patterns of land use (Fig. 3.3). The Sammamish valley drainage system is all at relatively low elevation and heavily subjected to the pressures of urbanization and agricultural practice. Although direct pollution of this water system has been restricted, the area still receives a very high input of nutrients through secondary sources.

The contrasting Cedar River watershed originates at higher elevation in the Cascade Mountains, primarily from forest ecosystems. This drainage includes several small lakes above the 1067-meter elevation, a large reservoir system (Chester Morse Lake) at the 474-meter elevation, and the Cedar River. All of the watershed above 183 meters in elevation is part of the municipal water supply of the City of Seattle. The forest ecosystems have been systematically harvested and reforested during the past 60 years, providing a wide range of forest ages and types.

The Cedar River, with its relatively low nutrient composition, enters Lake Washington at its southernmost point, while Sammamish Slough, with its high nutrient load, enters on the north. The effect of these drainage systems on the quality of the lake has been discussed by Sylvester (1952) and Edmondson (1968).

The Lake Washington drainage basin falls under a wide range of ownership and administrative structures. The Municipality of Metropolitan Seattle (METRO) surveys and regulates the biology and chemistry of Lake Washington. The principal tributary, the Cedar River watershed, is administered by the City of Seattle Water Department. Both METRO and the Seattle Water Department are committed to the objectives of this Biome proposal. A letter of understanding between the city and the Biome director on the use of the Cedar River was included in the initial proposal.

The aquatic systems found within the Lake Washington drainage include the following:

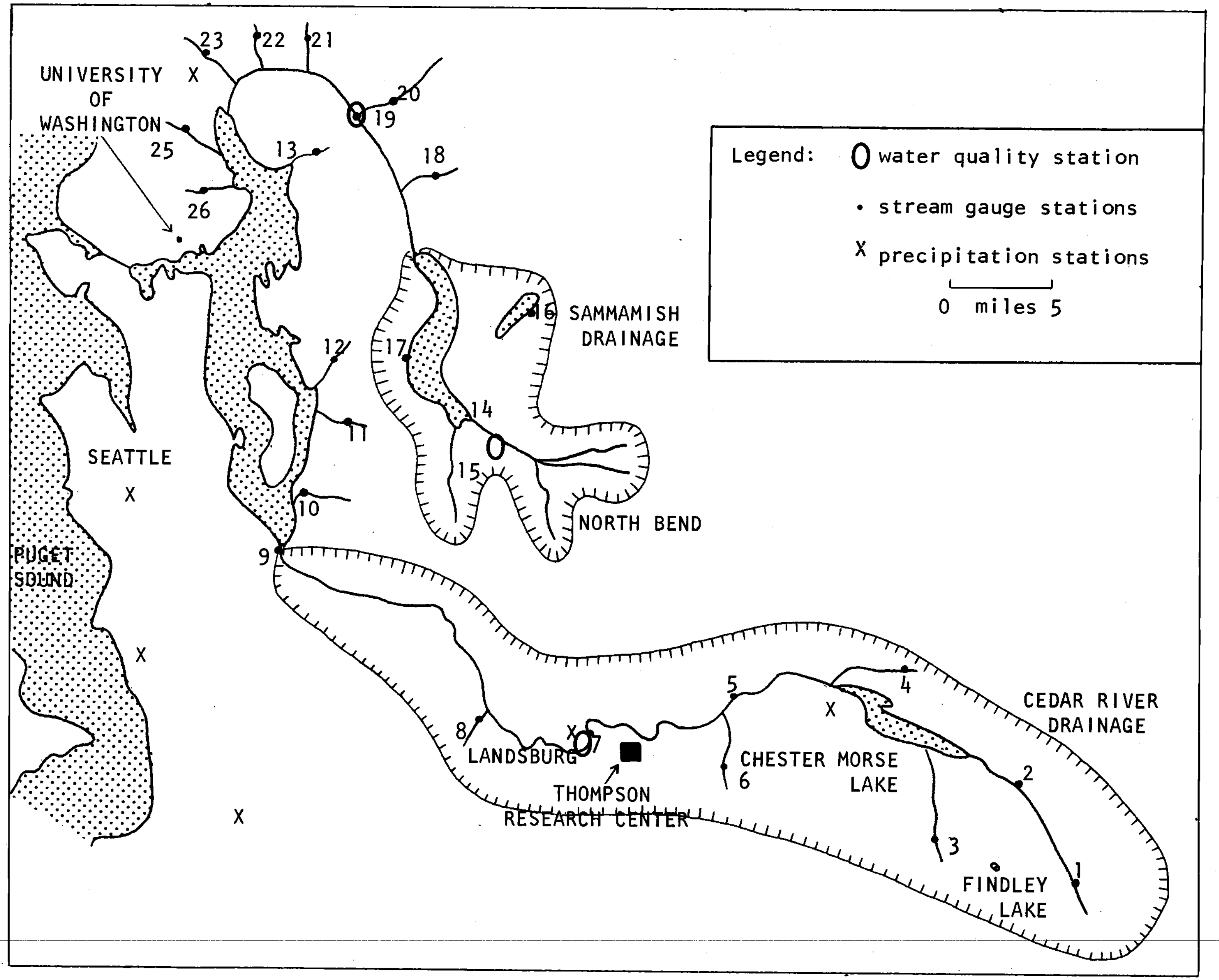


Figure 3.2 Location Map, Cedar River Watershed Area

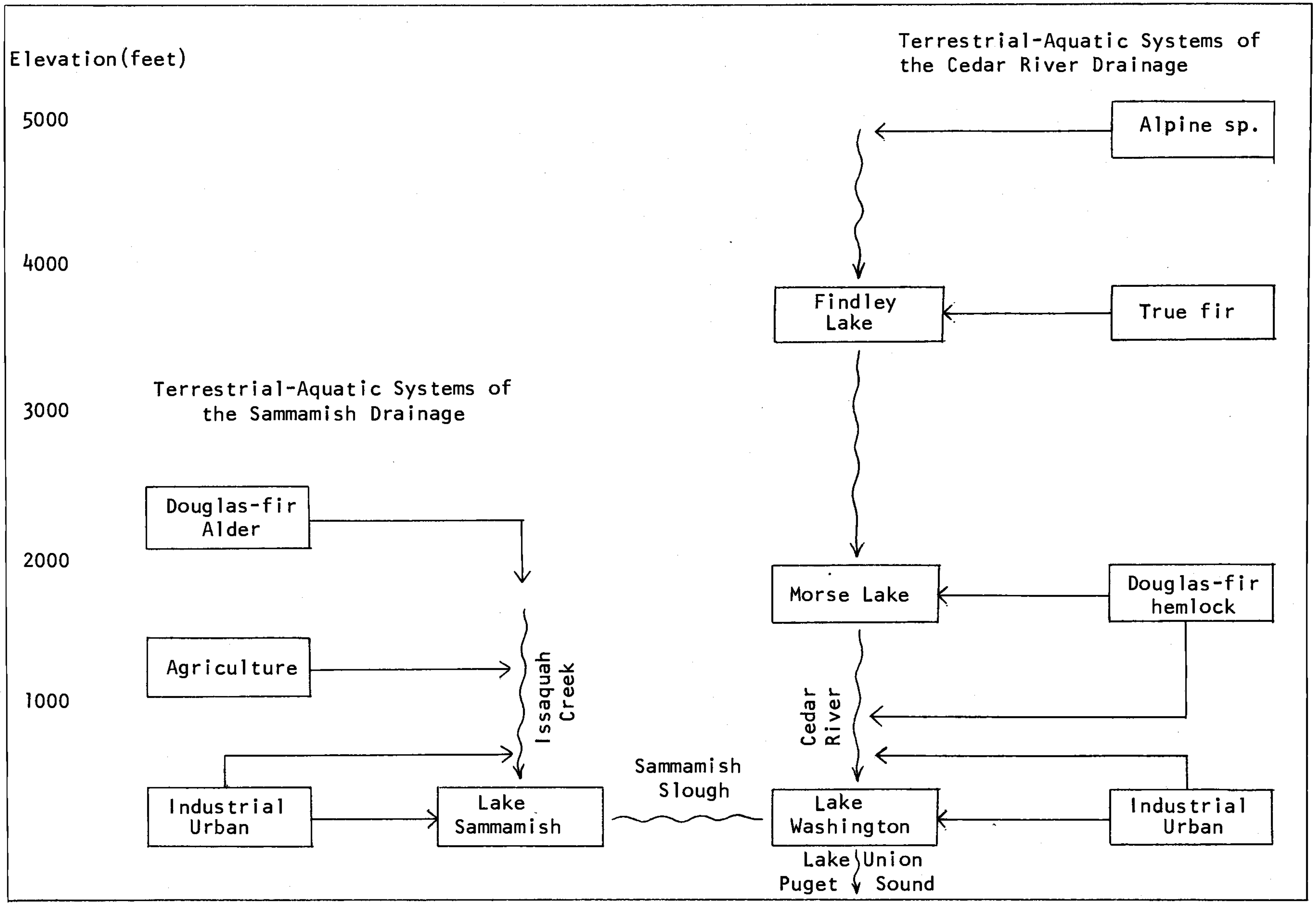


Figure 3.3 Principal Components and Pathways of Transfer in the Lake Washington Drainage Basin

a. Lake Washington, the lowermost lake (895.9 ha, 64 meters deep, 4.3 meters elevation), has a documented history of eutrophication and is now in a rapid state of change, since municipal wastes only recently have been diverted from the lake. Fish populations are again of particular interest. The long documented history of fish stocking permits an evaluation of its impact on total productivity.

b. Chester Morse Lake (680.7 ha, 35.4 meters deep, 474 meters in elevation) is the uppermost of the two large lakes in the Cedar River watershed. Although the lake level was slightly raised in 1902, the lake in other respects is the least disturbed major lake in the state. Access to the lake has been rigidly controlled since 1911 and no fish have been planted or harvested since that time.

c. Among several small lakes, two are located in totally unmanipulated watersheds of approximately 162 ha. It is proposed to use the Findley Lake watershed in an integrated terrestrial-aquatic study in the second phase (see Fig. 3.2). Findley Lake watershed is a small unit of the Cedar River drainage, located at 1128 meters elevation. The watershed contains two small lakes with a total water area of 10.5 ha. The land area consists of 155.4 ha of undisturbed mature fir-hemlock forest. The lake has no resident fish population but zooplankton are present in moderate abundance.

d. Studies of streams within the watershed can simultaneously monitor inputs to the lakes and measure terrestrial-aquatic interrelationships. For example, Rex River basin contains one of the major contributors to Chester Morse Lake (Rex River Creek, minimum flow 425 meters/sec). The basin was last logged at the lower levels in 1935 and is scheduled to be relogged during the next five years. Simultaneous study should be made of the terrestrial, stream, and lake responses to this manipulation.

e. Lake Sammamish (1981.7 ha, 30.5 meters deep, 8.5 meters elevation) represents an intermediate condition, as it was oligotrophic until very recently and is now expected to undergo eutrophication as the forest is replaced by an increasing urban community.

The hydrological history of the Cedar River watershed has been documented since 1895. The City of Seattle Water Department has preserved this history in its annual reports and in a book, "The Seattle Water Department History, 1854 to 1954" by Mary McWilliams (1958). The City of Seattle Water Department, in cooperation with other government agencies, maintains complete water quality and quantity records. Weekly measurements of bacteriological content are taken at 21 fixed points at Chester Morse Lake, the Cedar River, and its tributaries. Continuous monitoring of water temperature occurs at Chester Morse Lake. Water turbidity is measured at Landsburg and Barnston on the Cedar River about 9.7 km upstream from Landsburg. A radiological station also exists at Landsburg. Measurements at Landsburg are checked manually every two hours. A complete chemical analysis of the Cedar River occurs at Station 12-1190 near Renton. In the Lake Sammamish watershed, water quality is monitored at Issaquah Creek near its mouth. Temperature data are collected at the Sammamish River near Woodinville. Seven stations continuously record river fluctuations. The locations of these stations are described in the year-1 proposal.

Precipitation in the Lake Washington drainage basin varies from 8-9 cm annually at Seattle to 264 cm at Morse Lake. Greater precipitation can be expected at higher elevations in the Cedar River watershed because of orographic effects. Seventeen permanent precipitation gages are scattered throughout the Cedar River watershed at various elevations and are measured monthly. A continuous record of precipitation is also maintained by the City of Seattle at its forestry headquarters at Cedar Falls. Air temperature is recorded at Cedar Falls headquarters, Morse Lake, and Landsburg. The forestry division of the City of Seattle Water Department maintains four mobile stations near logging areas from May to September. Precipitation, wind speed, air temperature, and humidity data are collected daily. Similar data are collected at a lookout tower on the watershed.

The soils and geology of the drainage are well known. During the Vashon state of Fraser glaciation, the Puget lobe of the ice sheet flowed southeast across the Lake Washington basin covering most of the land area to an elevation of approximately 823 meters. When the ice receded, various associated glacial depositions occurred such as glacial lake sediments near Issaquah, outwash trains, and glacial till. This material constitutes the origin of the soil in the basin. Bedrock consists of consolidated sediments and volcanics of Tertiary age, with scattered bodies of igneous intrusives. Extensive research has been done on the bedrock geology and Pleistocene geology of the Lake Washington basin. Publications of the research are found in various geological journals and theses at the University of Washington (see year-1 proposal). The remaining geological work will be completed as part of the year-2 program. The U.S. Soil Conservation Service has in part mapped the soils of the basins. The information is published in the King County Soil Survey. It is proposed to complete a detailed soils map of the Findley Lake watershed during this coming summer.

As mentioned above, one of the strong attributes of the Lake Washington study is its location. The University of Washington campus is adjacent to Lake Washington and the ship canal through which this basin drains into Puget Sound. There is only a limited necessity for the development of field facilities. Even the very farthest corner of the area can be reached within two hours from Seattle. The original research facilities at the Thompson research site were developed prior to the IBP program. They include a storage building, a research building, and a relatively complete data recording system. An AC power line was brought to the site in 1967 by the University of Washington and the City of Seattle.

During the first year of the Coniferous Biome program facilities have been improved in several ways: (1) A well has been drilled and plumbed to the research building. (2) Sanitary facilities, specifically an electrical disposal system, have been installed. (3) A second study area was established approximately 762 meters from the previously existing area, which required the construction of a new road, and burial of an AC power line and a water line. The facilities at the Findley Lake site are only in the initial stages of development. A trail system to the lake (approximately 2.4 km) will be developed this summer. Shelter tents will also be erected for temporary overnight accommodations, awaiting a permanent building planned for year 2.

Prior to the IBP, numerous research projects in both limnology and terrestrial biology were conducted within this drainage basin. During the past year, under IBP sponsorship and coordination, many of these projects have been focused on the Biome objectives. The substance and diversity of these programs is indicated in the following discussion.

3.2.2.2. Terrestrial studies in the Cedar River research area

Intensive research on basic mechanisms of mineral cycling within a second-growth Douglas-fir ecosystem was initiated in 1961. It was first necessary to construct the field facilities, design specialized instrumentation, and develop systems of data acquisition, completion, and analysis. Many of the basic pathways and transfer functions among major components of this system have been defined. An initial accumulation and production model has also been developed (Dice, 1970). An annotated listing of these publications by subject area is available from the site director's office.

During Biome year 1 the terrestrial studies have continued to emphasize production processes and mechanisms of elemental transport. New work includes a detailed examination of net assimilation, energy balance, water budget, and dimensional analysis.

3.2.2.3. Aquatic studies in the Lake Washington basin

Historically, the aquatic system of the Lake Washington drainage basin has received extensive attention. A bibliography has been completed, along with a checklist of the fishes in the basin. Complete limnological surveys were conducted in the early 1920's and 1930's. These earliest studies, in fact, included measures of the fish production potential of the system. Throughout the 1950's, attention in the Lake Washington system was directed toward understanding the intricate relationship between primary and secondary production. From these studies the rapid tendency toward eutrophication became apparent, a result of sewage discharges; W. T. Edmondson was instrumental in calling attention to the problem. In the mid-1960's, a sewage collection system that circumscribed Lake Washington was constructed to combat this problem. Subsequent limnological studies have documented improvements in lake conditions and produced extensive information on phosphate-nitrate budgets and primary and secondary production estimates, including zooplankton and bottom fauna.

Lake Sammamish, a tributary to Lake Washington, is undergoing eutrophication similar to that in Lake Washington a decade ago. Some significant nutrient inputs have been recently diverted from the lake; however, because of rural location, a trend toward eutrophication is expected to continue. Limnological and bacteriological studies have been conducted on this system in more recent years.

Both lakes are vital as nursery and migration areas for extensive salmonoid and other resident fish populations. Washington State fisheries management agencies and an experimental unit at the University have fish hatcheries that plant millions of migrant salmon. These migrate through the lakes, enter the ocean for a few years, and return as adult salmon to be harvested or to spawn. Within the Lake Washington system the salmon may travel up to 56 km to their point of origin.

In addition to the managed fish populations, there is an extensive native salmonoid population that uses tributary streams and the lake for spawning, rearing, and finally migration seaward. Sockeye salmon populations have increased greatly and are using all available spawning territory, possibly saturating the rearing area. From 907 to 2268 metric tons of sockeye are expected to return from the sea this summer, providing a tremendous amount of nutrient input (or objectionable pollution) when they die after spawning. Significant populations of resident fish are also present. Some play a significant role as predators and some an herbivorous role. Several provide a sport fishery.

Extensive fishery research on salmonoid behavioral and homing, spawning success, fry survival, selective breeding, and feeding patterns has been done in the system. More recently, estimates of juvenile sockeye salmon populations have been made with acoustic techniques involving echo integration. Population estimates of littoral species are also being made. Life history studies of a majority of the fish in the system are under way or have been completed.

Before the IBP study was started, limnological or biological surveys had not been made of the upper Lake Washington system, including Morse Lake, Cedar River, and the upper tributaries including Findley Lake. The area has had controlled access (since 1911), precluding fish management and harvest. The Morse Lake fish population should be at a very interesting stable state and should provide an interesting contrast to the eutrophic lower lake system.

Because of the extensive wealth of background and continuing research on the Lake Sammamish and Lake Washington systems, the primary production measures hopefully can be supplemented by additional research at the decomposer and secondary level, as well as at the tertiary consumer level.

3.2.2.4. Interface program

One of the most important objectives of the Coniferous Biome is to study the boundary conditions between the terrestrial and aquatic systems. An interface program examining the role of a terrestrial ecosystem on a freshwater body has been initiated at Findley Lake. This program is only in its very beginning stages and ecosystem components are still being defined. It is planned to concentrate many of our first efforts in analyzing this interface within the Findley Lake basin. Advantage will be taken of the Fern Lake studies and descriptive models in developing this program.

3.3. Coordinating Sites

As previously pointed out, this proposal contains a section allowing for review and selection of one or more coordinating sites for development in year 3. Figure 3.2 shows the outline of the Cedar River watershed without specifying localities for coordinating studies. This is, of course, different from our year-1 proposal, which did include an array of specific possibilities. Further deliberations and realization of budget limitations has led us to the appointment of a coordinating site director and writing of a proposal to study the question. In the meantime, certain segments of the total research proposed herein will be carried out at locations which fit into the total development of the Biome and by researchers who have specific capabilities. In other instances researchers from other institutions will come to one of the intensive sites to make their contributions.

4. BIOME ORGANIZATION

4.1. General

The work of the Coniferous Forest Biome investigators will constitute an integrated research program within the Analysis of Ecosystems program of the U.S./IBP. Coordination with other Biome programs will be through the director of the Analysis of Ecosystems program and the Biome directors' organization. International coordination will be maintained on the same basis and through direct communication with IBP programs in other countries.

Among the mechanisms envisaged for coordination of work spread over a wide geographic area are the regular circulation of newsletters, both of general interest and covering particular specialized needs; the frequent use of long-distance telephone communication; and, above all, the organization of meetings of people working in different parts of the Biome in the same field of specialization. Carefully planned meetings of a limited group (say, a dozen) of specialists in workshops will make possible the exchange of ideas and information about techniques in a far more effective way than would any other mechanism.

Apart from communication among the numerous groups involved in the program, it will be necessary for the Biome organization to establish and maintain mechanisms to ensure that the goals and objectives of the IBP are attained, both by encouraging necessary research and by ensuring that work in progress continues to serve the overall purpose of the program.

The organization of the Biomes is at several levels covering policy, research, and site coordination. The Executive Committee and directors formulate Biome policy and overall guidelines within the context of the U S. Analysis of Ecosystems program. The Planning and Program Committee defines objectives and annual work plans along lines of subject matter. The site directors coordinate and concentrate the research work plans on specific focal points of selected field ecosystems. A diagram of the Biome organization is given in Fig. 4.1.

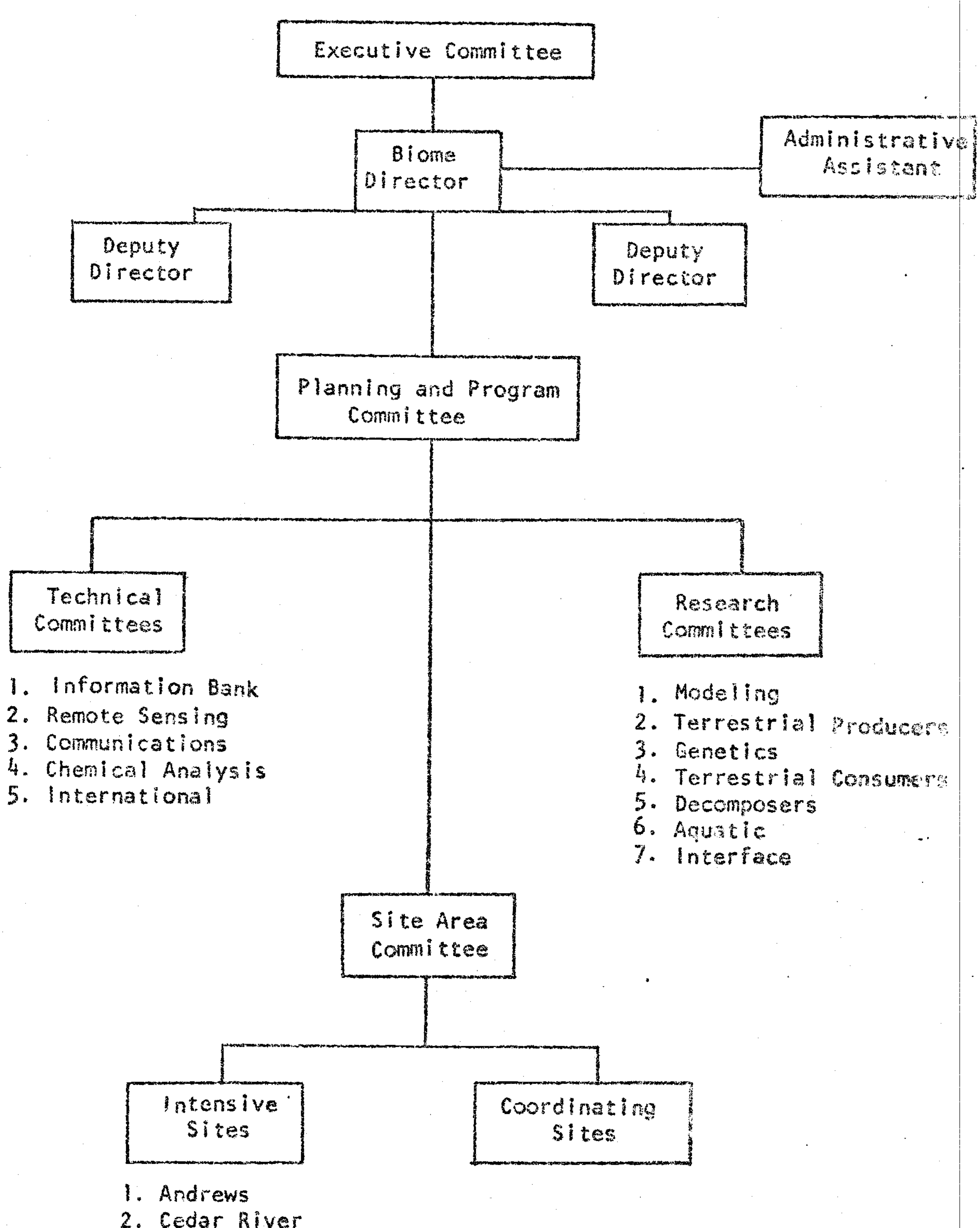
4.2. Central Office

4.2.1. Biome directors

The Biome director appointed in December 1968 by the Executive Committee of the U.S./IBP is Stanley P. Gessel. The director is assisted by two deputy directors, Jerry Franklin (Oregon) and William Hatheway (Washington), and an administrative assistant, Hans Riekerk.

The major role of the Biome director and his deputies will be to organize, develop, and coordinate a Biome-wide program on the analysis of coniferous ecosystems. Facilitation of communication will have high priority within the Biome director's office. The need is already apparent for enhanced communications. There are many in the coniferous forest area who are interested in becoming involved in some way in the integrated effort of the IBP, and an effective communications net is essential to ensure economy of effort and optimum use of manpower, and to reduce the risk of misunderstanding.

Figure 4.1 Coniferous Biome Organization



The Biome director will organize the development of a major program for integrated research within the Coniferous Forest Biome, arranging for the inclusion of existing research efforts wherever appropriate. A related task will be to establish Biome staffs, special committees, planning groups, and program services. The modeling aspects of the total program will be delegated to Douglas Chapman, director of the Center for Quantitative Science of the University of Washington, and to appropriate program coordinators.

The Biome director will be primarily responsible for ensuring effective contact with other Biome programs, with other IBP programs outside the Analysis of Ecosystems, and on the international scale. In this he will collaborate with the headquarters office of the Analysis of Ecosystems program and with that of the U.S./IBP in Washington.

4.2.2. Executive Committee

The director and deputy director will be supported by an Executive Committee consisting of the original Biome Steering Committee. Membership of the committee represents the intensive and coordinating sites which are included in the year-1 proposal or will be in year 2. The Biome Executive Committee will function as a coordinating and general advising group representing a broad coverage of the Biome, including all participating sites.

4.3. Subject Matter Committees

The primary function of these committees is to assist in the formulation of research work plans and technical coordination. Other functions are the representation of the Coniferous Biome in national and international discussions in subject areas.

4.3.1. Planning and Program Committee

The chairmen of the research committees advise the Biome directors as to the development of a long-term research program. They review research proposals and work plans presented by the research committees according to well-defined criteria for selection and incorporation in the annual Biome proposal.

4.3.2. Research committees

These subject matter committees are organized to pool the talent of scientists of the Biome in broad specialty groups. The combined efforts of the participants will ensure adequate coverage of necessary subject matter. The main responsibility is to develop integrated research proposals for review and selection by the Planning and Program Committee and to direct and assist the individual investigators as to a proper execution of the work plans. Each research committee chairman acts as a project leader for the committee proposals. Another function of a research committee is to assist in standardization of data collecting and sampling methods.

4.3.3. Technical committees

The function of these committees is to advise the Biome directors as to the feasibility and coordination of services in the technical subject matter areas. Standardization of methodology, sampling procedures, analysis, and data management is their major responsibility.

Informing and checking Biome participants as to agreed upon procedures is also an important function. Publicity and dissemination of noteworthy achievements to the U.S. Analysis of Ecosystems office, the press, and the public in general is a specific function.

4.4. Research Site Coordinators

The basic function of the site coordinators is to ensure the integration of and cross-linking among research committee proposals by focusing the research on selected ecosystem sites.

4.4.1. Intensive sites

Each site coordinator will in general be director of the project for the validation and process studies at that site. Besides conducting his own personal research at the site and coordinating the activites of the numerous specialists involved in particular aspects of these validation studies, he will also act as coordinator for those parts of the process studies which are being performed in the same area or making use of site facilities.

Each site coordinator will be expected to maintain close contact with the studies being carried out at his site, to avoid overlap between different process studies, to fill gaps between them, and arrange for discussion of techniques and agreement on uniform procedures where appropriate. The site coordinator will be responsible for assembly and transmission of data to the Central Data Bank. He will also supervise modeling activites at the site. Dale Cole has been appointed as site coordinator for the Cedar River—Lake Washington site, and Richard Waring is coordinator for the H. J. Andrews site.

4.4.2. Coordinating sites

The coordinating sites have been established to assist ecosystem model development in aspects of validation and extension of ecosystem conditions. Edwin Mogren of Colorado State University is the chairman of the Coordinating Sites Committee. He has accepted the responsibility to organize a comprehensive research program in close cooperation with the Planning and Program Committee and representatives from participating coordinating sites.

4.5. Committee Composition

<u>Executive Committee</u>

Dr. Edwin W. Mogren	Colorado State University	(303)491-6519
Dr. Donald R. Wooton	Chico State College	(916)345-6340
Dr. Arden R. Gaufin	University of Utah	(801)322-7211
Mr. Robert W. Harris	U.S. Forest Service	(503)234-3361
Dr. Donald W. Stark	University of Idaho	(208)885-6243
Mr. George Staebler	Weyerhaeuser Company	(206)PE6-7678
Dr. Douglas Chapman	University of Washington	(206)543-1191
Dr. Robert Burgner	University of Washington	(206)543-4650
Dr. Dale W. Cole	University of Washington	(206)543-2762

Dr. Keith Van Cleve	University of Alaska	(907)479-7344
Dr. Paul Zinke	University of California	(415)642-6472
Dr. R. W. Waring	Oregon State University	(503)752-4281
Dr. George E. Hart	Utah State University	(801)752-4100
Dr. D. W. Rains	University of California	(916)752-2468

Planning and Program Committee

Biome director

Dr. Stanley P. Gessel	University of Washington	(206)543-2730

Deputy directors

Dr. William Hatheway	University of Washington	(206)543-1191
Dr. Jerry Franklin	U.S. Forest Service	(503)752-4281

Chairmen of Research Committees

Dr. C. T. Dyrness	U.S. Forest Service	(503)752-4281
Dr. Richard D. Taber	University of Washington	(206)543-2740
Dr. Robert Burgner	University of Washington	(206)543-4650
Dr. Frieda Taub	University of Washington	(206)543-4281
Dr. James Hall	Oregon State University	(503)754-1531
Dr. Douglas Chapman	University of Washington	(206)543-1191
Dr. Reinhard Stettler	University of Washington	(206)543-2723

Site directors

Dr. Dale Cole	University of Washington	(206)543-2762
Dr. Richard Waring	Oregon State University	(503)753-9166
Dr. Edwin Mogren	Colorado State University	(303)491-6519

Administrative assistant

Dr. Hans Riekerk	University of Washington	(206)543-2757

Research Committees

Modeling

Dr. Douglas Chapman	University of Washington	(206)543-1191

Terrestrial Producers

Dr. C. T. Dyrness	U.S. Forest Service	(503)752-4281

Biomass and structure

Dr. Jerry Franklin	U.S. Forest Service	(503)752-4281

Processes

Dr. Richard B. Walker	University of Washington	(206)543-1942

Genetics

Dr. Reinhard Stettler	University of Washington	(206)543-2723

Terrestrial Consumers

Dr. Richard D. Taber	University of Washington	(206)543-2740

Decomposers

Dr. Frieda Taub	University of Washington	(206)543-4281

Aquatic

Dr. Robert Burgner	University of Washington	(206)543-4650

Aquatic-Terrestrial Interface

Dr. James D. Hall	Oregon State University	(503)754-1531

Nutrient cycling

Dr. Richard Fredriksen	U.S. Forest Service	(503)752-4281

Hydrology

Dr. George Brown	Oregon State University	(503)753-9166

Meteorology

Dr. Leo J. Fritschen	University of Washington	(206)543-2748

Technical Committees

Information bank

Dr. Bruce Bare	University of Washington	(206)543-1191

Remote sensing

Dr. Robert Colwell	University of California	(415)642-1351

Communication

Mr. Robert Harris	U.S. Forest Service	(503)234-3361

Chemical analysis

Dr. Mark J. Behan	University of Montana	(406)243-5092

International

Dr. Richard Waring	Oregon State University	(503)753-9166

Site Areas Committee
(composed of intensive- and coordinating-site directors)

H. J. Andrews Experimental Forest

Dr. Richard Waring	Oregon State University	(503)753-9166

Cedar-River-Lake Washington drainage

Dr. Dale W. Cole	University of Washington	(206)543-2762

Coordinating sites

Dr. Edwin Mogren	Colorado State University	(303)491-6519

Central Office

Dr. Hans Riekerk	University of Washington	(206)543-2757

5. SERVICES

5.1. Central Office

5.1.1. Administration and accounting

An important task will be to communicate the research objectives and research progress to colleagues throughout the Coniferous Biome working area and certainly to the public at large, including the political component at both the local and national levels. The Biome director will also improve communications with the national office and both national and international IBP committees. With a skeleton organization in year 1 we have not been able to perform this function as it must be performed.

Among the mechanisms envisaged for coordination of work spread over a wide geographic area are the regular circulation of newsletters, both of general interest and covering particular specialized needs; the frequent use of long-distance telephone communication; and, above all, the organization of meetings of people working in different parts of the Biome in the same field of specialization. Carefully planned meetings of a limited group of specialists (workshops) will make possible the exchange of ideas and information about techniques in a far more effective way than could any other mechanism.

Apart from communication among the numerous groups involved in the program, it will be necessary for the Biome organization to establish and maintain review mechanisms to ensure that the goals and objectives of the Analysis of Ecosystems program are attained, both by encouraging necessary research and by ensuring that work in progress continues to serve the overall purpose of the program.

Principal costs for direction of the Biome will again be contributed by the University of Washington through the time of both the director and one of the deputy directors. However, in order to support these individuals and the deputy director at Oregon State, a full-time administrative assistant is needed. We were fortunate to secure the services of Dr. Hans Riekerk for this position in year 1 and his continued employment is anticipated and planned for.

Accounting services for the Biome are considerable. Grant contract negotiations will be handled by the University of Washington. Accounting and money management of the individual proposals will be the responsibility of the central office and handled by an additional half-time bookkeeper in the accounting department of the College of Forest Resources.

A considerable amount of secretarial service is needed at the Biome office to provide needed support for the administrative staff. Secretarial services for site directors and researchers beyond that related to the central office is requested in individual budgets.

Various kinds of services must be provided by the Biome office at an increased level as the organization develops. These include editorial assistance for various levels of communication, report writing, scientific papers, and proposals.

An information service item is proposed to provide some assistance to our library system in fulfilling requests for information related to Biome interests and to maintain a file of publications on IBP work for both students and research workers, as well as the general public. Since the initiation of the Coniferous Biome program, heavy demands for additional services from these groups have been placed on our college library, and this request is for some hourly assistance funds.

Travel must be considered from several points of view related to the total management and research progress of the Biome. First, there is the need for the Biome administrative staff to travel to all parts of the Biome to confer with researchers and plan the orderly development of Biome activity. There is also the need for the Biome director or his representative to travel to inter-Biome meetings at both the national and international level. These meetings may be for either administrative or research purposes. Secondly, the importance and role of intra-Biome meetings by research or administrative committees, including conferences and workshops, has been clearly demonstrated during the initial stages of development. So far many of these meetings have been related to development of the second-year proposal and general organizational development. Coniferous Biome philosophy is to insist that each researcher and each research group is aware of research throughout the Biome and the role of his or her activity with respect to the total model. Therefore workshops and conferences will continue to be a mainstay of Biome operation and must be provided for. The Biome office will plan these and therefore the fund request for the total Biome is included in the central office budget.

5.1.2. Program services

Essential program services include the provision of technical assistance or consultation on special problems of wide significance to the integrated research effort, such as data analysis, processing, taxonomy, environmental monitoring, and chemical analysis. It is expected that program services offered through the office of the Biome director or his deputies will promote liaison between investigators at major study sites.

Program services will be provided in several ways. Special and technical committees (such as committees on chemical analysis, data processing, and biometrics) will be established and funded so that they can meet as needed, or travel from site to site. Special capabilities and expertise which develop at various sites will be made available to the Biome by an effective communication net and special consultantships. The following services will be rendered through the central office:

5.1.2.1. Editorial services.

As the work develops, considerable volumes of reports and other documentation will be produced. Much of the editorial work involved should be taken off the shoulders of investigators; it is proposed to centralize these activities under the Biome director along with other information and communication aspects of the Biome program.

5.1.2.2. Laboratory services

Central organization will be desirable for certain analytical procedures where expensive equipment is required, where there are economic savings possible from large-scale operation or automation, or where uniformity and consistency call for it. There are in existence in institutions within the Biome a number of laboratories with excellent capabilities which are not fully used. As far as possible, arrangements will be made to use such facilities for routine determinations for the whole Biome, wherever centralization would be advantageous. If facilities are required which cannot be provided in this way a central unit will be set up for the purpose under the Biome director.

5.1.2.3. Taxonomic services

For many groups of organisms in the region with which we are concerned taxonomic studies have been in progress for many years, collections and expert advice are available in most institutions, and difficulties in identification are unlikely to arise. There are, however, certain groups which are less well known and where the expertise is more difficult to come by. It is not proposed to set up facilities for identification at the central Biome office but to concentrate the tasks of identification at institutions where these difficult groups have been under study for a considerable time and where valuable taxonomic collections have been built up.

5.1.3. Workshops

Conferences and workshops will be a necessary major activity in the Biome during year 2. During year 1 we have relied heavily on workshops provided by other Biomes and have received expenses for attendance at many of these from the Central AOE Office. In the course of developing the year-2 proposal, each research committee expressed a need and desire to hold one or more specific workshops or technical conferences, usually to bring all participating research workers up to the same level of competence or to explore methodology in specific fields. The workshop requests have all been combined into one organizing activity of the central office in order to provide the necessary related services. 5

5.1.4. Research participants

Because of the concentration of research work at the intensive sites during the second year there is a need to bring scientists from other institutions to participate in various research programs. These will be researchers who have specific capabilities in certain critical areas of research or who will be acting as principal investigators at coordinating sites in year 3. In the latter case these scientists will become familiar with research techniques and modeling procedures so that specific validation studies can be carried out at the appropriate coordinating site. The selection of participating scientists will be done by the Research Planning Committee and the Coordinating Site Committee.

5.1.5. Information bank

Since all programs in the Biome will involve a great body of data that is to be available to all Biome investigations some unit must be given the responsibility of overall supervision of an information bank. Moreover, a large collection of data is already available, some published, some not published but scattered throughout different institutions, laboratories, and offices in the Biome, which will be essential to the modelers as they begin their work. It is appropriate also to consider some central analysis of this mass of data though this is not to suggest that investigators will not analyze their own data.

It is a responsibility of those concerned with any study to gather initial information from all possible sources and pass it on to the modeling groups and the information bank. This will be done at the outset, prior to or concurrently with the beginning of research in the studies. Relevant data will be made available promptly through the information bank to other collaborators in the Analysis of Ecosystems program throughout its duration.

Since this will constitute a substantial body of data, its handling will constitute an important activity of the central Biome office. Apart from the maintenance of these records, the data processing unit in the modeling group will also be responsible for summarization and analysis of the data after reception at the bank, in consultation with the investigators interested. Operations performed on any set of data, whether by the central modeling group staff or by other investigators, will be reported immediately to the participating scientist who collected them and the approved reports will be distributed to participating scientists at frequent intervals, indicating the current status of the data records, and describing any new sets of data that have been incorporated; listings or copy tapes will be available to participating scientists on request. Publication of data abstracts will be handled by a central group within the U.S./IBP effort. Two types of data abstracts will be included by the investigators in the annual contract reports: first, a short key-worded abstract leading to a more detailed data description summary, which then leads to the original data source. Duplication and data transfer to information bank magnetic tape will be financed by the requestor.

5.2. Intensive Sites

5.2.1. H. J. Andrews Experimental Forest

Most research activities will be concentrated in a few locations within the H. J. Andrews intensive site. Watershed no. 10 has been selected as a primary focus for high-resolution studies, with watershed no. 2 as a follow-up for studies requiring more space. These areas will be kept undisturbed and any destructive sampling or manipulation will occur nearby but outside these watersheds. In addition, general surveys for inventory purposes will be continued covering the whole of the experimental forest.

During year 1 minimal capital improvements have been achieved including temporary housing for scientists and assistants working in the field for several days at a time. Services and existing facilities have been provided by the U.S. Forest Service. Planning for future work with the required additional personnel and facilities has been coordinated with the developmental program of the Forest Service for the area.

For year 2 a number of capital improvements and additional personnel are requested both for the H. J. Andrews intensive site as well as for facilities and services on the OSU campus. These include:

1. increased living and working accomodations, laboratory space, and lecture room at the Andrews intensive site, including required emergency equipment;

2. conversion of existing structures at OSU to a plant sample-preparation laboratory;

3. a computer high-speed linkage to provide access to the University of Washington computer complex for rapid program and data exchange;

4. additional personnel to assist the site director with the high volume of anticipated work in manuscripts, coordination of analyses and seminars, and installation and maintenance of field facilities;

5. travel for the deputy director, and the full-time technician and visiting scientists when residing at the H. J. Andrews intensive site.

5.2.2. Cedar River—Lake Washington drainage

As discussed in the research components of this study, the research activities in the Cedar River—Lake Washington drainage basin will be focused on several lakes and on the Thompson Research Center. During year 1 a considerable improvement has been made to the facilities at the Thompson site, including a water supply (deep well), sanitary facilities, and an expansion of the storage capabilities. These improvements were made possible in part from first-year funding by the NSF and from contributions by the City of Seattle Water Department. The Findley Lake site has not been developed for either access or field facilities. The drainage basin is located approximately 2.4 km from the end of the nearest road. Construction will begin on a trail leading from the end of the road to the lake during the summer of 1971 using the fire crew of the City of Seattle. Specifically, the new facilities needed during year 2 at the Cedar River intensive study site include the following:

5.2.2.1. Thompson Research site

1. Extend power line 0.8 km to new research plots.

2. Build overnight living accommodations for 6--approximately 3716 square meters.

3. Improve the laboratory and storage space in the current buildings.

5.2.2.2. Findley Lake

1. Build overnight housing at the lake. Building will be prefabricated and taken to the site.

During year 1 of the intensive site program chemical analyses were performed with existing equipment and facilities located throughout the University of Washington campus. To permit full utilization of existing instruments and be able to increase analytical capability most economically, equipment will be centralized during year 2. This is necessary in order to handle the increased load of samples efficiently as fieldwork expands in terrestrial and aquatic systems in the second year.

With the expanded complexity of organizing and administering the Cedar River program, additional assistance is requested for the Cedar River site director. It is proposed to hire an aquatic biologist as an associate site director because of the importance of limnological studies in the Lake Washington drainage basin. This aquatic biologist will also serve as coordinator of the Findley Lake study. Both hourly and secretarial assistance will also be needed at approximately the same level as was requested for year 1.

5.3. Coordinating Sites

The coordinating site system is an integral and necessary part of the Coniferous Forest Biome research structure. The function of the coordinating sites is to extend and reinforce the research program and results of the intensive sites. The coordinating sites will also provide the measure of variability of the Biome. In addition, they will evaluate the generalities and consistency of results from investigations on the intensive sites. Research on the coordinating sites will be directed toward the achievement of these objectives.

For an area to be designated as a coordinating site within the Biome research program it must meet several specific conditions. First, it must be relatively undisturbed and representative of the segment of the Biome under investigation. Also, the area must be of sufficient size to accommodate the planned studies. In addition, a group of scientific and supporting personnel must be present that are capable of completing the proposed project and these personnel must be interested and willing to work in an integrated research program. Finally, the institutions involved must have sufficient control over the area to enable treatments to be imposed in an adequate experimental design.

During year 2 the role of the coordinating sites will be the extension and testing of models from the intensive site studies. No field-oriented studies are submitted for funding in this proposal for any of the coordinating sites. However, a proposal is included for the organization and implementation of the coordinating site program for future years 3, 4, and 5. To accomplish this organization and implementation a number of steps must be undertaken:

5.3.1. Development of a coordinating site committee

This committee is to be appointed by the Biome director from interested personnel representing various institutions and geographic locations throughout the Biome. The Biome directors should be members of the committee. The role of this group will be to establish guidelines, determine eligibility and function of new sites, and invite specific proposals from coordinating sites for the program.

5. SERVICES

5.1. Central Office

5.1.1. Administration and accounting

An important task will be to communicate the research objectives and research progress to colleagues throughout the Coniferous Biome working area and certainly to the public at large, including the political component at both the local and national levels. The Biome director will also improve communications with the national office and both national and international IBP committees. With a skeleton organization in year 1 we have not been able to perform this function as it must be performed.

Among the mechanisms envisaged for coordination of work spread over a wide geographic area are the regular circulation of newsletters, both of general interest and covering particular specialized needs; the frequent use of long-distance telephone communication; and, above all, the organization of meetings of people working in different parts of the Biome in the same field of specialization. Carefully planned meetings of a limited group of specialists (workshops) will make possible the exchange of ideas and information about techniques in a far more effective way than could any other mechanism.

Apart from communication among the numerous groups involved in the program, it will be necessary for the Biome organization to establish and maintain review mechanisms to ensure that the goals and objectives of the Analysis of Ecosystems program are attained, both by encouraging necessary research and by ensuring that work in progress continues to serve the overall purpose of the program.

Principal costs for direction of the Biome will again be contributed by the University of Washington through the time of both the director and one of the deputy directors. However, in order to support these individuals and the deputy director at Oregon State, a full-time administrative assistant is needed. We were fortunate to secure the services of Dr. Hans Riekerk for this position in year 1 and his continued employment is anticipated and planned for.

Accounting services for the Biome are considerable. Grant contract negotiations will be handled by the University of Washington. Accounting and money management of the individual proposals will be the responsibility of the central office and handled by an additional half-time bookkeeper in the accounting department of the College of Forest Resources.

A considerable amount of secretarial service is needed at the Biome office to provide needed support for the administrative staff. Secretarial services for site directors and researchers beyond that related to the central office is requested in individual budgets.

Various kinds of services must be provided by the Biome office at an increased level as the organization develops. These include editorial assistance for various levels of communication, report writing, scientific papers, and proposals.

An information service item is proposed to provide some assistance to our library system in fulfilling requests for information related to Biome interests and to maintain a file of publications on IBP work for both students and research workers, as well as the general public. Since the initiation of the Coniferous Biome program, heavy demands for additional services from these groups have been placed on our college library, and this request is for some hourly assistance funds.

Travel must be considered from several points of view related to the total management and research progress of the Biome. First, there is the need for the Biome administrative staff to travel to all parts of the Biome to confer with researchers and plan the orderly development of Biome activity. There is also the need for the Biome director or his representative to travel to inter-Biome meetings at both the national and international level. These meetings may be for either administrative or research purposes. Secondly, the importance and role of intra-Biome meetings by research or administrative committees, including conferences and workshops, has been clearly demonstrated during the initial stages of development. So far many of these meetings have been related to development of the second-year proposal and general organizational development. Coniferous Biome philosophy is to insist that each researcher and each research group is aware of research throughout the Biome and the role of his or her activity with respect to the total model. Therefore workshops and conferences will continue to be a mainstay of Biome operation and must be provided for. The Biome office will plan these and therefore the fund request for the total Biome is included in the central office budget.

5.1.2. Program services

Essential program services include the provision of technical assistance or consultation on special problems of wide significance to the integrated research effort, such as data analysis, processing, taxonomy, environmental monitoring, and chemical analysis. It is expected that program services offered through the office of the Biome director or his deputies will promote liaison between investigators at major study sites.

Program services will be provided in several ways. Special and technical committees (such as committees on chemical analysis, data processing, and biometrics) will be established and funded so that they can meet as needed, or travel from site to site. Special capabilities and expertise which develop at various sites will be made available to the Biome by an effective communication net and special consultantships. The following services will be rendered through the central office:

5.1.2.1. Editorial services

As the work develops, considerable volumes of reports and other documentation will be produced. Much of the editorial work involved should be taken off the shoulders of investigators; it is proposed to centralize these activities under the Biome director along with other information and communication aspects of the Biome program.

5.1.2.2. Laboratory services

Central organization will be desirable for certain analytical procedures where expensive equipment is required, where there are economic savings possible from large-scale operation or automation, or where uniformity and consistency call for it. There are in existence in institutions within the Biome a number of laboratories with excellent capabilities which are not fully used. As far as possible, arrangements will be made to use such facilities for routine determinations for the whole Biome, wherever centralization would be advantageous. If facilities are required which cannot be provided in this way a central unit will be set up for the purpose under the Biome director.

5.1.2.3. Taxonomic services

For many groups of organisms in the region with which we are concerned taxonomic studies have been in progress for many years, collections and expert advice are available in most institutions, and difficulties in identification are unlikely to arise. There are, however, certain groups which are less well known and where the expertise is more difficult to come by. It is not proposed to set up facilities for identification at the central Biome office but to concentrate the tasks of identification at institutions where these difficult groups have been under study for a considerable time and where valuable taxonomic collections have been built up.

5.1.3. Workshops

Conferences and workshops will be a necessary major activity in the Biome during year 2. During year 1 we have relied heavily on workshops provided by other Biomes and have received expenses for attendance at many of these from the Central AOE Office. In the course of developing the year-2 proposal, each research committee expressed a need and desire to hold one or more specific workshops or technical conferences, usually to bring all participating research workers up to the same level of competence or to explore methodology in specific fields. The workshop requests have all been combined into one organizing activity of the central office in order to provide the necessary related services. 5

5.1.4. Research participants

Because of the concentration of research work at the intensive sites during the second year there is a need to bring scientists from other institutions to participate in various research programs. These will be researchers who have specific capabilities in certain critical areas of research or who will be acting as principal investigators at coordinating sites in year 3. In the latter case these scientists will become familiar with research techniques and modeling procedures so that specific validation studies can be carried out at the appropriate coordinating site. The selection of participating scientists will be done by the Research Planning Committee and the Coordinating Site Committee.

5.1.5. Information bank

Since all programs in the Biome will involve a great body of data that is to be available to all Biome investigations some unit must be given the responsibility of overall supervision of an information bank. Moreover, a large collection of data is already available, some published, some not published but scattered throughout different institutions, laboratories, and offices in the Biome, which will be essential to the modelers as they begin their work. It is appropriate also to consider some central analysis of this mass of data though this is not to suggest that investigators will not analyze their own data.

It is a responsibility of those concerned with any study to gather initial information from all possible sources and pass it on to the modeling groups and the information bank. This will be done at the outset, prior to or concurrently with the beginning of research in the studies. Relevant data will be made available promptly through the information bank to other collaborators in the Analysis of Ecosystems program throughout its duration.

Since this will constitute a substantial body of data, its handling will constitute an important activity of the central Biome office. Apart from the maintenance of these records, the data processing unit in the modeling group will also be responsible for summarization and analysis of the data after reception at the bank, in consultation with the investigators interested. Operations performed on any set of data, whether by the central modeling group staff or by other investigators, will be reported immediately to the participating scientist who collected them and the approved reports will be distributed to participating scientists at frequent intervals, indicating the current status of the data records, and describing any new sets of data that have been incorporated; listings or copy tapes will be available to participating scientists on request. Publication of data abstracts will be handled by a central group within the U.S./IBP effort. Two types of data abstracts will be included by the investigators in the annual contract reports: first, a short key-worded abstract leading to a more detailed data description summary, which then leads to the original data source. Duplication and data transfer to information bank magnetic tape will be financed by the requestor.

5.2. Intensive Sites

5.2.1. H. J. Andrews Experimental Forest

Most research activities will be concentrated in a few locations within the H. J. Andrews intensive site. Watershed no. 10 has been selected as a primary focus for high-resolution studies, with watershed no. 2 as a follow-up for studies requiring more space. These areas will be kept undisturbed and any destructive sampling or manipulation will occur nearby but outside these watersheds. In addition, general surveys for inventory purposes will be continued covering the whole of the experimental forest.

During year 1 minimal capital improvements have been achieved including temporary housing for scientists and assistants working in the field for several days at a time. Services and existing facilities have been provided by the U.S. Forest Service. Planning for future work with the required additional personnel and facilities has been coordinated with the developmental program of the Forest Service for the area.

For year 2 a number of capital improvements and additional personnel are requested both for the H. J. Andrews intensive site as well as for facilities and services on the OSU campus. These include:

1. increased living and working accomodations, laboratory space, and lecture room at the Andrews intensive site, including required emergency equipment;

2. conversion of existing structures at OSU to a plant sample-preparation laboratory;

3. a computer high-speed linkage to provide access to the University of Washington computer complex for rapid program and data exchange;

4. additional personnel to assist the site director with the high volume of anticipated work in manuscripts, coordination of analyses and seminars, and installation and maintenance of field facilities;

5. travel for the deputy director, and the full-time technician and visiting scientists when residing at the H. J. Andrews intensive site.

5.2.2. Cedar River–Lake Washington drainage

As discussed in the research components of this study, the research activities in the Cedar River–Lake Washington drainage basin will be focused on several lakes and on the Thompson Research Center. During year 1 a considerable improvement has been made to the facilities at the Thompson site, including a water supply (deep well), sanitary facilities, and an expansion of the storage capabilities. These improvements were made possible in part from first-year funding by the NSF and from contributions by the City of Seattle Water Department. The Findley Lake site has not been developed for either access or field facilities. The drainage basin is located approximately 2.4 km from the end of the nearest road. Construction will begin on a trail leading from the end of the road to the lake during the summer of 1971 using the fire crew of the City of Seattle. Specifically, the new facilities needed during year 2 at the Cedar River intensive study site include the following:

5.2.2.1. Thompson Research site

1. Extend power line 0.8 km to new research plots.

2. Build overnight living accommodations for 6--approximately 3716 square meters.

3. Improve the laboratory and storage space in the current buildings.

5.2.2.2. Findley Lake

1. Build overnight housing at the lake. Building will be prefabricated and taken to the site.

During year I of the intensive site program chemical analyses were performed with existing equipment and facilities located throughout the University of Washington campus. To permit full utilization of existing instruments and be able to increase analytical capability most economically, equipment will be centralized during year 2. This is necessary in order to handle the increased load of samples efficiently as fieldwork expands in terrestrial and aquatic systems in the second year.

With the expanded complexity of organizing and administering the Cedar River program, additional assistance is requested for the Cedar River site director. It is proposed to hire an aquatic biologist as an associate site director because of the importance of limnological studies in the Lake Washington drainage basin. This aquatic biologist will also serve as coordinator of the Findley Lake study. Both hourly and secretarial assistance will also be needed at approximately the same level as was requested for year 1.

5.3. Coordinating Sites

The coordinating site system is an integral and necessary part of the Coniferous Forest Biome research structure. The function of the coordinating sites is to extend and reinforce the research program and results of the intensive sites. The coordinating sites will also provide the measure of variability of the Biome. In addition, they will evaluate the generalities and consistency of results from investigations on the intensive sites. Research on the coordinating sites will be directed toward the achievement of these objectives.

For an area to be designated as a coordinating site within the Biome research program it must meet several specific conditions. First, it must be relatively undisturbed and representative of the segment of the Biome under investigation. Also, the area must be of sufficient size to accommodate the planned studies. In addition, a group of scientific and supporting personnel must be present that are capable of completing the proposed project and these personnel must be interested and willing to work in an integrated research program. Finally, the institutions involved must have sufficient control over the area to enable treatments to be imposed in an adequate experimental design.

During year 2 the role of the coordinating sites will be the extension and testing of models from the intensive site studies. No field-oriented studies are submitted for funding in this proposal for any of the coordinating sites. However, a proposal is included for the organization and implementation of the coordinating site program for future years 3, 4, and 5. To accomplish this organization and implementation a number of steps must be undertaken:

5.3.1. Development of a coordinating site committee

This committee is to be appointed by the Biome director from interested personnel representing various institutions and geographic locations throughout the Biome. The Biome directors should be members of the committee. The role of this group will be to establish guidelines, determine eligibility and function of new sites, and invite specific proposals from coordinating sites for the program.

5.3.2. On-site evaluation of proposed coordinating site programs

When guidelines have been established for work of the coordinating sites in agreement with the modeling requirements of the Biome, the selected programs found to fit into the overall Biome objectives will be visited by the committee and an on-site evaluation will be made.

5.3.3. Review of specific research proposals from coordinating sites

Research proposals from the coordinating sites will be reviewed by the committee as to their appropriateness to the coordinating site program objectives and those that meet the objectives will be forwarded to the Planning and Program Committee for evaluation.

5.3.4. Conduct workshops for principal investigators during year 2

To ensure coordination of research efforts on the coordinating sites and to acquaint investigators with the Biome objectives and program, at least one meeting will be conducted during year 2.

The purpose of the proposed organizational structure is to ensure that the role of the coordinating sites program meets the objectives of the total Biome program and to maximize the input from the coordinating sites to this program.

6. RESEARCH MANAGEMENT

6.1. Coordination among Projects

The Coniferous Forest Biome investigators envisage the development of computer simulation programs which, with appropriately varied inputs, will model the behavior of all ecosystems covered. Accordingly, a high degree of coordination among the various research projects is required. It is important, for instance, that observations from the various validation studies should be comparable. It is also important that the process studies be directed toward preparing submodels which can accept as inpur data the observations of the initial state, and of input and output from the validation studies, together with the appropriate outputs from the models for other subsystems developed by other parts of the process studies. Furthermore, their output should meet the requirements of the other subsystems models and provide for suitable comparisons with field data derived from the validation studies. This will call for a spirit of cooperation on the part of the individual research teams--a willingness to subordinate their efforts to the needs of their colleagues and of the program as a whole.

Within the process studies, an important function of research coordination will be to achieve economy of effort. Efforts will be made to determine where certain studies can best be performed, to coordinate the work of investigators at different places concerned with the same subsystem, and ensure that their efforts both fit together and do not overlap. It will be important to eliminate gaps in the coverage of the process studies. Criteria will be developed to ensure (1) the optimal design of validation studies and the maximum contribution of prospective additional projects; (2) the nonoverlap of objectives among process studies; and (3) that all projects contribute substantially to the Biome-wide research goals. These criteria will be used in judging the suitability of additionally proposed research.

Responsibility for these coordinating activities will be as follows: (1) Within each of the validation studies, the site coordinator will ensure that the appropriate sets of data are recorded as regards the initial state, the input - output, and regular monitoring: (2) Within each of the process studies, the project leader will ensure that all important aspects of the behavior of that subsystem are covered and there is no duplication of effort. (3) Each subject matter committee will ensure that the validation and process studies will be properly coordinated. The necessary contacts and communications among specialists will be arranged to ensure the selection of appropriate techniques and interchangeability of data. (4) The Biome director's office eill insure the coordination between the modeling study and process and validation studies, will organize the central information bank, and will arrange for such meetings and communication systems as are needed for the effective integration of the Biome-wide program.

6.2. Review Procedures

6.2.1. Proposed research

Proposals submitted through the Biome organization for inclusion in the integrated research, as well as those generated outside the Biome organization and submitted as IBP-related projects, will be considered. Ad hoc committees composed of scientists engaged in similar research, both inside and outside the Biome, will review proposals and make recommendations to the Biome committee. Criteria for evaluation of proposals will be developed by the committee.

6.2.2. Ongoing research

The process of selection, recommendation, and funding of projects for Biome-integrated research is only the first step toward attaining the objectives of the IBP. Mechanisms will be developed to ensure that investigators and projects remain on course. Procedures will be established for assessing the progress of research under way, making decisions to retain or adjust objectives, or to implement alternative means of achieving proposed ends.

During the first year of the work, the Biome director, the deputy directors, and the Executive Committee developed guidelines and procedures for inclusion in the future program for the Biome. Data sharing, with proper acknowledgments, is basic to the success of the overall program and is consequently a fundamental prerequisite for support of projects to be included in the integrated research program. Provisions for scheduling of work and periodic site reviews by special panels will be included.

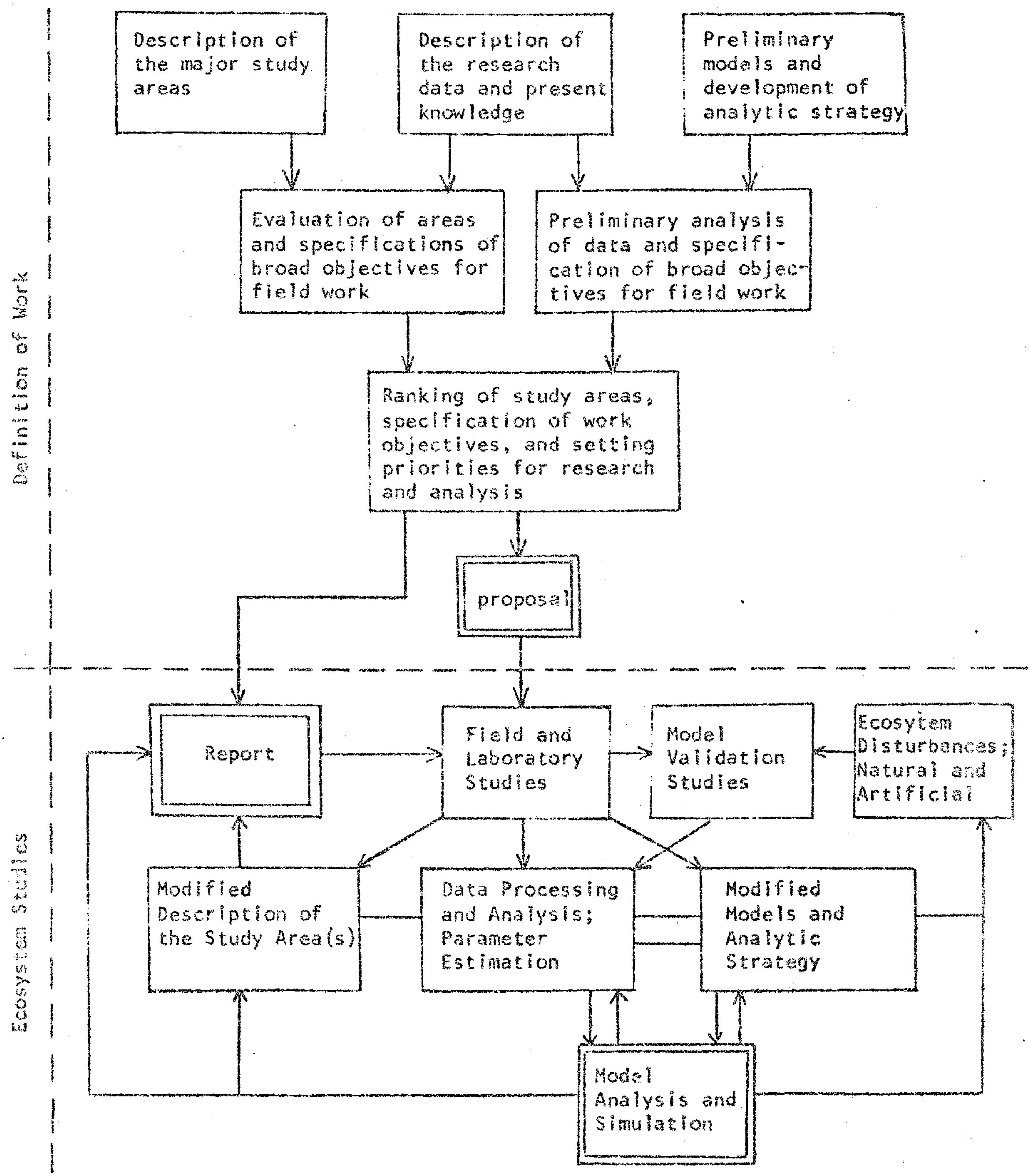
6.3. Research Strategy

We will not attempt to construct Biome-wide simulation models during the early stages of the work. Instead, modelers at each site will develop models of local subsystems and combine these into computer models of their local ecosystems. Frequent seminars, conferences, and visits will enable modelers at the intensive and coordinating sites to maintain close contact with one another and with modelers working in other Biomes.

The strategy of research in the Coniferous Forest Biome may be said to consist of process study, computer modeling, and validation, in that sequence; the procedure, however, will be cyclic. As discrepancies are encountered between the predictions of the simulation model and field observations of validation and manipulation studies, explanations will be sought and new process studies will be suggested which will refine and extend the range of applicability of the functions that will be incorporated in ecosystem models. A schematic flow chart of research strategy is given in Fig. 6.1.

In the final steps of the research, emphasis will be placed on integration of the results already obtained. Biome-wide models of processes in subsystems, such as the ones describing movement of water and nutrients through soils or the growth and development of certain organisms that are widely distributed over the Biome, will be attempted. In addition, models of

Figure 6.1 A Schematic Flow Chart of the Strategy of Ecosytem Study



entire local ecosystems will be compared and the feasibility of construction of Biome-wide models for whole ecosystems will be studied.

Throughout the entire program we hope to demonstrate to fellow scientists and society at large the desirability and importance of ecological research of the type sponsored through the Analysis of Ecosystems program. Workshops, graduate training programs, seminars, special courses, and news releases will be part of the activities of our Biome. Much of the information generated will also be incorporated in courses at member institutions.

6.4 Research Phasing

The basic sequence of any research phasing is as follows:

1. Orientation and program planning, survey of existing information, and technique development.

2. Data acquisition over at least two years in "undisturbed" baseline ecosystems.

3. Concurrent modeling of incoming information.

4. Validation of models in other similar "undisturbed" ecosystems.

5. Validation of models in dissimilar and/or disturbed (naturally or manipulated) ecosystems.

6. Concurrent publication for resource managers to make accurate predictions of the effects of alternative strategies of land use on resource productivity and the quality of the environment.

This approach was discussed in the year 1 proposal for the Biome as a whole, but is obviously different for the various ongoing programs which are at different stages of development. Modeling activities are continuous and diffused throughout each and every study.

To provide proper coordination of the research effort in the Coniferous Biome, it is necessary to identify those areas of study which will contribute most importantly to the objectives of the program. Experience gained in fieldwork at two intensive sites during year 1 will permit the Biome director, in consultation with representatives of the several research committees and the local site coordinators, to plan research at the coordinating sites that will be carried out in subsequent stages of the program. Considerable effort has been invested by the intensive site scientists on the Biome program planning in the years prior to funding. The present proposal will make it possible to fund the planning of an integrated coordinating sites research program. Consequently, the major funding for this will not be available until 1973, creating approximately a two-year lag with the intensive site programs.

Research efforts at the coordinating sites will be primarily oriented toward validation and application studies of ecosystem models or submodels. Aspects of these validations are (1) ecosystem conditions different from baseline ecosystem models, (2) natural disturbances, and (3) artificial disturbances (manipulations, applications).

Research efforts at the intensive sites will be focused to develop baseline ecosystem models in the western Cascade Douglas-fir region with subsequent validation and application studies in other but similar ecosystems.

During year 1 most of the available resources went into gearing up for future coordinated research, including reorientation and integration of existing programs, definition of gaps and research priorities, and initiation of the development of a coordinating sites program.

For year 2 considerable effort has been focused on the nonapplied aspects of the intensive site studies. This effort is to be reduced for year 3 to about half that of year 2 and reach a low continuing level in year 4.

Conversely, the effort directed toward validation and application studies at the intensive sites will be increased drastically during year 3 and will remain at relatively high levels for the duration of the program.

7. RESEARCH PROPOSED FOR YEAR 2

7.1. Introduction

During year 1 our plan for achieving the Biome's long-term goals emphasized program planning and study of existing data. An important objective was early development of models that we hoped would guide us in planning our research. We recognized at the outset, however, that this would not be a simple task. Few participating scientists had attempted to formulate mathematical theories or to express the results of their work in the form of causal functional relationships. Only scientists in the field of meteorology and hydrology, which are increasingly dominated by applied physics, and of fisheries, where the central role of population dynamics and other models to planning resource utilization has long been recognized, provided notable exceptions. Good general models existed in these areas, and the principal modeling problems were in applying them to situations in a coniferous biome. In many basic areas, however, such as tree physiology and decomposer processes, which are the primary points of biomass production and reduction in coniferous ecosystems, functional relationships that would be helpful in planning process studies are poorly developed at best.

In year 2 we have been forced to modify our research strategy and to proceed concurrently with process, modeling, and validation studies in all subject matter areas. If we were to postpone process and validation studies in some poorly understood fields until better theories were available, we would be unable to complete these field studies in any reasonable time period. We would also be unable to develop our unit watershed studies, which are integrated over almost all disciplines. In planning the process studies we have relied heavily on judgments of the Research Committees. The chairmen of these committees have consistently requested support from the modeling group and, as a result, modelers have been closely associated with the Research Committees and have participated in the planning of process and validation studies.

In the following sections the proposed research program for year 2 is presented. Initially we outline the procedures by which it was developed and the specific year-2 objectives. The research itself is presented at increasing levels of detail: (1) the general program as it is related to year-2 objectives, which shows how subject matter projects are integrated toward common, system-oriented goals (sec. 7.2); the program in each subject matter area as developed by the Research Committees (sec. 7.3); and (3) abstracts of the individual research projects (sec. 8).

7.1.1. Research design

As emphasized in our first proposal, our purpose is to understand and predict the behavior of whole ecosystems. We intend to study processes and develop models that are relevant to entire systems. Therefore each project, however narrow or detailed, must relate to an essential component of a system under study. Our approach continues to emphasize the interplay of process, modeling, and validation.

Furthermore, we have designed our program to take the fullest possible advantage of existing related research projects and facilities. This will allow us to proceed more quickly through the initial stages of modeling and data synthesis, thus avoiding needless delays and duplication of effort in acquiring certain types of data. It also will allow us to minimize investments in capital improvements and maintenance and to apply a greater percentage of our budget to actual research.

The specific procedures by which our research program was planned, although not unique, are nevertheless characteristic of the Coniferous Forest Biome and illustrate the strategy for a research design which we have chosen. There are always several ways in which a large program of this type can be developed and organized--various research sites, levels of resolution, trophic or functional levels, specific tasks, etc. We have used two approaches: (1) subject matter research committees and (2) integrated packages of work based on the year-2 objectives or tasks.

This year most of the research has been planned and organized to utilize a number of subject matter committees (Terrestrial Producers, Terrestrial Consumers, Aquatic, Interface, Decomposer, Genetics, Modeling, and Genetics Committees and their subcommittees). Each committee covers a major trophic level or other functional segment of the program regardless of site location or level of resolution. The objectives provide the constraints and focal points in the committees' activities.

The research committee structure functioned reasonably well in organizing the program and ensured that all activities in a particular subject area were coordinated throughout the Biome. The chairmen were responsible for summarizing the proposed research programs of the committees and for providing information requested by chairmen of other committees. Through a series of personal and written exchanges, the programs of the various committees were integrated and necessary interconnections and adjustments regarding plans, abilities, data needs, etc., were worked out. For example, the chairman of the Decomposer Committee specifically indicated to other chairmen the need for gross estimates of primary productivity, climate, chemical composition of the atmosphere, the water-holding capacity of the soil, etc. Her position papers and those of her counterparts were reviewed by all committee chairmen and the Biome director, deputy directors, and site directors. The exchanges and reviews were not sufficient to fully integrate the program but any deficiencies were made up by utilizing the year-2 objectives to focus the committee's activities.

Each committee chairman solicited proposals from members of his subject matter group across the Biome, having first informed them of the needs and objectives of the Biome and of his group. Relationships of studies to one another within each group and among groups were stressed and gaps and overlaps were identified.

Over 110 specific proposals were received and summarized in writing by the group chairmen. Each then defended his group's proposed program at two meetings of committee chairmen and directors. Proposals were judged on the bases of their relationships to other projects, likelihood of success, relevance in terms of specific Biome objectives, and their apparent level of importance. At various points proposals were dropped, reduced in scope, or reoriented as necessary to provide a fully integrated Biome proposal and bring the total budget to the absolute minimal level needed to achieve our objectives. The final selection was made by the central office from the revised Research Committees' packages.

The central role of modeling has been recognized by the members of the subject matter committee. Each committee has requested that the modeling group provide the services of one or more modelers, who will be closely identified, therefore, with a subject matter group.

7.1.2. Year-2 objectives and integration of work

This segment of the proposal identifies the specific objectives or operational questions for our Biome year-2 program and shows how the individual projects are planned and will function as integrated units of work aimed at these specific year-2 tasks.

It is difficult to channel the activities of a diverse and geographically dispersed program as large as this one toward truly common, fully understood (by both participants and granting agency), and coordinated ends on a yearly basis. General objectives, like those adopted for the AOE and Coniferous Forest Biome program, are necessary but also tend to be all-inclusive. Consequently, they give insufficient direction for allocating the Biome's limited resources on a yearly basis since nearly an infinite number of research projects can be justified under the broad directives.

To provide specific direction for the Biome's year-2 activities, particularly to focus the activities of the Research Committees (the key organizational unit) and ensure full integration with regard to trophic levels, sites, etc., the Biome adopted a series of specific tasks or objectives for year 1 (Table 7.1). These evolved from joint efforts of the Research Committee chairmen and the director and his staff in the central biome office. They include work in the general area of inventory, process, and modeling studies, and development of the coordinating site program. These objectives are the integrated units of work which the Biome plans to accomplish during this funding year. They function as our operational questions. They are the priority tasks toward which most of the individual proposals are directed, although a few proposals aim primarily at laying necessary groundwork for year 3. It should be noted that many of the projects are designed to contribute simultaneously to achievement of several Biome objectives.

Modeling has a central role in the organization of research around these integrated units of work or objectives. Models are, of course, one final product, but the modeling group has been deeply involved in the formative planning stages for these activities. Organization of research by ecosystem units, such as the unit watersheds or stands, will lead to the development of unit ecosystem models or submodels which can be generalized and extrapolated, hopefully forming the bases for Biome-wide models.

Table 7.1.

Specific Objectives of Coniferous Forest Biome for Year 2

1. Carry out general ecosystem descriptions at the intensive sites at the specific locations and degree of resolution required to support the modeling and research work outlined below.

2. Develop the necessary additional data and conceptual models for modeling transfer mechanisms and pathways of nutrients, particulate matter, water, and energy in selected intensive site ecosystems. Specifically including:

   a. interfaced terrestrial-aquatic systems; i.e., rates, pathways, and controls on nutrient and water cycling in stable terrestrial-aquatic systems (on unit watersheds or drainages) and energy transfers between the terrestrial and aquatic parts of the systems;

   b. interfaced terrestrial-groundwater systems; i.e., energy, water, and nutrient budgets including transfer mechanisms, rates, and pathways in a second-growth Douglas-fir stand (Thompson Research Center);

   c. determination of the relative importance of various energy and nutrient sources for production in higher trophic levels (e.g., fish) in aquatic systems (including primary production, direct transfers from terrestrial systems, and fish carcasses);

   d. acquisition of data and conceptual framework for developing resolution models of the detritus or decomposer segment of terrestrial and aquatic systems.

3. Model assembled information on the other important facets of coniferous ecosystems including:

   a. disruptive influences of terrestrial consumers on terrestrial producers, as well as consumptive influences;

   b. influence of environment on primary productivity in terrestrial systems;

   c. theoretical modeling of ecosystems specifically including the conceptual framework for extrapolation from one scale of study to a larger scale.

4. Further develop the total Biome strategy of ecosystem study particularly the role and specific operating plan for the coordinating site research program.

7.2. Research Program as Related to Year-2 Objectives

7.2.1. General ecosystem descriptions at intensive sites

Inventory studies, including descriptions of forest structure, soils, and climate, and estimates of nutrient capital and biomass of different groups of organisms, are essential and integral parts of the ecosystem studies under way in the Biome. These descriptions provide an initial data base that is required for understanding and modeling processes such as respiration, photosynthesis, nutrient uptake, etc., as well as those on the larger scale such as cycling within entire unit watersheds. Some inventory work has been incorporated within appropriate research proposals and in all cases we propose to direct this work to the specific locations (e.g., stands or unit watersheds) under study in the intensive sites, and at the level of resolution required to support the modeling and research work outlined below. In year 2, within these constraints, we will continue the general ecosystem inventories at H. J. Andrews Forest and in the Cedar River drainage including the following procedures:

1. Complete the coarse-resolution mapping of the vegetation, soils, geology, and water bodies within these areas.

2. Establish a series of permanent reference stands or plots within the major ecosystem types as sites for much of the terrestrial research and to provide comparisons between systems.

3. Characterize the forest biomass, structure and composition, some environmental factors (e.g., temperature), and phenology within the reference stands and unit watersheds under intensive study.

4. Estimate population densities, food sources, and consumption by terrestrial and aquatic animals within each of the intensively studied areas.

7.2.2. Understanding and modeling the rates and pathways of nutrient, water, and energy transfers in ecosystems

The bulk of the research program for year 2 is directed toward achieving the four tasks listed below. Basically, this means acquiring the field data and adapting or building the basic models for understanding the following systems:

1. Nutrient and water cycling within unit watersheds which include a stream in one case and a lake in the other. Since this is where the aquatic and terrestrial research program are interfaced, energy, elemental, and water transfers between these two components are of interest. This work involves scientists in almost all subject matter areas and initially is at a relatively coarse level of resolution.

2. Pathways and rates of energy, nutrient, and water transfer, and accumulation in a uniform forest stand, in this case of second-growth Douglas-fir. This effort involves the terrestrial producers process, nutrient cycling, hydrology, and meteorology groups and is at a finer level of resolution.

3. The relative importance of various energy and nutrient sources for primary and secondary production, especially of fish, in aquatic systems. Involved are studies of stream systems, including experimental stream facilities, and of a series of lakes responding to a range of environmental gradients from undisturbed coniferous forest through urbanized lowland areas at the intensive study sites. Internal (e.g., primary production) as well as external (e.g., allothonous material and fish carcasses) energy sources for secondary production will be evaluated. Studies of direct energy and nutrient transfers from terrestrial sources, through leaf fall, dead animals, erosion, and other means, link the aquatic and terrestrial programs through the unit watershed studies.

4. The structure and functioning of the decomposer subsystems. The research here is functional--the goal is to identify the role of major groups of organisms and the rates and pathways by which detritus is reduced to the elemental or organic components which are recycled or lost from the system. Also involved are nitrogen transformation and fixation accomplished by this group of organisms and factors which control these processes. The lack of adequate information on this subsystem and its essential importance to conifer ecosystems (over 95 percent of the organic matter goes directly from primary producers to decomposers) have dictated the need of the Biome for this work.

We emphasize that the research outlined above is directed toward understanding the functioning of relatively stable ecosystem units over short time spans. We have concluded logically that we must begin our program by understanding how these ecosystems are built and function, in the respects outlined, before beginning studies of effects of human manipulations and other perturbations on similar systems. By accomplishing the tasks outlined for year 2, we will be ready in following years to proceed with validation studies involving an extended time scale, natural disturbances, and manipulative applications.

7.2.2.1. Terrestrial-aquatic interface studies (watershed level)

As previously indicated, the research work planned on the unit watershed drainage level is a core unit of our program since it is here that the aquatic and terrestrial activities are interfaced and the relationships between these two systems (or subsystems) can be studied. We will be examining and comparing two different kinds of ecosystems simultaneously: small drainages or unit watersheds which contain streams (terrestrial-stream system) and one which contains a lake (terrestrial-lake system). As recognized and planned in year 1, the terrestrial-stream research is designed around the gaged watersheds at H. J. Andrews Forest and the terrestrial-lake research is focused upon Findley Lake in the Cedar River drainage. This year the research and modeling are concerned primarily with nutrient and water cycling in these systems, but energy transfers between the terrestrial and aquatic components are also of interest. We also wish to better identify and quantify the similarities and differences between stream and lake systems.

The basic philosophy underlying this program is not new but can usefully be reiterated here:

1. The biogeochemical cycle is, of course, a whole, but it can be differentiated into components, e.g., biological, edaphic, geochemical,

terrestrial, aquatic, etc. Water movement interconnects these components and serves as an important transporting agent for the energy and elements released, absorbed, and accumulated. By knowing the movement of the elements and suspended material among the several parts of the system one can begin to understand the major processes affecting the system and to develop predictive capabilities.

2. Investigations conducted on small vegetated watersheds have illuminated the gross pattern of mineral and water cycling. By subtracting meteorological inputs from the geological, the impact of the biological factor has been assessed, but seldom measured directly. In this way, the cycle of a number of elements has been established and quantified. We know at certain areas and for simple ecosystems the distribution and transfers of a number of major elements. But the specific processes involved (e.g., in the biological, edaphic, and geochemical components) are imperfectly understood. Our work must be directed to these processes, following the movement and changes through various components of the system, recognizing that the end products in one component become the reactants in the next one. A useful approach is to consider the components as a series of ecosystem compartments connected by transfer functions.

3. In a natural system both surface and subsurface waters are collected by lakes or streams, adding another dimension to the cycling. Ions, radicles, molecules, and suspended material derived from processes in the terrestrial system react, for example, in both the trophogenic and tropholytic layers of a lake. The terrestrial biogeochemical cycle is therefore closely interdigitated with that of the aquatic, and our studies must acquire a knowledge of the two, treated as parts of a single cycle.

There are two essential interacting requirements for successful cycling models on unit watersheds: (1) the identification and quantification of major components, processes and controlling factors, and (2) development or adaption of basic conceptual models. We believe that we have developed a series of studies which are not only highly efficient in providing for these immediate needs but are integral parts of other present or planned Biome activities as well.

The basic sampling designs are followed in all of our unit watershed work. Some studies will utilize the entire watershed (e.g. streamflow, terrestrial vertebrate consumers) or some proportional subsample (e.g., biomass-nutrient capital estimates and process studies) as the sampling unit. The sampling strategy for many other habitat level of resolution studies (e.g., decomposer processes, litter fall) involve a permanently preserved series of reference stands which (1) are representative samples of the major plant community—environmental stratification units found on the unit watershed, and (2) span the major environmental (e,g., moisture and temperature) gradients. Data collected from these reference stands are then extrapolated to the parts of the unit watersheds having comparable stratification units. Some studies (e.g., destructive analyses of vegetation must, of course, be carried out entirely outside (but nearby) the intensively studied unit watersheds and reference stands and extrapolated to them using nondestructive measures.

Conceptual modeling to support this objective already is well in progress. As previously pointed out, a great deal of information has been collected within the Coniferous Biome on nutrient levels within different components of the system, as well as on changes over time and transfers within the system. This is particularly true at the Thompson Research site of the Cedar River watershed and at Fern Lake, where research has been conducted since 1958 under projects directed by Lauren Donaldson of the College of Fisheries, University of Washington. There is also other information from the Cedar River watershed, from sites in Oregon, and from Castle Lake in California. To utilize this accumulated information and initiate the model development, teams have been established that include modelers and those who have participated in the original data collection. These include two teams at the University of Washington, one at Oregon State University, and the Castle Lake research group. Further details are spelled out later. At the moment the models under development involve simple differential equations and a variety of assumptions about the nature of the transfer processes. As discussed in section 1.3, some of the work has progressed to the point of comparing model output with actual observations and this will help in refining parameter estimates, identifying needs for better compound models, and designing further research.

Some simple models of the water balance of the Fern Lake watershed have been previously developed in unpublished work, but establishment of a computer model based on the graphical model of Olsen (as shown in section 8.3.1.) and utilizing better models for some of the terrestrial processes clearly provides a more reasonable approach. Fern Lake is not an intensive site of the Biome but the information gathered here on the terrestrial-aquatic interface will be useful in this phase of our studies. The results of the Fern Lake and Castle Lake studies should be very helpful as we begin more intensive research and models for the lakes of the Cedar River watershed and possibly elsewhere in the Biome.

The modeling of hydrologic and nutrient cycling in Oregon centers, of course, around the unit watersheds at the H. J. Andrews site. Past hydrologic records are being summarized, and Riley at Utah State University has already met with the IBP group to explain his hybrid computer models, which appear to have well-developed submodels accounting for snowmelt and nutrient movement through watersheds. A synthesis of the hydrologic modeling discussions in Oregon is in preparation by Brown, Overton, and Fredriksen. The effects of nutrient concentrations and other water qualities upon aquatic stream communities are being modeled by Warren and Calvin from studies conducted at Berry Creek and Oak Creek Experimental Laboratories. This work is related to studies on the Andrews site now in progress concerning energy and nutrient exchange in the terrestrial-aquatic interface. One of the teams at the University of Washington is developing models of the nutrient movement into and within streams and their effort will be coordinated with the Oregon studies.

Terrestrial-stream studies. Although we have available eight unit watersheds at the H. J. Andrews site, several of the watersheds will not be used until later when studies and manipulations of middle-aged (e.g., 125-year-old) coniferous forests are begun. In year 2, activities are aimed at obtaining data needed to model nutrient, water, and energy flow in old-growth (450-year-old) Douglas-fir—western hemlock ecosystems, exemplified by watersheds 2, 9, and 10.

The largest and most specific task in year-2 terrestrial-stream work is to develop a basic coarse-resolution model for nutrient and water cycling for undisturbed old-growth watershed, and to examine direct energy transfers between the terrestrial and aquatic components. Watershed 10 is the focus of this work because of its relatively small size and simplicity. This segment will be discussed in detail and will illustrate how the numerous research studies on the unit watershed are integrated. Few studies are confined solely to this segment, because the other important goals for year 2 include preparation for: (1) energy modeling of unit watersheds and extension of all models to a larger, more complex, old-growth watershed (no. 2); and (2) watershed-level manipulative studies in year 3 of the Biome program.

Some components and transfers within, additions to, and losses from this watershed 10 are already known. For example, streamflow and precipitation and their nutrient content have been monitored for several years. For year 2 more than twenty separate research projects have been coordinated to provide all the data required for a Mark I model of this system or the model itself. We will continue to monitor streamflow and concurrent nutrient losses and nutrient input in rainfall. More detailed meteorological data than have been available will be collected on an area adjacent to the watershed.

One large task involves completion of vegetation, soil, geologic, and animal inventories. In the quantitative characterization of forest communities, linear measurements will be emphasized allowing allometric data developed from destructive analyses of trees and shrubs in nearby areas to be applied immediately for first approximations of biomass and nutrient capital. These estimates will be improved in future years using special nondestructive surveying techniques under study this year and further destructive analyses. Mean values and variation in physical and chemical properties of soil will be determined, and soil moisture monitoring will be carried out. Estimates of populations and consumption by terrestrial consumers including vertebrates (mammals, birds, reptiles, and amphibians) and invertebrates will be developed. Decomposer inventory will include both soil fauna and flora.

Terrestrial process studies will determine major transfers of water and/or nutrients. We will continue and expand a study of litter fall and canopy drip initiated in year 1. A tritiated water technique will provide direct measurement of transpiration losses over the entire year. Rates of subsurface flow (soil water movement) will be measured and linked directly with another study of soil retention capacity and rate of mobilization and transport of cations and nitrogen within the forest floor and soils. Decomposer studies will provide estimates of decomposition rates and nitrogen fixation and release in the forest floor and soil, as well as nitrogen additions by epiphytic organisms. All will be carefully coordinated with the stand and lysimeter level studies at the Cedar River Thompson Research Center so that any submodels developed there can be immediately tested at the unit watershed level.

Aquatic biologists will determine the structure and primary and secondary productivity of the stream systems. Our focus upon the land-water interface stresses determination of the relative importance of terrestrial detritus inputs into the food web of the stream biota. Estimates of allochthonous input under a variety of conditions, including the undisturbed condition, will receive emphasis.

Structure and productivity of aquatic plant communities will be evaluated under a variety of conditions including different light intensities and stream velocities. Density and standing crop of insects will be determined using three different types of samples--benthos, emergence, and drift. Their role in energy transfer between trophic levels and the action of detritivores, which comminute allochthonous material, will receive special attention. Fish population and production studies will be aimed primarily at validation of some preliminary models. Amphibians will be studied as part of the terrestrial consumer program but with attention to their role in the stream system and as "carriers" of energy and minerals from the aquatic back to the terrestrial subsystem.

The supportive modeling effort for the unit watershed studies is provided by several modeling projects. The Biome modeling group will provide general support and advice for scientists, as well as some specific submodels. Two projects aimed specifically at modeling nutrient and water cycling on unit watersheds will utilize the H. J. Andrews data. One is focused on subsurface flow processes and the other on hydrologic simulation models for entire watersheds, which utilizes the subsurface flow submodel. Work on a model of trophic relations based on density-dependent processes in aquatic communities, initiated in year 1, will be continued and will provide a major submodel for part of the aquatic program. Adaptation of a tentative model developed for eastern woodland streams, where particulate organic matter appears to dominate primary production as an energy source, will be considered.

Terrestrial-lake studies. The aquatic studies in the Cedar River drainage are conducted in four lakes: Sammamish, Washington, Chester Morse, and Findley, and the connecting streams, most importantly Cedar River itself. In year 1, Findley Lake was identified as the best site for focusing studies of interactions between terrestrial and aquatic components of lake drainage systems. Terrestrial-aquatic relationships are also being studied on a less intensive basis, on the other lakes and their larger and more diverse drainage basins; they will receive more attention, however, when we move into studies of human influences (manipulations or disruptions) in later years.

During year 1, most of the research involved ecological descriptions of the principal ecosystem components in the Findley Lake basin, including descriptions and maps of principal vegetation types, soil types, and geological formations. The chemical, physical, and biological properties of the lake were monitored periodically during the first year. A coring of lake sediment was completed to begin a historical documentation of ecological stability and rates of accumulation that have occurred in the drainage.

Studies in year 2 will consider the Findley Lake drainage model as a series of discrete compartments connected by transfer functions. The studies are organized into two major groups of integrated research proposals--terrestrial (biochemical) and aquatic (limnological) programs. The focus of the programs, however, as previously discussed, will be directed to understanding the linkages between the terrestrial and aquatic parameters of this unit watershed.

The terrestrial program in year 2 will be concerned primarily with completion of the basic inventories of ecosystem components and initiation of work on fluxes or transfers in the system. Small plots or reference stands will be established within each vegetation type for detailed observations. The vegetative structure and composition of each will be quantified. The physical and chemical characterization of the soils will be completed. Precipitation, temperatures, and phenological events will be monitored. Movement of materials from the producers to the forest floor by litter fall, throughfall, and stemflow will be measured. Losses from the forest floor and resulting additions to soil will be periodically examined with tension lysimeters. The chemistry of the percolating solutions and chemistry and mineralogy of suspended material in different soil horizons will be characterized and attempts will be made to correlate the physical, chemical, and mineralogical properties of the soils with movement of ions and particulate matter. Documentation of the hydrological cycle of the system will be initiated and preliminary installations will be made for gaging water and elemental fluxes into and out of Findley Lake. The vertebrate and invertebrate consumer populations in the drainage will be documented as to population densities and consumptive behavior. Insects and amphibian consumers, the principal consumers in the lake, will receive special attention since they materially affect transfers of both energy and minerals from the oligotrophic aquatic to the terrestrial component.

In the aquatic component of the Findley Lake drainage, the plan is to quantify and document chemically the hydrologic cycle, and determine the impact of nutrients upon the biota. The intent is to provide a preliminary chemical balance sheet by the end of year 2, which can be further refined as the dynamics and interactions of various processes are measured in year 3. The chemical dynamics of the hydrologic cycle will be analyzed with special emphasis on the role of phosphorus in the system. The utilization of these nutrients by the primary and secondary consumers and the resulting biomass will be measured and compared with that of the other three lakes in the Cedar River drainage. Paleoecological work, initiated in year 1, will be completed and the analysis of bottom-deposit accumulations will document the history and stability of the drainage.

Supportive modeling effort for this work will be provided by several modeling projects. One will be concerned specifically with the phosphate balance sheet, using Findley Lake drainage as one example. The Biome modeling group will provide general support and advice. The models and submodels developed for the unit watersheds (stream system) will also be adapted and tested for validity in this lake system.

7.2.2.2. Terrestrial-aquatic interface studies (habitat level of resolution)

Many studies essential to a thorough understanding of ecosystem structure and function are not very useful when approached at the relatively coarse watershed level of resolution. This is particularly true of terrestrial process studies such as photosynthesis, respiration, nutrient uptake and loss, interception and evapotranspiration, soil water flow, etc. Consequently we have developed an integrated series of studies in which assimilation, transpiration, and growth by individual trees will be examined simultaneously with nutrient and water cycling and the development of energy, water, and CO_2 budgets in and out of the stand. In this way, it will be possible to relate rates of net CO_2 assimilation and transpiration by individual trees to fluxes of nutrient, water, and energy in and out of the forest stand as a whole. The resulting understanding and models will provide us with an ability to predict the influences of natural or manipulative changes in inputs, factors, etc. on these wholestand fluxes as related to the interface section of ecosystem modeling. One of the major objectives in year 3 will be to extend or validate in other ecosystems the models developed here. The site selected for these studies is a young second-growth Douglas-fir stand at the Thompson Research Center in the Cedar River drainage.

During year 1, a number of investigations in this system were carried out or continued including research on various terrestrial production processes (assimilation, transpiration, tree dimension change) and ecosystem attributes (particularly nutrient and water cycling, energy, water, and CO_2 budgets). The present research contemplates building on this earlier research and synthesizing certain of these studies in a manner that will be sufficiently representative of the entire ecosystem to hold promise for a very considerable advance in our understanding of production-environment relationships. The proposed studies are outlined below; for details see the sections on terrestrial processes (7.3.2.1), nutrient cycling (7.3.7.1), and meteorology (7.3.7.3), and the proposal abstracts (sec. 8.3).

Research planned for year 2 includes the description of vertical profiles of air temperature and humidity, wind speed and direction, atmospheric carbon dioxide content, long- and short-wave radiation, and spectral distribution. A weighing lysimeter will be installed beneath one dominant or codominant tree to provide definitive water balance data and biomass gain. Dynamics of water movement through the system, both in quantitative terms and in anion and cation chemistry will be examined, using appropriate gages or troughs above ground and tension plates at various intervals from the forest floor to the lower limit of rooting. Water potential in the soil profile will be determined by psychrometers or Tensiometers as appropriate.

Productivity process studies will include patterns of net assimilation and certain aspects of respiration within and between trees using cuvette and infrared gas analyzer equipment. Much of the work will be based on the superior Siemens cuvette technique, which has become standard equipment for IBP studies. This equipment will be used to calibrate the less sophisticated but satisfactory thermoelectrically cooled cuvettes of local fabrication, which will be used for measurements of genetic, spatial, and temporal variations.

Water regimes in trees will be examined using Scholander bomb stress assessment and relative flow rates with heat probe equipment. Relative stomatal aperture dynamics in the foliage will be followed with an alcohol infiltration technique. Transpiration patterns within and between the tree crown will be determined by cuvette infrared gas analyzer techniques. The cuvette technology does permit the measurement of transpirational rates on samples of foliage, but environmental effects may be far different from those in natural stand conditions. In this integrated study it will be possible to compare transpiration as measured by a weighing lysimeter on a large specimen with that measured on foliar samples by cuvette methods. It will also be possible to assess the influences of radiation load, temperature and vapor pressure gradient, and water stress on the transpirational rates on diurnal and seasonal bases.

The dynamics of dimension change and biomass development in trees will be assessed on diurnal, weekly, seasonal, and annual bases using xylem marking and/or dendrometer bands (recording and ocular) on stems, branches and roots. Samples of tissue will be collected periodically for chemical analysis and related to the stand nutrient cycling work.

Simultaneous collection of all these data at appropriate intervals throughout the year will provide certain bases for relating biomass dynamics, growth processes, population structure, environmental parameters, and ecosystem attributes in model form. This, in turn, will provide insight into ecosystem workings and develop predictive capability. Most of the modeling support for integration of the results of these studies will come from the central modeling group and the scientists themselves.

The sharp focus of the above studies on a few trees makes it imperative to know more about genetic variation. Classification and stratification of genetic variation in the field will materially increase the level of confidence for extrapolation of results from the detailed studies to the more general unit watershed studies elsewhere. Genetic variation in tree populations will be assessed in Douglas-fir during year 2 by studying patterns of genetically controlled enzyme variation by electrophoresis in parent-progeny sets from two adjacent populations in the Cedar River watershed, forming part of the productivity process studies. Enzyme "fingerprints" are relatively independent of environmental variation and may be uniquely suited to delineate genetic hierarchies; they may thus help in the design and interpretation of all those studies investigating genotype-dependent variables.

The models referred to in the section above can begin simply as budgets of the materials involved. However the various modeling teams are already exploring more deeply into the processes involved so that higher resolution models can be created. For example it is necessary to know much about the evapotranspiration process to understand the water movement and, since water movement influences nutrient movement and energy flow, to understand these also. Several models have been proposed by researchers for the evapotranspiration processes. These are being fitted into our ecosystem models even though some of these submodels have been developed for other types of plants and other areas.

The availability of a nutrient to a sedentary organism depends upon both the physical mechanisms that transport the nutrient to the organism and the chemical reactions that supply the nutrient in a chemical state compatible with the organism's absorbing mechanism. The mechanical transport of substances within the soil is governed by principles of soil physics and physical chemistry. The uptake of nutrients by plant roots and by soil organisms can be explained by physiological theories. Our models must incorporate the definite laws that are involved in these theories. The theories are not fully formulated for the plants of a coniferous biome, however, and even less is known of the required parameter estimates of these laws. The needed research will be conducted according to designs established by the preliminary models in the balance of the first year of the Biome study and in the second year now being proposed.

As the models advance to this stage, it is apparent that it is necessary to know more of the regulations of the processes involved. It is desirable that some steps be taken to build regulatory models in the second year of the program so that appropriate studies can be designed if important data are missing.

7.2.2.3. Food and nutrient sources for production in aquatic ecosystems

During year 1 aquatic activities concerned primarily planning, program development, and preliminary modeling studies on some ecosystem components at the intensive sites. The purpose was to coordinate approaches and to develop inventories, sampling schemes, or techniques for year-2 research. Much of the input resulted from non-IBP research programs, particularly at Lake Washington and Lake Sammamish.

In year 2 much of the aquatic research effort has as its specific task determination of the relative importance of various terrestrial and aquatic energy and nutrient sources for primary and secondary production. This work will examine the major components, inputs, control functions and processes that control and maintain productivity in small stream systems, larger streams or rivers, and lakes of contrasting character in a coniferous biome setting.

Some components of the aquatic research program outlined here service other Biome objectives as well. Several of the studies already have been described in the previous section on unit watershed interface studies--i.e., the terrestrial-stream and terrestrial-lake programs. Aquatic research in year 2 will also provide inputs on conversion and recycling of dead organic matter as part of the decomposer subsystem studies and of existing data for the ecosystem modeling efforts described elsewhere.

The primary aquatic-terrestrial interface occurs in watershed streams and it is here that direct material transfers from the terrestrial subsystem will receive greatest study. The terrestrial-stream studies at the Andrews Forest provide the closest intertie. Salmonid fish, because of their numerical abundance and high value in a coniferous biome, will receive emphasis at the higher aquatic consumer level in the study of transfer of nutrients and energy through that trophic level. Past laboratory stream studies at Corvallis and year-2 stream community experiments at Davis will help to elaborate, under controlled conditions, the effects of temperature and organism density on consumption, metabolism, and growth of consumer organisms.

The large stream study will continue on the Cedar River, which flows through the Chester Morse Reservoir and terminates in Lake Washington. Emphasis in the study is on the change in water chemistry, nutrient content, primary production, and aquatic insect production along its course relative to its changing characteristics and hydrology. The importance of nutrient contribution from salmon carcasses to stream productivity and to productivity in Lake Washington is of special interest. Contributing to this understanding will be a controlled study of the biogenic enrichment from salmon carcasses at Berry Creek (an experimental stream).

While lakes tend to be slower than streams in response to environmental pressures originating on land, they will in most cases be more indicative of long-range effects of land use on aquatic systems. This already has been indicated by lake core studies showing effects of timber harvest, and by studies of changes in eutrophy of Lakes Washington and Sammamish. Proposed additional paleoecological studies accompanying existing programs will provide information on the history of the pristine and oligotrophic Findley Lake.

Primary emphasis will be on a comparative study of trophic dynamics in the lakes of the Lake Washington-Cedar River drainage to determine how contrasting land uses influence enrichment and productivity in lakes of a common watershed in a coastal forest. Aquatic studies in Findley Lake, as described earlier, will provide the best opportunity for terrestrial-lake interaction measurements. Details are outlined in section 7.3.6.2.

Preliminary modeling of existing data on the aquatic components of lakes Washington and Sammamish was initiated in year 1 and will be intensified and extended as data accumulate. The concurrent modeling of extensive data from Fern Lake, Washington, and the salmon-producing Wood River Lakes in Alaska provides a valuable parallel and validation opportunities.

7.2.2.4. Decomposer subsystems in terrestrial and aquatic ecosystems

There is almost certainly no component of coniferous forest ecosystems as important functionally yet so poorly understood as the decomposer or detritus subsystem. Release of the energy and nutrient elements bound up in organic matter by primary and secondary producers and their recycling in the system is dependent upon this subsystem of decomposers. Nitrogen fixation and transformations are accomplished primarily by these organisms. Elements of the decomposer subsystem are important in alteration of the structure of the forest and possibly in algal communities as pathogens or pathogen antagonists. They function directly as symbiotic components of primary and secondary producers (e.g., mycorrhizae)and as nutrient sources for zooplankton.

During year 1 the necessary techniques and conceptual basis for a systems-oriented decomposer program have been largely developed. With the experience gained during the first year, and the considerable integration of the various programs that has been accomplished in planning sessions, we are ready to proceed on an expanded program in year 2.

In the past, it has been assumed that the decomposer component of the ecosystem can and should be approached as a "black box," and that there is no need to know the organisms or pathways involved so long as we can measure the disappearance of substrate and release of products. We believe this is a serious fallacy which has led to continual problems in agriculture and medicine and could do so in natural systems. Certainly the "black box" approach would seriously reduce our understanding of how ecosystems work and would undermine our ability to predict responses to manipulation.

Consequently, a major task of our year-2 program is a better understanding of the decomposer subsystem which is to be reflected in the definition of necessary degrees of resolution required to build realistic models or submodels having predictive ability with regard to effects of natural or human perturbations. Three basic elements in the proposed research are: (1) identification of the major groups of microorganisms involved; (2) idenfification of the substrates consumed and products released by the major groups of organisms and the rates at which these transformations take place; and (3) determination of how environmental factors influence the growth and metabolism of the major groups of decomposers. Each of the decomposer proposals addresses itself to at least two of these elements.

The identification of major populations of decomposers will concentrate upon those actually involved in decomposition of specific components of biomass, litter detritus, and dissolved materials; it will not involve development of exhaustive lists of all species present at the intensive sites. A common criticism of decomposer inventories is the production of species lists that have little information on organism activity. Equally significant, such lists often omit important populations either because they escape the screening procedures used or because expertise in isolation and identification of one or more groups is lacking. We intend to avoid both of these weaknesses.

As mentioned, we will concentrate upon decomposer species involved in decomposition of specific substrates. For example, the buildup of saprophytes on living needles and the succession of organisms which reduce them after needle fall will be followed. In the aquatic community, both aerobic and anaerobic organisms associated with the breakdown of specific compounds will be studied. Consideration will be given to compounds such as chitin and cellulose, or groups of compounds such as protein and lipids (e.g., fish carcasses). This emphasis on substrate (habitat, decomposition site) focuses attention upon those organisms which are important in major processes. By following this procedure with each of the major components of biomass and detritus we expect to be able to identify the major populations of decomposers--those which occupy a position comparable to the dominants among forest trees. In some instances classification will be as to functional groups, i.e., groups of species which are so similar physiologically that they can be treated identically at the levels of resolution in this program. Cluster taxonomy of the aquatic bacteria and protozoa populations will serve this purpose. If this approach proves fruitful in year 2, the technique will be expanded to soil microorganisms.

Within the team of decomposer researchers are people with expertise in the isolation and determination of all groups of decomposer organisms including bacteria, actinomycetes, fungi, and microfauna. Each group of decomposer populations and each habitat or decomposition site is covered within the program.

Quantitative data on functioning of organism groups, such as estimates of decomposition rates of major substrates, respiration (measured as or converted to O_2 uptake), and of nitrogen fixation and release, will be obtained simultaneously. Initially, relatively crude estimates will be developed to provide data on transfer rates for the total ecosystem nutrient and energy cycling models discussed earlier. Since decomposer biomass is probably insignificant, the measurements will concentrate upon activity. In most instances, during year 2, the estimates of activity will probably be order-of-magnitude estimates. However, attempts will be made to balance these estimates of productivity and accumulation. In some instances (e.g., loss to decomposers from living primary producers) the data may be expected to provide important correction factors for estimates of primary productivity based on standing crop.

In the terrestrial environment (including temporary streams), data to be collected will include the following: (1) loss of carbon by respiration of parasites and release by decomposers from standing healthy trees (e.g., direct loss to leaf-inhibiting nonpathogenic bacteria and loss due to heart rot fungi); (2) loss of carbon by litter including annual totals and subtotals by component and decomposer organisms; (3) loss of organic particulates (e.g., pollen and humus fragments; (4) disappearance of dissolved carbon from soil solutions, leachates, etc.; and (5) nitrogen fixation by free-living and symbiotic microorganisms, including epiphytic lichens.

In the aquatic environment, the data to be collected will include the following: (1) verification of a method for estimating carbon flux among primary producers, zooplankton, decomposers, and the dissolved organic pool; (2) cluster taxonomy of bacteria and protozoa; (3) degradation of organic compounds; (4) respiration measurements of the water column; (5) respiration measurements of the lake sediments; (6) estimates of detrital contributions to the higher trophic levels; (7) estimates of nitrogen fixation by blue-green algae and anaerobic bacteria; and (8) evaluation of fungal parasites as potential controllers of algal blooms. Studies will extend to all major aquatic sites.

Although the long-term objectives involve development of models which predict the effects of perturbation, we view the initial task in year 2 as development of models or submodels for more stable populations in balanced systems. Although a great deal is known about the dynamics of microorganism populations in culture, studies of natural populations have been limited chiefly to disease organisms in epidemic conditions. Models for more stable situations are the essential first step and the research program in year 2 is designed to provide the components for such models. We plan to begin model development with animals (soil arthropods), proceed to the bacteria, and finish with the filamentous fungi, simulating the dynamics of these populations in nature. These models will be tested, first in culture and then in the field.

Eventually we will probably have to develop fine-resolution submodels at several points which involve decomposers if we are to understand the functioning of the total ecosystem. These include: (1) factors influencing the explosive growth of populations of toxic or pathogenic organisms; (2) systems, such as mycorrhizae, which may result in retrieval of nutrients which might otherwise be lost to leaching; and (3) the role of microorganisms in controlling population densities of primary producers and consumers. Most existing population models are developed from populations composed of reproducing individuals. Many decomposers are fungi in which the entire colony may consist of a single long-lived mycelium with several genomes preserved as a heterokaryon. It is not at all clear what modifications of existing population models should be applied in treating such organisms.

7.2.3. Modeling

7.2.3.1. Regulation models

It is estimated that in coniferous forests ten percent or less of the biomass developed by trees and other primary producers passes through animal consumers before being decomposed and released to the soil and atmosphere. As consumers of plant biomass or as producers of food, the animals of the coniferous forest are relatively unimportant. As regulators of the primary production process, however, their impact may be far greater than their limited biomass suggests. It has been shown that the diversity of prey species can increase in the presence of predators--apparently because competition among the prey species is reduced. For example, the high diversity of tree species in tropical forests seems related to the existence of host-specific seed-eating insects, which can effectively prevent the reproduction of a host tree if they can locate it. Thus insects, by affecting a critical phase in the life history of a dominant species, may affect its abundance and distribution and hence the very character of a stand. This is also true, of course, of certain pathogenic fungi, as well as of mammals which selectively browse, and even of fire and windthrow. In some coniferous forests where steady-state conditions extend for only a few generations such disruptive effects are obviously important. We have, therefore, as a major goal for our second year of work, the development of models describing regulatory or control functions of animals and plant pathogens. This modeling effort will be based entirely on data already available and the experience of the terrestrial consumer and decomposer scientists involved in the Biome program.

7.2.3.2. Influence of environment on productivity

Much of our modeling work in the second year will also consist of the development of process submodels, and these will be concerned, directly or indirectly, with the production of biomass (chiefly by commercially important trees and fishes) in coniferous forest and aquatic ecosystems. We will be especially concerned with the identification and understanding of critical mechanisms which maintain the productivity of the system. The nutrient element cycles are central to this problem. We will attempt to determine the factors that prevent the steady attrition and eventual loss of essential nutrients from forest systems which develop under regimes of heavy precipitation, runoff, and subsurface leaching. We will ask how serious and long lasting are the effects of logging and forest fires on the nutrient capital of a site and to what extent these effects depend on the physical and chemical properties of the soil. We will also be concerned with the effects of climate and other environmental factors on the rates of production. For example we know that, at lower elevations, Douglas-fir is able to carry on photosynthesis throughout the entire year, but during the dry summer months moisture stress may limit production. Therefore it will be essential to examine photosynthetic rates as functions of temperature, moisture, and nutrient stress. Photosynthetic rates are also related to light intensity and to CO_2 concentrations in the forest. Since much carbon dioxide is released by the activity of decomposers in the forest floor and is subsequently taken up by the leaves of trees, its concentration decreases with increasing height in a still-air column above the ground. On the other hand, light intensity diminishes from the forest canopy to the ground. These intricately interconnected relationships require that all process models be closely and carefully linked.

Two specific tasks proposed for year 2 are: (1) modeling of photosynthetic and environmental data collected in European spruce forests as part of the IBP activities there; and (2) completion of an environment-productivity model which utilizes measurements of the type proposed for a Biome-wide environmental grid.

7.2.3.3. Study of ecosystem models

To assure that our modeling effort maintains a sound biological and physical structure as well as a mathematical symmetry, we have encouraged the study and modeling of certain important processes. A task of the research scientist, therefore, is to work closely with members of the modeling group to develop an internally structured model having both general application and predictive power.

In practice, this means that submodels are developed in areas such as nutrient element and water cycling or net assimilation. Each scientist in such a group has a specific task--for example, development of a set of mathematical relationships describing the flow of potassium ions from surface detritus to mineral soil. He will often require collaboration with a modeler to meet his objectives. All such contributions are assembled in a computer program after review by a large group. Once parameters have been estimated from existing data, it is possible to run computer simulations, the output of which are compared with known results or the general experience of the members of the research group in such matters, and deficiencies are identified and corrected. The simulation will clarify too, by sensitivity analysis, where the most important future research must be focused.

Clearly if there were no coordination among the modeling efforts of the several research groups, a chaotic assemblage of unrelated simulation models would accumulate. Coordination at successively higher levels is essential and is accomplished through the forming of additional teams of research scientists and modelers. At these levels, however, problems of computer programming become critical, imposing restraints on the kinds of simulation models that can be developed.

A framework for a general site or watershed ecosystem model encompassing many submodels has been recognized as needed from the outset of our program. It becomes urgent now that the submodels are beginning to proliferate. In the Coniferous Biome, we will take advantage of the ecosystem simulation model already developed by the Grasslands Biome group. We are not sure, however, that this model can or should be adopted--even with suitable minor modifications--to coniferous forest terrestrial and aquatic systems and their interfaces. Accordingly we regard the study, development, and comparison of new general models for entire coniferous ecosystems as a matter of great urgency in the second year of our work.

One specific task in conceptual or theoretical ecosystem modeling will be to provide the techniques and sampling bases for expanding models from one scale to another. Here such questions as how an ecosystem model of a unit watershed can relate to a larger drainage basin and how they can be interfaced will dominate our interest. We believe our organizational approach will prove adequate to the task and look forward to testing it as well as the models.

7.2.4. Development of Biome strategy and coordinating sites program

The tasks involved here are (1) planning in more detail the overall Biome objectives for later years and (2) developing the specifics of the coordinating site program--the role of the system, plans for each coordinating site, site selection criteria, and schedule for implementation. The first task will be carried out primarily by the Biome director and his staff with the advice and help of the site directors, Executive Committee, and chairmen of the various research and technical committees.

The second task is the primary charge of the Coordinating Site Committee working with the Biome director and his staff. The specific objectives in year 2 are to determine: (1) the role of the coordinating site system, the manner in which these sites will be used to further the Biome program; (2) the research program planned at the coordinating sites, whether there will be a minimal standard program, or whether utilization of each site will be highly variable in intensity; (3) the basis for selection of coordinating sites, e.g., the relative importance of geobiologic coverage of the Biome, research history, available manpower, facilities, etc.; and (4) a detailed plan for implementing the program in years 3 and 4. In formulating this program, the clear direction of the NSF office encouraging use of coordinating sites only as validation sites and, more specifically, insisting on full use of existing data for the Biome-wide validation work (as opposed to additional field data acquisition) has to be considered.

The chairman of the Coordinating Site Committee will be responsible to the Biome director for seeing that the above tasks are accomplished satisfactorily and will work with scientists from the coordinating sites and the director's staff in fulfilling the objectives. A part of this job will require on-site evaluations of possible coordinating site locations. In this evaluation work he will be assisted by data compilations and critical reviews on possible coordinating lake-system sites and by a thorough and critical appraisal of non-IBP watershed study sites and programs presently going on in the Biome.

7.3. Research Presented by Subject Matter Committees

7.3.1. Modeling

The philosophy of modeling as well as a discussion of different types of models, included in last year's proposal, has been reproduced in section 8.4. Further developments of the modeling approach within the Coniferous Biome have been reviewed at length in section 1.3. The relationship of modeling at present and as proposed for year 2 are to be found in section 7.2.3. These interrelationships are important because the modeling group serves in part as a research committee but also as a coordinating committee and service group to other committees and to the individual scientists doing field- and laboratory work. The modeling group provides support to such scientists and their parent committees to assist them in the development of component submodels.

To repeat, toward such ends teams have been established to develop workshop sessions that will lead to subcomponent or process models and in some cases to ecosystem models.

In the Coniferous Biome we strive to encourage every experimental scientist to be a modeler, responsible for the development of his own models. Obviously, this idea can be approached only where the experimenter has a strong background in mathematical methods. Lacking this, the experimenter can make important contributions to the modeling process by advising a collaborating member of the modeling group at every stage of development of process submodels and on the formulation of the general framework of larger system models.

Regular weekly meetings with members of the modeling group provide a basis for the research scientist's contributors to process models in his area of specialization. At the outset the objectives of the modeling efforts are discussed. We wish to predict an ecosystem's response, to produce causal models that will lead not only to predictions of plant and animal biomass but also to understanding the interrelated processes controlling composition and stability. Air and water quality are both possible outputs as well as controlling variables in our finished models of forest ecosystems. At this time economic considerations are outside the scope of our program.

Stressed next is the relation of the process model to be developed to the larger model of the ecosystem. For example, in a study of nutrient element cycling in Douglas-fir, rate of potassium uptake by a tree (or a stand) depends on rate of growth of the stand as well as the availability of potassium. Here the research scientists make especially improtant contributions. The nature of feedback systems is discussed and the importance of a realistic conceptual framework is emphasized, for proper formulation of the linkages among processes such as photosynthesis, transpiration, soil moisture, and nutrient availability will be crucial to the success of the overall ecosystem model.

Finally, a detailed investigation of the process model is begun. A box-and-arrow graphic diagram usually provides the most convenient starting point for this work. Generally we are concerned with the flow of some measurable mass, such as water or a nutrient element, through several components of the system such as soil, roots, stems, leaves, or atmosphere. Occasionally, however, we may be interested in other kinds of fundamental variables, such as water potentials whether of the plant or soil system. At this point the contribution of the research scientists is essential, for the members of the modeling group must know if field measurements of the variables under consideration are contemplated. Consequently units of measurement come under careful scrutiny.

Once the graphical representation of the model is generally accepted, forms of the relationships implicit in the diagram are sought out. Because we are interested in flows of materials among components of the system and subsystems, we usually attempt to formulate relationships as differential equations. These are arrived at by discussion with research scientists--who may be asked to present Cartesian plots of the relationships between two variables or who may be familiar with existing formulations in the literature. In this way a set of equations describing the subsystem under study is built up and parameters (such as flow rates) are identified for which estimates will be required.

As these small workshops begin to produce useful process models, the meetings will be expanded to encompass two or more groups and perhaps occasionally all of the groups so active. Such workshop sessions will expand not only among the Biome investigators of one intensive site, but also between the two intensive sites, between these and other sites, and also between Biomes.

The progress report below shows the teams that have been established to date in both Oregon and Washington. Others will be developed with the additional funds requested for 1972. Through a seminar exchange between Oregon and Washington, both live and on magnetic tape, scientists and modelers interact with different groups. Thus many groups share information and build on the experience of other groups although each group may pursue slightly different goals and varied approaches. The modelers on these teams are assisting in the development of submodels but also are working toward the total ecosystem model. As this is developed, a series of work sessions will be necessary to bring all possible expertise to bear on its critical evaluation and to make the biologists cognizant of the uses of the overall model. Such meetings and workshop sessions will follow the same patterns as outlined above, that is, of increasing scope both in discipline and area, with time.

A number of projects of the total proposal have been identified as modeling projects since they involve no fieldwork. Research done on such projects will involve data collected already or being collected by others or will involve the team research discussed above. The largest project so designated is that for the Modeling Committee members at the University of Washington and Oregon State University (Chapman et al.), which is the primary support project for the research at the two intensive sites. The modelers noted in the teams below are associated with this project. This is not the only modeling activity ongoing, however, since the ultimaty responsibility for the model building rests with the substantive scientist. Many will carry on such activity with little if any support from the Modeling Committee, though there will be increasing interaction as research progresses. Projects 9 (Waring, Webb), 70 (Wooldridge)and 73 (Fritschen) exemplify such a situation. In addition, other biologists who are principal investigators have now or will obtain research assistants who have competence in their substantive field and in modeling and thus will develop the subcomponent models required. Again, it is to be emphasized that these are not to be created in isolation but will be drawn into the other team activities, when and where necessary.

While support of other committees is one focus of the modeling group, its other primary mission is the development of an overall ecosystem model or models.

A framework for a general site or watershed ecosystem model encompassing many submodels has been recognized as needed from the outset of our program. It becomes urgent now that the submodels are beginning to proliferate. In the Coniferous Biome we will take advantage of the ecosystem simulation model already developed by the Grasslands Biome group. We are not sure, however, that this model can or should be adopted--even with suitable minor modifications--to coniferous forest terrestrial and aquatic systems, and their interfaces. Accordingly, we regard the study, development, and comparison of new general models for entire coniferous ecosystems as a matter of great urgency in the second year of our work.

One specific task in conceptual or theoretical ecosystem modeling will be to provide the techniques and sampling bases for expanding models from one scale to another. Here such questions as how an ecosystem model of a unit watershed relates to a larger drainage basin and how they can be interfaced will dominate our interest. We believe our organizational approach will prove adequate to the task, but if not we will modify our structure.

Ultimately both the overall models and the submodels will require testing and will suggest further research that must be undertaken to answer new questions or replace inadequate parts of the models already derived. The modeling team will play a role in assisting in the design of such new research and new experiments. In this way the model building plays an essential role in the feedback loop referred to earlier.

The need of parameter estimation and of validating the robustness of the models to the accuracy of the estimates already has been stated. The simulation studies to test such robustness will be the responsibility of the Modeling Committee and some of this research will be undertaken in 1972.

Progress in year 1

As stated above, subgroups or teams have been established at the University of Washington and at Oregon State University to focus on simple models of the ecosystem and/or on specific process models. These include the following at the University of Washington.

1. D. G. Chapman and S. Olsen are working with a graduate research assistant, C. Fowler, to build a simple model involving water, energy, and nutrients. Development of this model is utilizing information from Fern Lake

studies but it is aimed toward a generality that will make it immediately adaptable to the Thompson Research Center site.

2. W. H. Hatheway and graduate research assistant Steven Smith are developing models for nutrient element cycling working with D. Cole and using the data already developed for Thompson Research Center. Hatheway and Smith will also develop models for photosynthesis and related topics.

3. L. Male is meeting with F. Taub, E. Welch, and others interested in primary productivity in the aquatic system.

4. L. Male and D. Rogers are working on a consumer model in Lake Washington and ultimately in other parts of the Washington intensive site.

5. R. Edmonds, a postdoctoral associate, has been assigned to support the decomposer group with their modeling efforts. He is also assisting several other groups, particularly with models for abiotic processes.

6. K. J. Turnbull has done a large part of the programming of a computer model of cellular growth and is now engaged in a study to develop a sampling plan for estimating cell growth parameters and for field sampling to obtain data on both individual tree allometry and structure.

The following subgroups are working at Oregon State University.

1. S. Overton is providing general support and is actively involved in the study of theoretical aspects of ecosystem models. One aim is the comparison of model prediction from models of two levels of ecological resolution as a means of model validation. He will also attempt to elaborate the idea of purposeful information as an ecosystem quantity.

2. C. Warren and his group have been working on modeling of aquatic secondary productivity in terms of food density and biomass.

3. The first round of modeling has been completed in the hydrologic group. A series of weekly sessions produced a set of definitions and a collection of materials for unit watershed 10 of the Andrews Forest, which will appear as a report by Brown, Fredricksen, and Overton. The series was terminated with a visit by J. P. Riley and presentation of his hydrologic models. The next round will be incorporation of Riley's submodels into the overall structure.

4. M. A. Strand has started work on a bibliography of invertebrate consumption and interaction and is abstracting the relevant literature. This is the first step in modeling these processes, and only preliminary attention has been given to actual models at this date.

5. D. Milne has a working model of population dynamics of a single insect species. He is currently working toward refinement within this framework.

6. Overton has done preliminary work toward development of a standard model for forest productivity. Several computer models currently exist. These are being reviewed and alternative approaches are being considered.

7. Waring and Reed are developing from previous data a computer model to predict forest composition and productivity on the basis of seasonal moisture stress patterns, temperature, vapor pressure deficits, and light. The indexes to environment are being synthesized to be widely applicable throughout the Biome.

The modeling group at the University of Washington under Chapman has been conducting a weekly seminar bringing in scientists with model building skill from many fields and from other universities. The modeling group at Oregon State University has begun a series of workshops designed to lead to initial model structure. Hydrology was first on the schedule, to be followed by consumers, decomposers, primary productivity, and nutrient cycling. Sessions are attended by central modelers and by persons active in the particular subject.

In addition to this work associated with the central modeling project, Rogers is utilizing the extensive data already collected on lakes of the Wood River system in Alaska to begin modeling some aspects of salmon production, an important aspect of productivity in some parts of the Biome. At the University of California at Davis fieldwork has been under way for some time on Castle Lake and these data are being used in a preliminary model.

Plans for year 2

Some of the submodels on which work is planned in year 2 include the following (see Fig. 7.1):

1. Several on aspects of primary productivity areas as follows:

    a. Photosynthesis and related processes will be modeled by Hatheway working with Scott, Walker, and Waring.

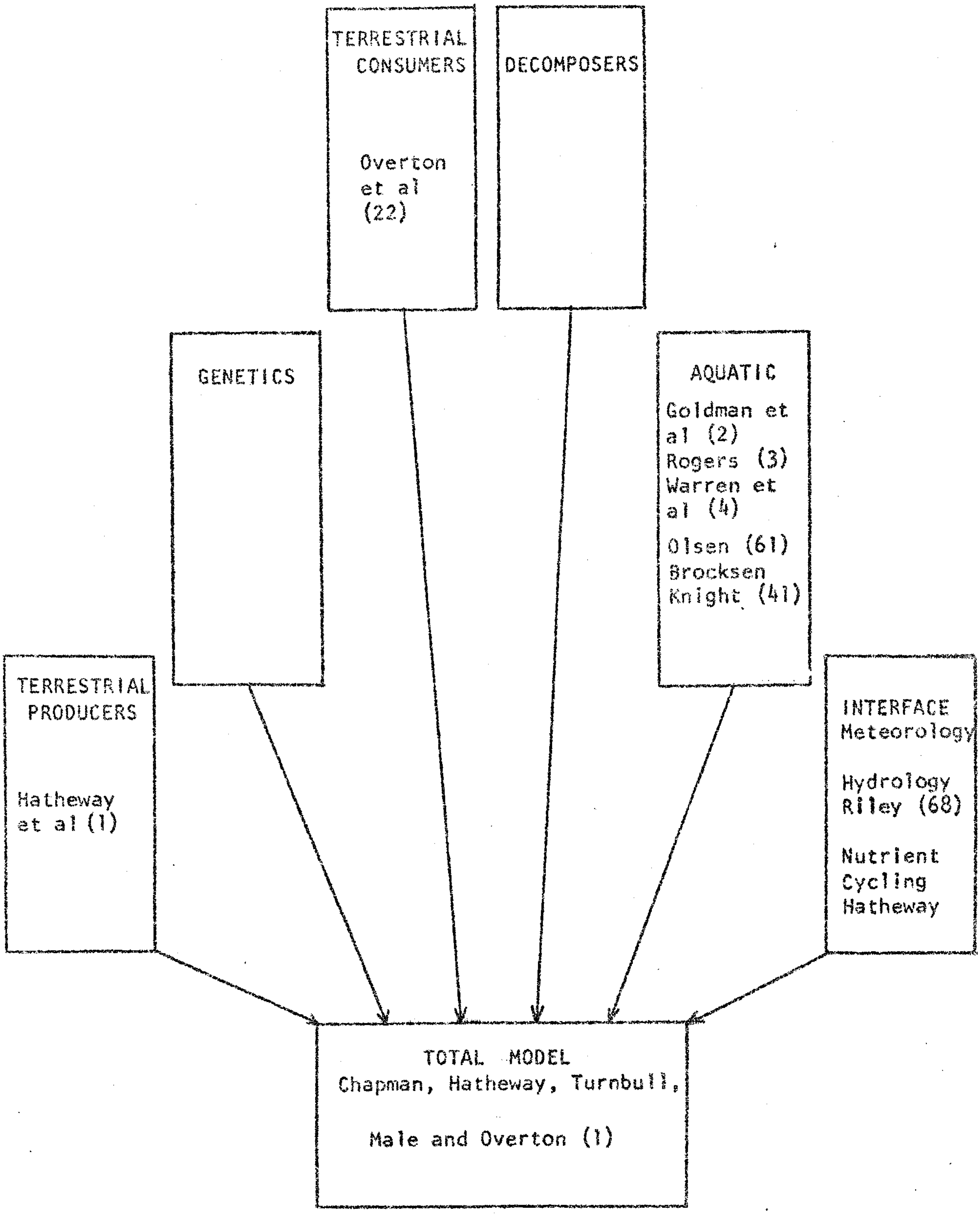
    b. Models of growth at the cellular level will be part of Turnbull's contribution.

    c. Growth of trees at the stand level will be included in Overton's modeling activities.

    d. Waring will develop an environmental and physiological response model for the Douglas-fir.

2. Milne will continue work on insect consumer models as well as provide support to the consumer research group in general; also an additional modeler will be expected to provide support for the research team working on problems of consumers. Rogers' model will deal with one aspect of aquatic consumers while the Warren-Calvin model will encompass trophic relations in the aquatic system.

Figure 7.1 Diagram of Relationships between Proposed Studies: Modeling
(Numbers refer to Proposals in Appendix - Section 6.2)



3. Several models of element cycling and related soil processes will be developed by Hatheway and Cole at the University of Washington; a high-resolution hydrology model will be developed by Riley in collaboration with Burgy.

4. The group at Washington (Chapman, Male, and an additional modeler) will lend support to the aquatic decomposers as well as those studying other aspects of the aquatic system.

5. Goldman and his co-workers at the University of California at Davis will continue work on the aquatic models of the Castle Lake ecosystem. Chapman will continue work with his group on Fern Lake. A comparison will be made of Fern Lake and Castle Lake models and work will be begun on their extension to other systems.

6. The low-resolution ecosystem model to be developed in 1971 will be refined in 1972, particularly utilizing the results of subcomponent models that have been developed in the interim. These ecosystem models should begin to play a role in the design of further experiments.

7.3.2. Terrestrial producers

Research activities carried out in the general field of terrestrial producers are of central importance to the entire Biome program. These activities are many and varied, but may be conveniently grouped under the following four main categories:

1. Determination of primary productivity at the individual plant and stand levels and for entire forests. Two main approaches will be used concurrently to develop this information. The first involves measures of plant biomass, while the second approach utilizes measurements of net photosynthetic and respiration rates to arrive at an estimation of primary productivity.

2. Determination of those factors which regulate the composition, distribution, and productivity of terrestrial communities. Studies in this category will concentrate on such problems as, for example, defining which environmental variables are most important in regulating tree growth, and the influence of genetic factors on stand productivity.

3. The investigation of uptake and internal distribution of water, minerals, and photosynthate within our important forest plants. Such studies of water relations, mineral nutrition, and translocation are of fundamental importance if we are to reach our primary goal of acquiring a basic understanding of coniferous forest ecosystems.

4. The provision of basic descriptive data on the composition, structure, and environmental relationships of those terrestrial communities under study. This descriptive work on study sites is essential to most other Biome activities, especially in providing data for interpretation of various studies of different trophic levels or processes.

The first long-range objective for the Coniferous Forest Biome is to determine the major factors, both components and processes, that control the productivity and distribution of organisms in coniferous forest ecosystems. A large portion of the responsibility for reaching this goal falls on those working with terrestrial producers. As mentioned under category (1) above, much of our total effort will be directed toward obtaining reliable estimates of net productivity for the ecosystems under study. This is, of course, necessary background information before studies of factors controlling productivity can be undertaken. In addition, it will be necessary to conduct field studies of plant processes (e.g., photosynthesis, respiration, translocation, etc.) in order to identify those which may be limiting individual or stand productivity.

However, we need to go beyond simply studying these processes in individual plants if we are to achieve understanding of the entire ecosystem. For example, we need to know the quantity and distribution of forest plant organs contributing to the various plant processes. Thus descriptions of forest structure are essential. Such descriptions will be obtained by dimensional analysis of above-ground biomass at the intensive study sites. These measurements can then be applied to allometric expressions estimating the weight and nutrient distribution of plant organs in forest stands.

Environmental factors are also extremely important in regulating forest productivity. Studies of this nature are are included under category (2). At the very least we need an understanding of how the widely distributed conifers respond to their environment. Plant response should be measured not only in terms of growth but also in terms of internal processes, such as distribution of minerals and photosynthate. Environmental responses should be monitored throughout the entire year in order that seasonal changes may be detected.

A second Biome objective of considerable importance to our work is to determine how various manipulations influence the structure and function of coniferous forest ecosystems. Work planned for year 2 will concentrate on those process, structure, and productivity relationships which exist in relatively undisturbed forest stands. We feel this information provides a necessary base line against which effects of stand manipulation can be measured. For this reason, studies of the effects of such activities as forest cutting and fertilization have been deferred until years 3 and 4.

A third long-range Biome objective is to produce models of temporal and spatial variation in coniferous forest ecosystems or system components. Researchers studying terrestrial producers will provide much of the basic data necessary for the development of such models. Specifically, much effort during year 2 will be centered on developing sufficient biomass and nutrient capital information to permit coarse-resolution modeling of an old-growth Douglas-fir watershed at the H. J. Andrews Experimental Forest. At the same time, we will also be intensively studying assimilation-water relations in a second-growth Douglas-fir stand at Cedar River in a joint energy flow modeling effort.

the H. J. Andrews site and the forest stand of the Thompson Research Center (in connection with inventory data); (2) provide data for testing existing relationships (e.g., allometric) available in the literature and for selecting those relationships that best describe these Cascade stands; (3) establish efficient and precise biomass subsampling techniques (branch harvest, foliage subsampling, etc.), which will permit generalizations on a unit area basis (when used with prediction equations with stand-dimensional variables); and (4) provide data for calibrating and testing nondestructive techniques for biomass estimation (theodolite and tritiated water) under study this year. Foliar biomass and area will be emphasized since it is particularly essential in conjunction with extrapolation of process work.

Total destructive analysis will be made of a small number of old-growth Pseudotsuga and Tsuga at H. J. Andrews Forest, including aerial (Lavender and Bell) and below-ground (Hermann) portions. These data will apply to all four of the objectives listed in the previous paragraph. Some additional work on fine-root distribution and biomass will be carried out on the same site (Hermann). Before these trees are dissected, they will be analyzed using theodolite (Bell and Cole) and tritiated water (Kline) techniques. Analyses of the biomass nutrient capital and productivity will be made of the important understory plant species (mostly shrubs) on the unit watersheds at the H. J. Andrews and Cedar River (Newton) sites. It is our plan that destructive analyses of terrestrial producers will be extended to other species, age classes, and sites in future years. This type of procedure will be minimized, because of its high cost, however, and nondestructive techniques or subsampling procedures will be used whenever practical.

As mentioned, it is essential that new tools for assay of forest biomass and productivity be developed, which can replace or supplement the expensive, relatively imprecise, traditional harvest methods. Nowhere is the need greater than in the massive coniferous forests of our Biome. Consequently, research projects will examine the precision and efficiency of optical (specifically a theodolite system) techniques (Bell and Cole) for biomass and productivity estimates, and of a tritiated water approach to total biomass estimation (Kline). The theodolite system has been undergoing testing during year 1 and, although final results are not yet available, pre- and postseason measurements using the system appear to provide a good estimate of aerial increment in young Douglas-fir stands. Money is requested (Bell and Cole) for acquisition of an improved system, an operator, and additional experimentation with the system including preharvest measurements of all trees selected for destructive analysis (Lavender and Bell) and monitoring of selected trees at Thompson Research Center (Cole et al.). Tritiated water (Kline) will also be used for preharvest biomass estimates of destructively analyzed trees (Lavender and Bell), a technique which provides total biomass estimates based on the total water pool of the tree. This technique has proved useful in biomass estimation on red pines in the eastern United States, but this will be its first application to trees of large size.

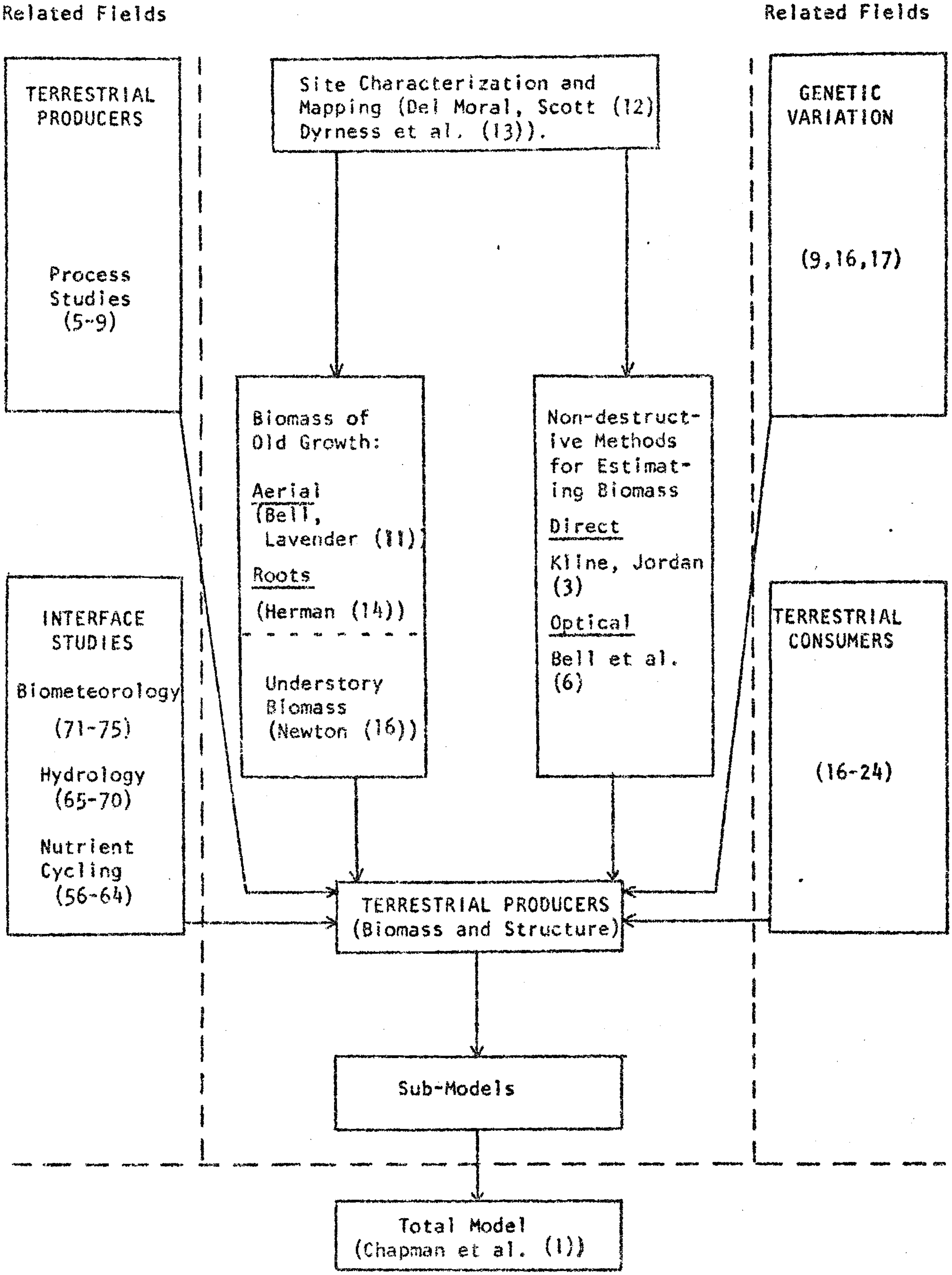
7.3.2.2.2. Site characterization. During year 1 we decided that study site characterization and inventory, insofar as terrestrial producers and some elements of environment are concerned, is best handled by the biomass and structure group. This descriptive program is essential to and must serve the Biome program by providing (1) the basis for stratification of research work in the Biome at the intensive study sites, (2) data needed to interpret results of other studies and to develop various ecosystem models, and (3) a basis for extrapolation of research work from one part of the Biome to another and, as important, from tree to stand to unit watershed to drainage basin levels. We include under site characterization (1) description of community composition and structure and development of the necessary classifications (stratifications); (2) some monitoring of environmental factors and biological features, such as phenology, plant moisture stress, etc.; and (3) mapping of vegetation and soil features as necessary. All description or monitoring of environmental variables (e.g., soils) is done with the complete concurrence and cooperation of the related research projects and subcommittees--nutrient cycling, hydrology, and meteorology. Inclusion of some environmental aspects is justified by the efficiency of assigning terrestrial producer-environmental description work to interdisciplinary teams and to ensure that efforts are fully coordinated and compatible.

Progress in year 1. In year 1 site characterization work was carried out under three proposals developed by Dyrness, Whitney et al., and Zobel. This work involved completion of detailed mapping of vegetation-soil types on the unit watersheds at H. J. Andrews Forest, initiation of environmental and biological monitoring in reference stands representing selected community types at H. J. Andrews Forest, and initiation of inventory work in the Findley Lake drainage in upper Cedar River. Excellent progress was made in all phases. A comprehensive classification of the communities at the Andrews site was completed. This community model is based on reconnaissance-level plots analyzed using similarity-ordination techniques and incorporates environmental as well as biological features. Use of the system in connection with mapping of the unit watersheds indicates its ability to meet practical program needs at H. J. Andrews Forest. Its most important initial use is as a stratification of the unit watersheds, providing ingress to these areas of relatively heterogeneous communities and soils. Reference stands have been established in modal communities of each of the major types, including types spanning moisture and elevational gradients found on the H. J. Andrews site and those that are most extensive on the unit watersheds. In year 1 these reference stands were monitored for air and soil temperature, plant moisture stress, and phenology. A checklist of the H. J. Andrews flora for use by IBP scientists was completed and published. At Findley Lake, year-1 funding arrived too late to allow significant fieldwork during the summer of 1970 but will be used during the 1971 field season to provide preliminary characterizations of the plant communities and soils in that drainage.

Plans for year 2. Vegetation site description proposals for year 2 are centered on the intensive sites, with an emphasis on the selected study areas (see Fig. 7.3). Dyrness and co-workers working in the Andrews Forest set the following tasks:

1. Quantitative analysis and mapping of the composition and structure of the vascular plant communities in selected reference stands and plots will be carried out, and terrestrial producers will be inventoried on

Figure 7.3 Diagram of Relationships between Proposed Studies: Terrestrial Producers - Biomass and Structure. (Numbers refer to Proposals in Appendix - Section 8.2)



the old-growth unit watershed no. 10 at H. J. Andrews Forest. In all cases, the quantitative data collected will emphasize linear measurements which can be immediately converted to biomass and nutrient capital figures as the relevant formulas become available.

2. Monitoring of environmental and biological features in the reference stands at the intensive sites is essential for the interpretation of other studies carried out in these same areas and for comparison of the two intensive study sites. Data to be collected at the H. J. Andrews site include phenology of major plant species (including cambial growth of trees), air and soil temperature, plant moisture stress, and nutritional status of dominant trees. These monitoring activities are carried out in cooperation with various other research projects (e.g., meteorological, nutrient cycling, hydrology, and modeling) to avoid duplication of effort and to ensure that data are collected by proper sampling designs in the most useful form. Soil moisture will also be monitored in reference stands and on watershed no. 10 to service other projects concerned with the hydrologic cycle (Brown; Kline).

3. Quantification of the present vegetation-soil classification at H. J. Andrews Forest will be done. The Andrews classification is presently based almost entirely on reconnaissance-level data, and it is essential that they be placed on a quantitative basis by obtaining measurements of plant and environmental features from subsamples of the reconnaissance stands used initially.

Del Moral and Scott, working in the Cedar River watershed, set the following tasks for year 2:

1. To distinguish the several ecologically unique higher plant components ofthe ecosystems of the Cedar River watershed, especially Findley Lake.

2. To develop an inventory of the location and extent of each of these and correlate with other inventory projects (edaphic, climatic, consumer, decomposer).

3. To quantify in some detail the present floristics and structure, reconstruct the origins, and forecast the future dynamics of each, and to establish type locations for further research and reexamination.

7.3.3. Genetics

Our understanding of ecosystems depends to some extent on our insights into their genetic machinery. In its simplest form each biological component, process, or control function contributing to an ecosystem represents a bipolar interaction between a genetic and an environmental element. The relative importance of the two varies from one interaction to another, and for the same interaction over time. Thus, while genetic analysis forms an integral part of any holistic approach to ecosystem study, it is safe to say that the importance of genetic information may be paramount with regard to certain components, processes, and control functions, but negligible with regard to others. The Coniferous Biome research program provides a unique opportunity to pinpoint some of the crucial genetic inputs into the structure, function, and development of an entire ecosystem.

Forest trees play an important role in this Biome. Their productivity serves as a critical argument for the artificial manipulation of many coniferous ecosystems. It is for this reason that the Genetics Research Committee pays primary attention to securing information on the kinds and amounts of genetic variation contained in forest tree populations, the processes by which this variation is released and regulated, and the degree to which these processes are dependent on time.

The Genetics Research Committee was formed only in November 1970 and has taken over some of the functions of the previous Technical Committee on Phenology and Genetics. Thus a minimal program is proposed for funding in year 2. In the meantime, the committee will hold several planning and modeling meetings during 1971, and will help organize a symposium/field trip to the Cedar River watershed at the 1971 annual meeting of the Western Forest Genetics Association, to be held jointly with the working group of tree physiologists of the West.

Long-term objectives

(1) Determine the amount of genetic variability present in the major ecosystem components, processes, and control functions, and affecting terrestrial productivity in coniferous ecosystems.

(2) Formulate mathematical models encompassing the information obtained under (1), with an emphasis on aspects of "information flow."

(3) Validate these models with new information from elsewhere.

(4) Determine how various genetic and environmental manipulations influence the structure and function of coniferous ecosystems, and how well the models can predict these consequences.

Year-2 objectives

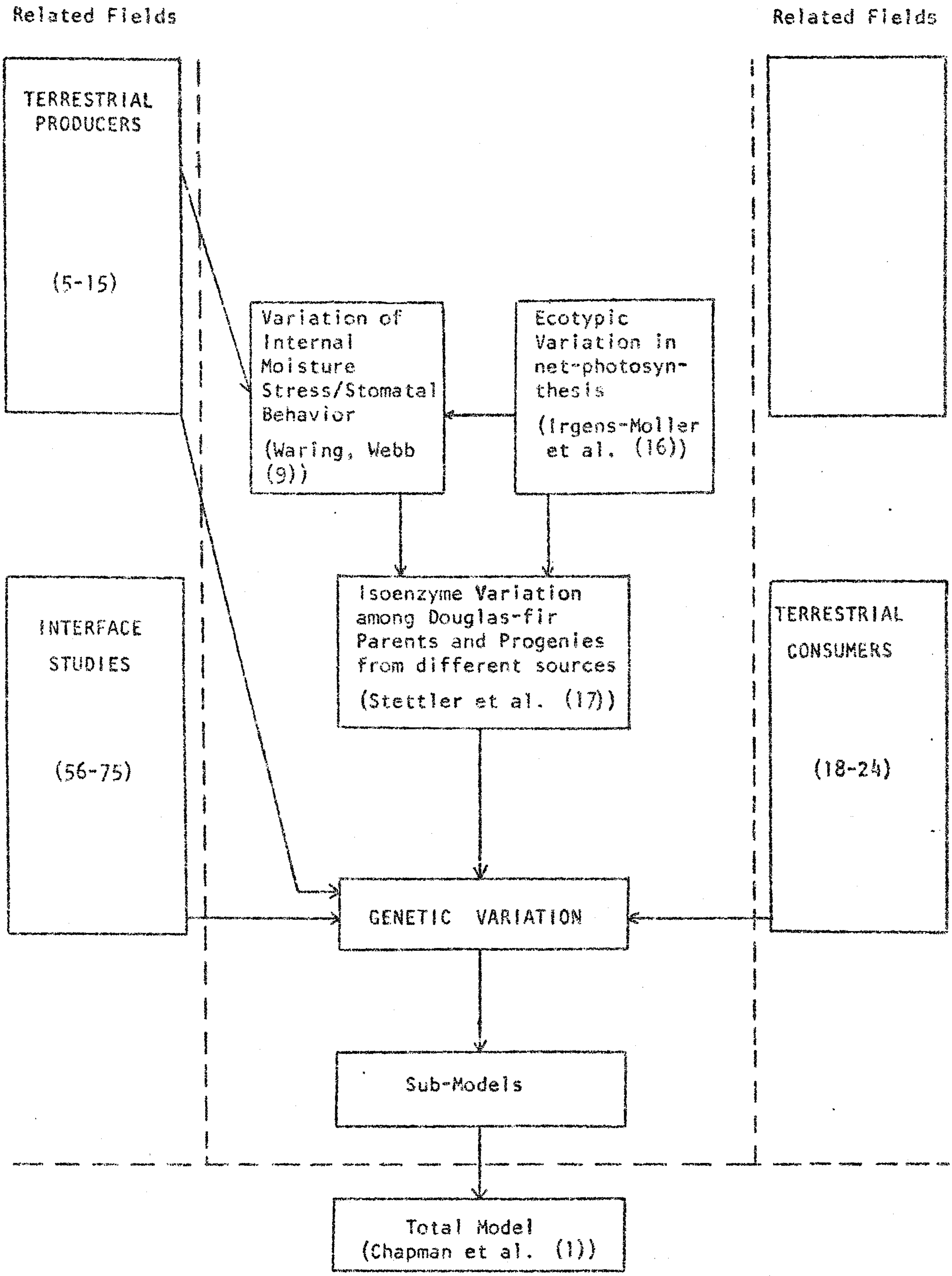
(1) Coordinate policies and methodology of genetic studies concerning terrestrial productivity within this Biome and between Biomes.

(2) Develop an inventory of genetic material (outplantings etc.) available for Biome-oriented studies.

(3) Conduct research on the genetic variability of one of the key terrestrial producers, Douglas-fir.

Work proposed for year 2. Plans for year 2 call for a major effort of organizing and coordinating a genetic research program to be compatible with Biome objectives (see Fig. 7.4). In addition, two research projects will be conducted, aiming at assessing genetic variation in Douglas-fir.

Figure 7.4 Diagram of Relationships between Proposed Studies: Genetics. (Numbers refer to Proposals in Appendix - Section 8.2.



Past genetics research on forest trees in the Coniferous Biome region has resulted in collections of plant material (e.g., plantations of different seed sources, progeny tests, clone banks of outstanding phenotypes, etc.) that may be quite useful for certain early studies in the Biome effort but will be particularly valuable for the manipulation phase of the Biome program. More such material will become available, especially if genetics researchers of the region are alerted to particular needs. To this end, a workshop will be held aimed at coordinating current forest genetics research with Biome objectives. At the same time, an effort will be made to generate a data bank of available genetic material in this Biome. Participants will include a spectrum of forest geneticists from universities, public and private land owners, one or two geneticists from other Biomes, and one or two specialists familiar with the operation of genetic resources data banks currently in use in agricultural research.

The two research projects proposed for year 2 are both concerned with genetic variation in Douglas-fir, each however, in a different way. The first, Ecotypic Variation in Net Photosynthesis of Douglas-Fir under Field Conditions . . . (Irgens-Moller), is an attempt to assess genetic variation in one of the key processes affecting productivity photosynthesis. It takes advantage of an available collection of about 600 different ecotypes from throughout the natural range of Douglas-fir, outplanted conveniently near one of the intensive study sites. Variation in net photosynthesis, internal moisture stress, and stomatal behavior (in cooperation with Waring) will be measured both within and between trees from sharply contrasting ecotypes, thus allowing an estimate of the degree of genetic control over these processes. In this work, much hinges on the resolution and reliability of cuvettes used for the measurement of assimilation. A special effort will be made to calibrate a locally constructed, comparatively cheap model with the Siemens cuvette which will be used by Walker and Scott at the Thompson Research Site. Altogether, this study will examine measurement technique in relation to genetic variability, thus providing important information on the methodology of other process studies.

The second project, Isoenzyme Variation among Douglas-Fir Parents and Progenies from Different Sources (Stettler, Wilson), is an attempt to look at population variation in a generalized way, taking enzyme polymorphisms as parameters for study. Enzyme "fingerprints," comparatively independent of environmental variables, have become an expedient tool for defining genetic hierarchies in animals and plants, and more recently in forest tree species. Enzyme variation will be studied in several parent-progeny sets derived (a) from selected ecotypes of the collection described in the previous project, (b) from two adjacent stands on the Thompson Research Site, and (c) possibly from trees under study by Helms near Berkeley, California. As much as possible, the selection of parent trees will be integrated with the tree physiological studies planned for the same stands or ecotypes so that inferences can be drawn as to the usefulness of enzyme variation in relation to other tree parameters. Information from this project may shed light on the genetic homogeneity or heterogeneity of stands and will thus help interpret variations measured by other studies of terrestrial productivity. It will also help in developing suitable forest stratification and sampling designs for future productivity studies and in predicting the range of productivity variation in the next generation of stands.

7.3.4. Terrestrial consumers

In the Coniferous Forest Biome terrestrial consumers include both vertebrates and invertebrates, and in each of these broad groups there are both primary consumers (herbivores) and secondary consumers--the consumers of primary consumers.

The animal component of the forest is important in ecological processes, exerting a strong influence, for example, on plant reproduction and the survival of young plants. In general, in a stable, mature, coniferous ecosystem the terrestrial consumers are of less importance in energy cycling than in many other kinds of natural ecosystems (e.g., grassland). But they can have drastic effects on these systems by focusing on key processes (e.g., reproduction of trees) or by occurring in epizootic numbers. Efforts to control these animal populations can lead to further disruptions of natural ecosystem function. It seems obvious that the Biome approach offers the most logical way of investigating the mechanisms of animal population dynamics, constructing predictive models, feeding back corrective data, and ultimately achieving predictability for population phenomena.

<u>Progress in year 1.</u> The main objective of year 1 studies was to define and coordinate ongoing and proposed studies of terrestrial consumers. Review of literature on the role of mammals in the coniferous forest ecosystem by Black and Voth has resulted in an outline for vertebrate studies. The combined expertise of scientists under the leadership of Taber has been focused on the formulation of a coordinated research strategy and definition of research priorities for the following years. The preliminary studies by Nagel on cone and seed insect influence on Douglas-fir stands has indicated some trends with age of trees.

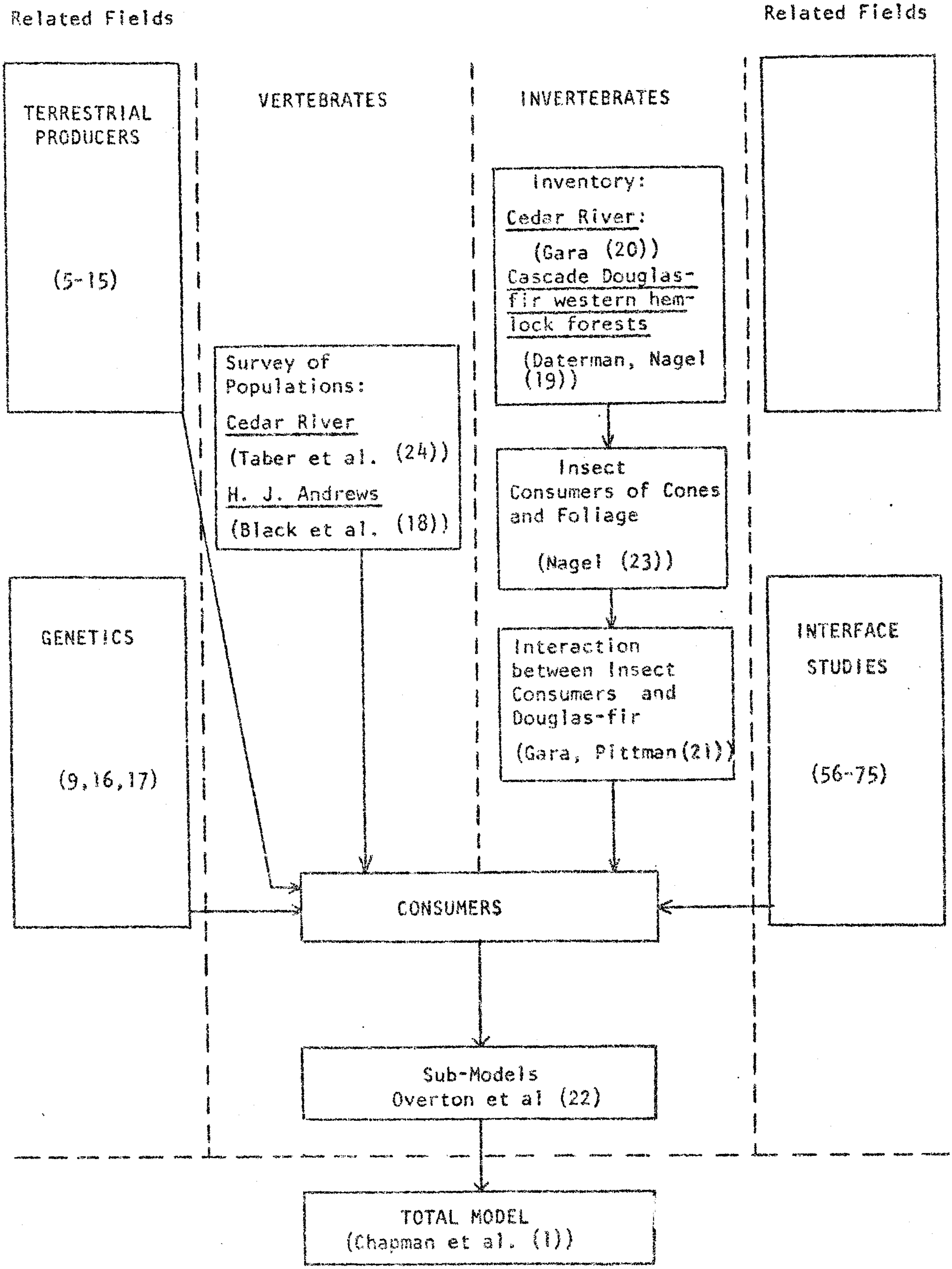
<u>Plans for year 2.</u> <u>Objectives.</u> Animals directly consume significant amounts of plant production, especially of certain sorts such as seeds, seedlings, terminal shoots of certain species and age-classes, subcortical tissue, and foliage. In addition, animal activites exert control functions on plant populations by influencing numbers, vigor, growth-form, productivity, competitive relationships, etc. Animals influence animals as well, through predation, competition, parasitism, exclusion, and the like.

This control function is of considerable interest to the modeling and terrestrial consumer scientists in the Biome. Aspects of energy (biomass) and nutrient contents and transfers by ingestion, metabolism, egestion, and animal movements is of much less importance, especially when compared with the magnitude of transfer by terrestrial producers, but it is a necessary item for ecosystem modeling and a basis for control function studies.

These considerations have led to the following objectives for year 2 (see Fig. 7.5):

1. Inventory of the intensive sites to provide data on animal species composition, abundance, and seasonal and yearly variations, especially for the intensively studied portions of the intensive sites. The level of resolution will be set by the needs for modeling and the degrees of detail needed by other studies on the study sites.

Figure 7.5 Diagram of Relationships between Proposed Studies: Terrestrial Consumers. (Numbers refer to Proposals in Appendix - Section 8.2)



2. Modeling of accumulated information on terrestrial consumer biomass, nutrient transfer, and control function. Research and modeling personnel will investigate existing population dynamics models and select one for adaptation to the coniferous forest system. Selection of this model will define the nature of the field data required to test the model.

3. Expansion of invertebrate biomass, nutrient transfer, and control process studies initiated during year 1.

4. Exploration and definition of application studies (consumers as forest products, model validation, natural and artificial manipulation) for the following years.

Inventory. The inventory of terrestrial consumers will be carried out with the general objective of determining densities and consumption for the principal or key terrestrial consumers which occur on selected portions of the intensive sites. It is not intended to attempt a complete catalog of every animal species, but to identify the major species of animals and the habitats they occupy, to obtain estimates of their density, and to determine the kinds of foods and approximate amounts consumed.

The bodies of animals are rich in scarce nutrients. Living, they form a nutrient sink, and dead they provide a nutrient resource which may transfer up the food chain to predatory forms, or may be decomposed and return again to soil or water.

The movements of animals are often extensive. For example, bird species move through or nest in the coniferous forest in the spring, pass through the forest in large premigration assemblages in the fall, and winter in lower or more southerly regions. Whether this means a significant introduction or a significant escape of materials from the ecosystem is as yet unknown. Also, there are substantial but as yet unquantified movements of nutrition from terrestrial to aquatic systems such as by beaver transport and accumulation of ungulate carcasses in streams and from aquatic to terrestrial such as by fish consumption and movement of water-breeding amphibians.

Studies of nutrient transfer processes by ingestion, metabolism, egestion, and animal movements will be coordinated with the nutrient cycling work in the Interface group. Studies of the effects of consumption on primary producers will be coordinated with the work of the Terrestrial Producers group.

Vertebrate species which can be readily captured (such as aquatic amphibians and many mammals) will be studied by capture-mark-recapture methods. Species which are readily observed (such as most birds and some mammals), can be studied through systematic direct measurements. These studies will be geared to the unit watershed level of resolution at the Andrews intensive site (Black et al.) and to the habitat level of resolution at the Cedar River intensive site (Taber et al.).

Abundant invertebrate animals (such as insects) will be inventoried through systematic trapping and exclusion techniques. In addition, there is a substantial number of important animals (mollusks, soil invertebrates, terrestrial amphibians) for which the best inventory data can be obtained through destructive sampling of small plots. This sort of sampling will provide a cross-check on other methods for aquatic amphibians, small mammals, and some insects (Paulsen). To provide maximum utility, destructive sampling also will be coordinated with the needs of such other research groups as the Decomposers.

Inventory studies of invertebrates will be closely coordinated with the ongoing and proposed invertebrate process studies. Sampling and collecting on the Andrews intensive site will be conducted in two or three forest stand types based on age and composition (Daterman and Nagel). Similar work on the Cedar River intensive site will be focused on forest habitats of variable vigor (Gara).

Modeling. Modelers will collaborate with the scientists studying consumers to ensure biological realism of modeled mechanisms and to help define the nature of the data needed to test and use the models (Milne and Strand). Having defined these data, researchers, modelers, and appropriate consultants will devise sampling strategies which will ensure data collection consistent with accuracy requirements and budget limitations. Researchers will then assemble from literature and field investigations in the Andrews, Cedar River, and other sites those data needed to test the above models.

Coincident with the acquisition of these data will be an effort by the modelers to generalize the model, so that it may be used with parameter changes to simulate the population dynamics of any single herbivorous vertebrate species occurring in western coniferous forests. If feasible, the modeled mechanisms will be extended to permit simulation of omnivorous predaceous vertebrate species as well. Provisions will be made for the future possibility of linking this model with others to permit simulation of multispecies complexes.

It is hoped that, by inclusion of appropriate information in the above model structures, any one or all will contain the elements needed to predict events which disrupt and/or control ecosystem processes, as well as those events more commonly observed. In order to increase the likelihood of obtaining such a model both modelers and researchers will meet regularly in an attempt to identify combinations of factors permitting disruptive and controlling events (Taber). Modeling of "information flow" will be of considerable interest (Overton et al.).

Four modelers will be involved in all phases of the research: Milne, Strand, Overton, and one to be hired. Milne and Strand will be primarily concerned with invertebrate populations and the modeler to be hired will work with vertebrate populations. Overton will act as a general consultant and will coordinate the activities of this project with those in the central Modeling Committee.

Processes. Two research projects will elucidate basic host-insect interactions at the two intensive sites. One endeavor will assess foliar consumption by insects and more extreme interactions involving seed and cone predation (Nagel). The second line of research will focus on control functions exercised with scolytids which represent important mortality factors of the principal host species (Gara and Pitman).

These research subjects will provide basic information needed to understand population dynamics of host species as well as the principal invertebrate consumers. By and large, analysis of cause and effect relationships developed by these projects will provide conceptual foundations for the modeling of consumer-host interactions. Results from the studies will be used to develop qualitative models which, in turn, will be the framework for quantitative working models.

Estimates will be made of the biomass of materials consumed with and without herbivore exclusion; within-tree comparisons will be made by studying exclusion techniques on paired branches. Between-tree variations will be sampled wherever tree exclusions are possible. Systematic sampling schemes are proposed to assess factors influencing cone and seed survival and consumption.

During cone and seed sampling, damage will be estimated by suspected mortality factors as related to the insect species and its life cycle. Important age intervals of seed survival will be determined by stepwise linear regression analysis.

Scolytid-host selections first will be studied on a qualitative basis by host and tissue analysis, to determine consumption in accordance to age class, phenology, and host condition. Trees undergoing scolytid attack will be plotted and their physiological condition will be determined by oleoresin pressure analysis and through the pressure-bomb technique. Weakened trees will be surveyed first and the succession of associated scolytids will be correlated with products of decomposition and host nutrients. Confirmatory tests also will be undertaken and scolytid activity will be traced by trapping and olfactometric techniques.

Finally, the influence of host-derived and tertiary mixtures of pheromones will be related to the host selection behavior of the Douglas-fir beetle and its associated insects--other consumers, parents, and predators.

7.3.5. Decomposers

The major objectives include (1) providing estimates of the rates and amounts of material converted by the decomposers and (2) indication of the organisms responsible. The first objective will provide data for ecosystem modeling. For the initial model, it may be necessary to measure whatever aspects are most feasible and to assume simple relationships between O_2 uptake , CO_2 production, substrate disappearance, and nutrient release. Major emphasis will be placed on C and N fluxes. For the second objective, it is necessary to complete inventories of major decomposer populations on the intensive sites. These will not be exhaustive, but will focus on those populations involved in the decomposition of specific elements of the litter and in situ loss from standing trees. Disease processes are considered as the decomposition of living material. In many instances, e.g., bacterial populations, cluster taxonomy by function is considered adequate. Where possible, annotated checklists will be prepared, including references to descriptions and voucher specimens, functional and growth attributes, and methods of collection, isolation, and maintenance culture.

This committee also will study nonvascular plants (procedures) and microscopic fauna (consumers) because of familiarity with techniques and organisms.

The research programs of the terrestrial and aquatic aspects are highly parallel, as can be seen in Figures 7.6 and 7.7. In many cases, taxonomic expertise will be provided in both environments by the same investigator, e.g., Dr. Whisler on unicellular fungi. All terrestrial studies will be conducted on both intensive sites, although to varying degrees. Wherever possible, large standard samples will be collected, divided, and distributed to the various investigators. All aquatic studies will be done on the series of lakes (Findley, Morse, Sammamish, and Washington) and preliminary studies will be done on the Cedar River. The temporary streams in the Andrews Forest will be considered as extensions of the forest floor and will be studied by the terrestrial group.

7.3.5.1. Aquatic

Progress in year 1. The only funded project was limited to coordination of researchers (Taub). A two-day coordination meeting was held in November 1970 for all investigators interested in cooperating in the Biome Decomposer studies. The geologic and vegetational aspects of the intensive sites were described and the Biome objectives were delineated. Progress in other Biomes was reported on by representatives of the Tundra, Deciduous, and Desert Biomes.

The Decomposer Steering Committee (Taub, Chairman; Driver, Lighthart, Denison, Gilmour) has met several times. A second coordination meeting on units of measurement was held on 23-24 April 1971. Units and data recording of mass, flux, species density, community structure, and indexes of activity were considered. Representatives from the Modeling group advised on unit systems most amenable to the sub- and total models. A third coordination meeting will probably consider techniques on nitrogen fixation and mass functional taxonomy.

Plans for year 2. The aquatic program (see Fig. 7.6) will strive to survey and compare the four lakes in the Cedar River study area (Findley, Chester, Morse, Sammamish, and Washington). During year 2, sampling for several of the studies may be limited to showing low-resolution seasonal patterns in each of the four lakes. These will also serve to show the feasibility of several new techniques.

The flux and pool sizes of carbon will be determined from a compartment analysis of (1) dissolved inorganic carbon, (2) phytoplankton, (3) zooplankton, (4) dissolved organic carbon, (5) detritus, and (6) heterotrophic bacteria using a C^{14} method developed by Saunders (Lighthart). This technique requires the measurement of primary productivity as the initial step in measuring exchanges between compartments. Results will be compared by the aquatic committees, with more frequent estimates of primary productivity (Welch), and with chemical and physical properties (Christman). The dominant organisms will be identified or functionally characterized by Lighthart and Matches. The oxidation of organic matter will be estimated by means of O_2 uptake in the water column by an enzyme activity method (Packard), and in the sediment by direct O_2 measurements (Pamatmat). Degradation of specific organic compounds in sediments, especially by anaerobic bacteria, will be studied by Matches. Nitrogen fixation by bluegreen algae and by anaerobic bacteria will be measured and indications of other nitrogen transformations will be made (Taub). Fungal

Figure 7.6 Diagram of Relationship between Proposed Studies: Aquatic Decomposers. (Numbers refer to Proposals in Appendix - Section 8.2)

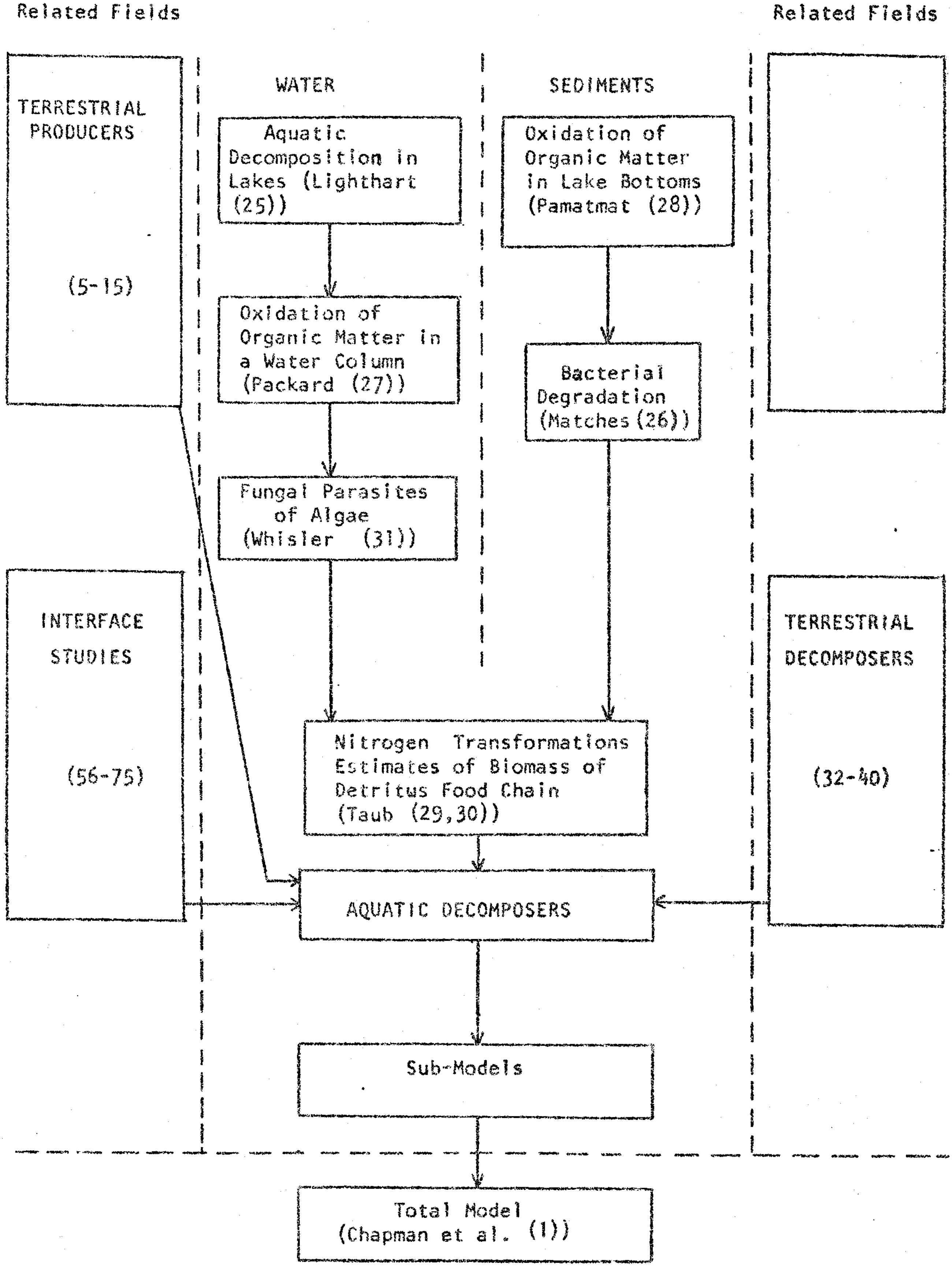
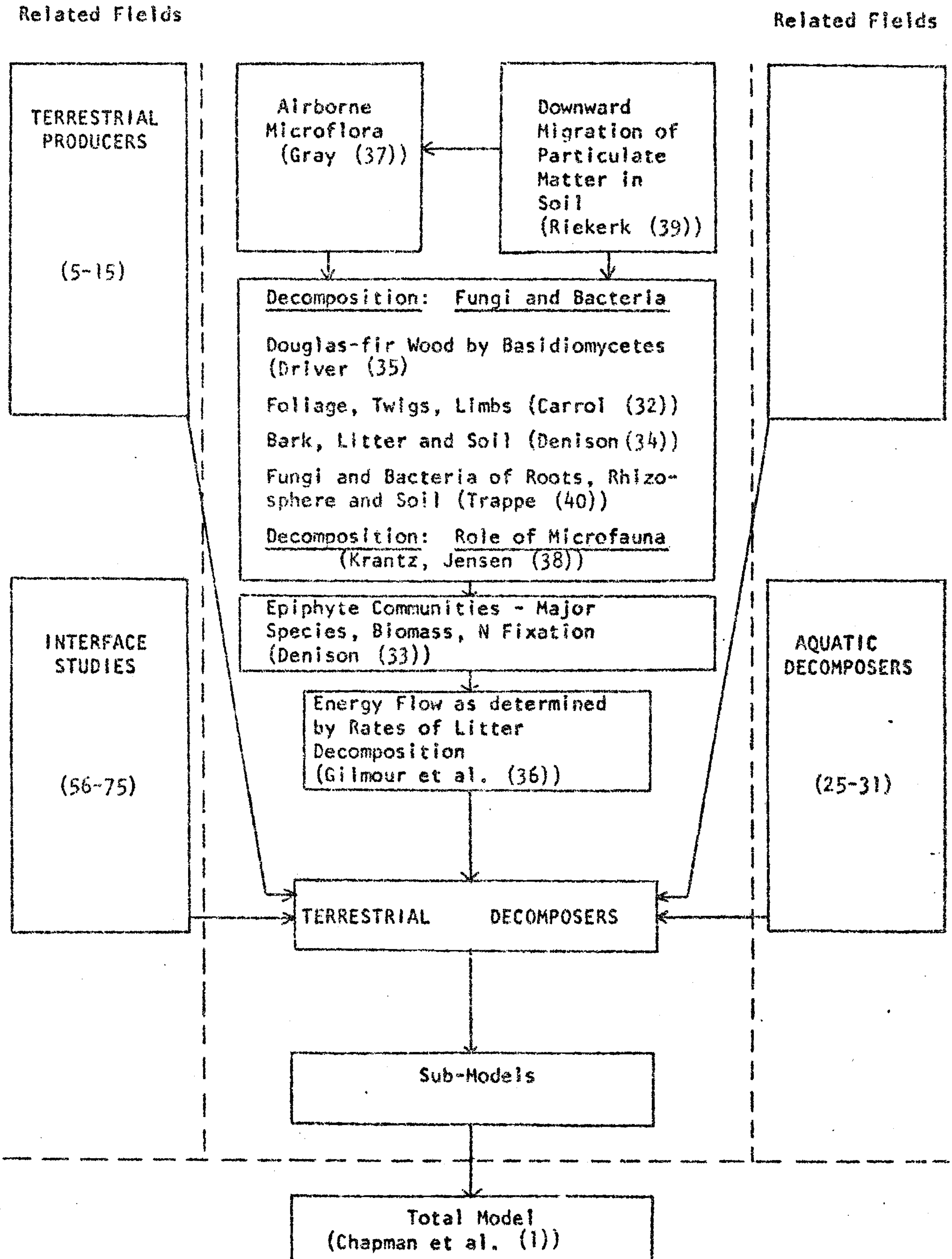


Figure 7.7 Diagram of Relationships between Proposed Studies: Terrestrial Decomposers. (Numbers refer to Proposals in Appendix - Section 8.2)



parasites will be evaluated as potential regulators of algal blooms (Whisler). The role of detrital biomass as food for higher trophic levels, e.g., aquatic invertebrates and fish, will also be evaluated in conjunction with the aquatic producer studies.

Close coordination with the Interface nutrient cycling group (Fredriksen et al.) and ecosystem modelers (Chapman) will be necessary. For example, information on the release of dissolved nutrients will be used in a model to relate the observed concentrations of nutrients, the primary productivity, and the estimated nutrient uptake as a function of that productivity. The comparison of the respiration measurements with the productivity measurements should provide a P/R ratio as an indication of whether in situ production is greater than use, and biomass is therefore accumulating, or if external sources of production (e.g., from leaf fall) contribute a major source of biomass. Information on fish carcasses etc. will be needed to estimate large masses of detrital material, while the caloric or oxidizable carbon value of sediments and benthic invertebrates (Taub), together with information of fish stomach contents (Burgner), should yield information in detrital food chains (Taub).

Proposed Studies. Aquatic: Includes the Lakes Findley, Morse, Sammamish, and Washington. Preliminary studies will be made on Cedar River samples, temporary streams will be studied by the terrestrial decomposition group.

7.3.5.2. Terrestrial

Progress in year 1. Studies of epiphytes on felled trees have given disappointing results. Better results were obtained on standing trees. Transects were established on two old-growth Douglas-firs and all major species were identified. Two papers have been written as a result. A preliminary sampling of common species of epiphytic lichens has established that several of them fix atmospheric nitrogen at high rates (Denison).

Abundant species of fungi of living twigs and foliage have been identified for three tree species. Some fungi are undescribed species. Most species are in pure culture. Techniques are being developed to measure extent of individual mycelia and extrapolate data to biomass, and for measuring rates of degradation of specific substrates. Collections of fleshy soil fungi have been made. Most have been identified, and a culture collection is being developed. Methods are being developed to determine rates of decomposition of foliage of Douglas-fir and hemlock needles. Identification of fungi decomposing needles is being approached three ways: (1) direct examination, (2) culture after washing, and (3) culture after surface sterilization. An accumulation for a pollen herbarium has been started (Gray) and 30 to 40 percent of approximately 6000 species occurring in the Andrews Forest area have been included. A piston core sampler for extracting samples from bogs has been purchased.

Consistent isolation of three fungi from Douglas-fir needles indicates probable involvement in decomposition (Driver). They have not yet been identified. Tests are now being initiated to identify the major process of decomposition that each fungus is capable of accomplishing. Decomposition rates and environmental factors affecting them will be determined.

Plans for year 2. The decomposition of organic material and the accompanying nutrient releases will be studied on living plants by the following scientists (see Fig. 7.7): wood, Driver and Denison; foliage, Carrol; roots, Trappe et al. Studies on nonliving materials will be made as follows: litter, Gilmour (chemical aspects), Denison (organisms), Trappe (organisms); standing wood, Driver; roots, Trappe.

The confirmation that the estimated amounts of nutrients have been released will be made by the determination of the downward flux of dissolved and particulate materials through the soil (Riekerk). The invertebrate fauna will also be evaluated as a possible mechanism of exchange between litter and soil (Jensen and Krantz). The airborne contribution of plant spores to the litter will be made by Gray. The downward migration in soil of these particles will also be studied by simulation with fluorescent particles in lysimeter studies. Nitrogen transformation will be studied in the epiphytes (Denison), litter (Gilmour), and soil (Trappe). The oxidation of organic matter will be estimated by respiration on wood (Driver) and on litter (Gilmour). The primary productivity and biomass production of epiphytes will be studied by Denison. Denison will also estimate all functions needed to complete the litter decomposition model he is developing with Moir. The role of invertebrates as decomposers will be evaluated by Jensen and Krantz. The contribution of fungi to mouse food chains will be evaluated by Trappe et al.

Several traditional kinds of microbiological studies have been purposely omitted or deemphasized for year 2. These include efforts to measure microbial biomass or to distinguish between living and dead cells either by vital staining or by comparison of direct counts with dilution plate counts. It appeared unlikely that these attributes would be sufficiently useful for a functional nutrient model to justify the efforts involved. It is necessary, however, to evaluate whether methods of enumeration do adequately sample active components of the microflora; studies of this were initiated by Gray and Denison in year 1 and will continue into year 2.

It has been hypothesized that the rate of nutrient release by the decomposers is a major controlling factor of the rate of primary productivity, especially in mature communities. This could account for the low productivity/biomass ratios which are thought to be characteristic of highly complex, mature communities.

Also, the maintenance of forest ecosystems is possible only when little nutrient loss occurs from the system. It has been hypothesized that this is accomplished because the nutrient release by the decomposers is extremely closely coupled to uptake by the producers and thereby prevents loss.

Currently, decomposition processes and rates are among the more poorly understood phenomena in ecosystems and are rarely studied. Rates, if estimated, are usually done by assuming steady-state systems and attributing all unaccountable processes to the microbes (which remain unstudied). This program provides an opportunity to explore and test above hypotheses.

7.3.6. Aquatic

As indicated in the year-1 proposal, a principal goal of the Biome studies is to gain an understanding of the interactions between terrestrial and aquatic systems in a coniferous biome setting. Because streams and lakes in the vast expanse of forests in the Western Coniferous Forest Biome are of particular importance to the economy of the western United States, the effects on the aquatic systems of environmental changes on the surrounding land must be understood. Streams with their seasonal fluctuaions are more immediately responsive to environmental pressures originating on land. Lakes, which are slower in response, are more indicative of long-range effects of land usage upon aquatic systems. At the same time production in streams and lakes substantially contributes to the energy budget of the Biome. Thus the part played by aquatic systems in the productivity, movements, conservation, and distribution of energy is a basic requisite to an understanding of the Biome.

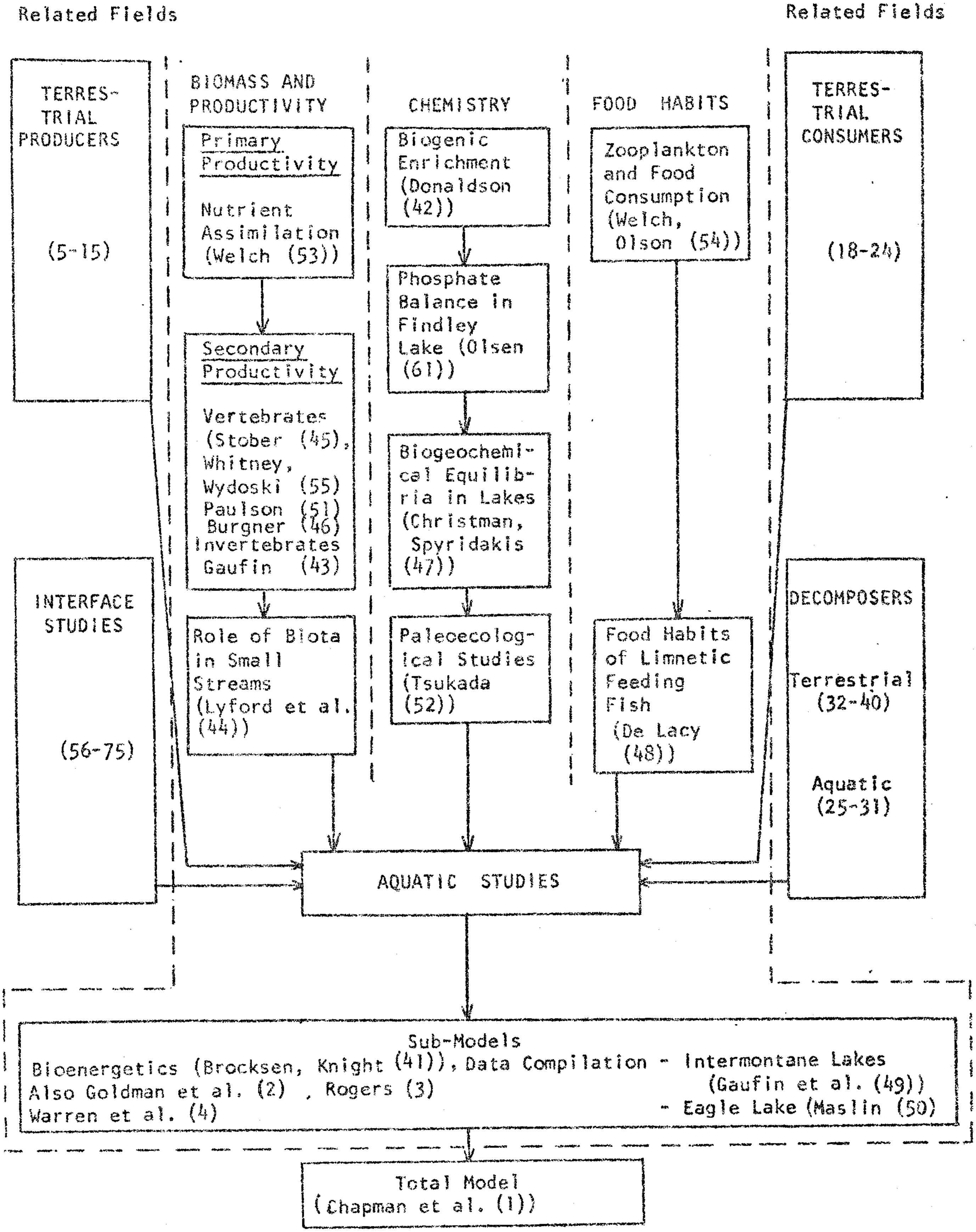
Currently the aquatic studies are primarily planning and developmental studies on some ecosystem components at the intensive sites to coordinate approaches and to develop inventories, sampling schemes, or techniques for year-2 research. The development of modeling concepts prior to entering a full-scale program has high priority. For this we are dependent upon series of data already collected on intensively studied systems, such as the Alsea Basin streams in Oregon, Fern Lake, the Wood River Lakes in Alaska, and Castle Lake in California, as well as the laboratory stream studies at Corvallis. Year-1 studies are also dependent heavily upon other non-IBP sources of funding, particularly for Lake Washington and Lake Sammamish in the Lake Washington–Cedar River drainage.

The immediate objectives for the aquatic studies (see Fig. 7.8) are to determine the relative importance of various energy and nutrient sources for primary and secondary production, especially of fish, in the aquatic systems as related to terrestrial conditions and forest types at the intensive sites. The selected aquatic systems are small unit watershed streams, a larger stream, and a series of lakes providing a graded sequence in environment and productivity. Internal as well as external sources for secondary production are being evaluated. External energy and nutrient sources include transfer from the terrestrial systems, which necessitates the link to the terrestrial program through unit watershed studies.

7.3.6.1. Stream systems

Progress in year 1. In this aspect of the program the ecology of streams was to be examined: natural streams and watershed management (Lyford, Anderson, Hall), larger natural streams (Stober), and laboratory streams (McIntire). To date, Lyford, Anderson, and Hall have been planning experimental designs and designs of sampling equipment. Stream morphometry and characteristics have been studied in order to select adequate experimental sites. Experimental work will progress rapidly as spring approaches. Selection of sampling techniques and construction of stream benthic and drift sampling devices have been carried out by Stober. Three cluster analysis programs have been adapted to the CDC (Control Data Corp.) system for modeling purposes (McIntire).

Figure 7.8 Diagram of Relationships Between Proposed Studies: Aquatic Studies. (Numbers refer to Proposals in Appendix- Section 8.2)



Plans for year 2. As indicated, the primary aquatic interface with the terrestrial component occurs in the watershed streams. At the H. J. Andrews site studies by Lyford, Anderson, and Hall in small streams of the unit watersheds will be intensified. Determination of relative influence of the allochthonous and autochthonous materials on stream productivity will receive emphasis. Aquatic plant community structure will be determined, rate of primary production will be measured by use of a specially designed respirometer, insect production will be measured, and studies will be conducted on the role of insects in energy transfer between trophic levels. The last will include some laboratory studies. In the first phase of the fish population studies the relationship between the density of cutthroat trout populations and the availability of their food source will be studied. Laboratory stream studies will be conducted by Brocksen and Knight at Davis, largely with other funding, to determine how a community of organisms typical of a coniferous forest is influenced by temperature and substrate. Energy maintenance requirements, as well as net and gross growth efficiencies, will be determined for each species tested to develop energy budgets and production equations, and to extend the models previously developed at Corvallis.

Stober's group will expand studies on the Cedar River, a much larger stream which flows through the Chester Morse Reservoir and terminates in Lake Washington.

Emphasis in the study is on the change in water chemistry, primary productivity, and aquatic insect production along its course from undisturbed conifer habitat to metropolitan area, and on the influence of the large population of sockeye salmon which spawn and die in its lower course. In year 2 Gaufin will coordinate with Stober in conducting field and process studies on the aquatic insects from the Cedar River sites. Growth rates for various size classes of selected insects will be determined in the laboratory and metabolic rates will be studied under different levels of temperature, oxygen, and current velocity. This information will be useful in predicting effects of changes in temperature and flow resulting from watershed manipulation. Donaldson will begin a study of the biogenic enrichment of aquatic areas resulting from the decomposition of salmon carcasses. The experiments will be conducted at Berry Creek by use of radioisotopes introduced before death of the salmon. Subsequent sampling of water, soils, and indigenous plants and animals will be used to identify and quantify the movements of the tagged elements. The importance of nutrient contributions from salmon carcasses will be evaluated later for the Cedar River and Lake Washington.

7.3.6.2. Lake systems

Progress in year 1. In this program Christman and Welch were to develop and evaluate analytical methods and procedures for measuring exchange rates of minerals between lake sediments and water. Two other year-1 proposals were concerned with development or testing of methods to obtain seasonal biomass estimates and life history information for consumer fish species in the three main lakes of the watershed: Lake Sammamish and Chester Morse Lake, limnetic feeding fish (Burgner and Mathison; a similar study in Lake Washington is already under way); and Lake Washington, benthic and littoral fishes (Whitney and Wydoski). Wydoski and Whitney were also to complete a literature review.

Following a detailed mapping of the Lake Sammamish basin (Christman), monthly monitoring of the chemical quality of the lake water as affected by sampling station and inflow and outflow was undertaken. In November, Findley Lake was included. A simulation system for nutrient regeneration is currently employed to study mechanisms and factors controlling phosphorus release from Lake Sammamish sediments.

Welch has defined the principal components of environmental factors affecting primary productivity in Lake Sammamish. The changes in nutrient concentration and plankton between Lakes Sammamish and Washington were compared following diversion of sewage. More than half the phosphorus income was diverted in both lakes, resulting in a greater reduction in Lake Washington than in Lake Sammamish. There was also a reduction in maximum chlorophyll and an increase in water transparency. The related studies of nutrient levels and primary and secondary productivity in Lake Washington were continued by Dr. Edmonson's group under other funding.

Burgner and Mathison have initiated field tests on Lake Washington. Three complete transect runs have been made to determine species composition and to obtain fish samples for size and age composition. Instrumentation of echo-sounder equipment and preliminary work prior to and in year 1 have established the feasibility of the combined use of echo sounders and net sampling to provide adequate resolution for population measurement of limnetic feeding fishes at frequent intervals and at relatively low cost and effort. Formulation of modeling schemes have been discussed. Mathisen spent fall quarter in the U.S.S.R. to obtain data and models currently developed for sockeye salmon lakes.

Whitney and Wydoski have formulated their basic goal and the plans to meet that goal. The goal was to develop a systematic sampling scheme to estimate the abundance of benthic and littoral fishes in Lake Washington. Upon their completion, the sample gear units were tested and the design was found to be sound. Regular sampling of all strata with all nine nets was begun on 1 January 1971. More than 200 fish have been sampled, yielding information on sample depth, species, sex, maturity, and size.

Plans for year 2. Primary emphasis in the four lakes of the Lake Washington—Cedar River watershed will be on a comparative study of trophic dynamics to determine the effect of distinctly contrasting enrichment in lakes of a common watershed relative to the terrestrial characteristics, hydrology, and nutrient sources. Tsukada will extend his present core sampling studies to Findley Lake to provide paleoecological information and tie in with decomposer studies as well as the lake bottom sampling of Christman and Spyridakis. Their concurrent study of the analytical chemistry of the waters is required to understand the mechanisms that maintain productivity. Their biogeochemical studies will (1) measure the nutrient levels in the lake water proper as a function of lake water nutrient inflow and outflow, (2) characterize the physical, mineralogical, and chemical constituents of lake sediments pertaining to nutrient regeneration in sediment-water interface, and (3) measure biological and chemical transformation of nitrogen. Studies of geochemical equilibria conducted during year 1 in Lake Sammamish will be extended to the other lakes in year 2.

Annual and seasonal primary productivity will be measured by Welch to determine if primary productivity is related to the ambient concentration or the total availability of limiting nutrients, determined by enrichment bioassays. Photosynthetic rates of phytoplankton will be measured in the photic zones by C^{14} method. Phytoplankton species composition and cell size will be studied to further elucidate effects of degree of eutrophy. Zooplankton standing crop and consumption rates of phytoplankton by size group will also be related to degree of eutrophy (Welch and Olson). At Findley Lake, with emphasis on interface studies, Paulson will study the production and dispersion of invertebrates (insects, amphibians) originating in the lake. Dr. Edmondson's group will continue limnological studies of Lake Washington under other non-IBP funding; this research is an essential component of the comparative lake study.

During year 2 the measurements of seasonal abundance and biomass of planktivore fish by species and age groups in Lake Washington, Lake Sammamish, and Chester Morse Lake will be intensified and process studies will be extended to determine seasonal food habits and growth rates (Burgner and Thorne, DeLacy). The four lakes vary from a high population density of planktivore fish (Lake Washington) to no planktivore fish (Findley Lake). The technique of combined use of echo sounders and net hauls will be used to obtain seasonal estimates of fish population, biomass, and growth rate in the larger lakes. Food consumption of planktivore fishes will be related to zooplankton availability. Measurements of seasonal abundance, growth, mortality, and biomass of planktivore fishes by species and age will be intensified in the three larger lakes.

The role of benthic and littoral fishes in the lake trophic dynamics is more difficult to determine. Year 2 effort by Whitney and Wydoski will be directed toward continuing inventories with emphasis on the development of systematic sampling schemes to determine distribution, relative abundance, and biomass of the important species. The effort is directed toward establishing the relative energy requirements and interrelationships of benthic and limnetic species. Process studies on feeding, growth, and reproduction will be initiated where possible.

Assembling of hydrological information will be coordinated with the Interface Committee in order to initiate a hydrologic model of the lakes. The lake and stream sampling studies will also be coordinated with the aquatic decomposer studies in order to coordinate sampling efforts. Modeling of aquatic information accumulated by long-standing studies on Castle Lake, California, will assist the ongoing development of lake system models (Myrup et al.)

7.3.7. Interface

The research work organized under the Interface Committee is closely related to several of the long-range objectives of the Coniferous Biome study. In the first Biome proposal it was established that the Coniferous Biome had an excellent opportunity to study the interrelationships between the terrestrial and aquatic components of the ecosystem, and this area of research will be a major thrust of our program.

In order to facilitate the planning and coordination of research the group was divided into three subcommittees: (1) nutrient cycling, (2) hydrology, and (3) meteorology. The nutrient cycling subcommittee is concerned with fluxes of the chemical elements within the system that relate to ecosystem productivity. Their work should provide a major insight into those mechanisms which maintain productivity in the ecosystem, one of the focal points for this year's research. The hydrology subcommittee is primarily concerned with movement through the system of water, which serves as a carrier for nutrients and itself is an essential element in life processes. The meteorology subcommittee is primarily concerned with fluxes of energy, water vapor, and carbon dioxide, the primary driving forces in the forest ecosystem. The work of the three groups is closely interdependent and also intimately related to many other programs in the Biome.

Because of prior research results that are available to build on, considerable emphasis in year 2 will be placed on developing models for flow of nutrients, water, and energy in small watersheds and plots. This modeling effort will involve all segments of the Interface Committee research program. Details of these modeling efforts are described under the respective subcommittees.

7.3.7.1. Nutrient cycling

An adequate level of nutrients is essential for production in terrestrial and aquatic ecosystems. To understand how levels of nutrition influence rate of production requires a knowledge of their supply and rate of transfer to growing tissue. The ultimate source of nutrients to terrestrial systems is from mineral weathering, fixation from the atmosphere, and fallout from the larger geochemical cycle of the earth. But the aquatic systems are situated so that their supply of nutrients arises largely as a result of losses from the terrestrial system. Nutrients may enter aquatic systems in ionic form, as a component of organic matter, or as suspended mineral particles.

The utilization of forests for timber and forage causes a major disruption to the forest ecosystem. A substantial loss of the available supply of nutrients may result from timber harvest operations. Erosion from logging roads frequently contributes large amounts of soil to streams and lakes. In future years, the Biome will study the effect of manipulation on the stability and sustained productivity of coniferous forest ecosystems.

In order to understand how to manage a resource on a scientific basis we must have knowledge of how an ecological system operates. To aid in planning and directing nutrient cycling research, the related long-term Biome objectives are listed below:

1. Determine the components and processes of a nutrient model that control productivity and distribution of organisms in coniferous forest ecosystems with reference to: (a) an analysis of nutrient capital in components of the general model; (b) determination of the rate of transfer of nutrients between components and how these transfer rates are important to productivity of the ecosystem; and (c) determination of the mechanisms of input and loss from the system and how the supply relates to long-term productivity of the ecosystem.

2. Examine the linkage between terrestrial and aquatic components to include: (a) transport of chemicals dissolved in water; (b) transport of chemicals as soil or organic material; (c) return of nutrients to the terrestrial system in fishes, birds, insect, and amphibians.

3. Determination of how manipulations influence: (a) the storage of nutrient capital within components of the ecosystem, (b) the exchange of materials between terrestrial and aquatic systems, and how these changes affect the stability and productivity of the ecosystem.

Progress in year 1. Intensive study sites were identified in the first proposal. Research funded in year 1 was designed to: (1) begin descriptive work for a new study area containing a terrestrial system and a lake (Findley Lake watershed), (2) expand the existing program on unit watersheds (H. J. Andrews), (3) study nutrient transport from a forest community to a stream (Thompson Research Center), and (4) summarize and model existing data (Van Cleve and Zinke).

Terrestrial-lake interface studies of the Findley Lake program have been defined by the interdisciplinary group involved under the direction of Whitney. Preliminary field surveys have been initiated. The studies of nutrient cycling in a forest stand of the Thompson Research Center have been continued by Cole and Gessel, and modeling of accumulated information has been initiated by Hatheway.

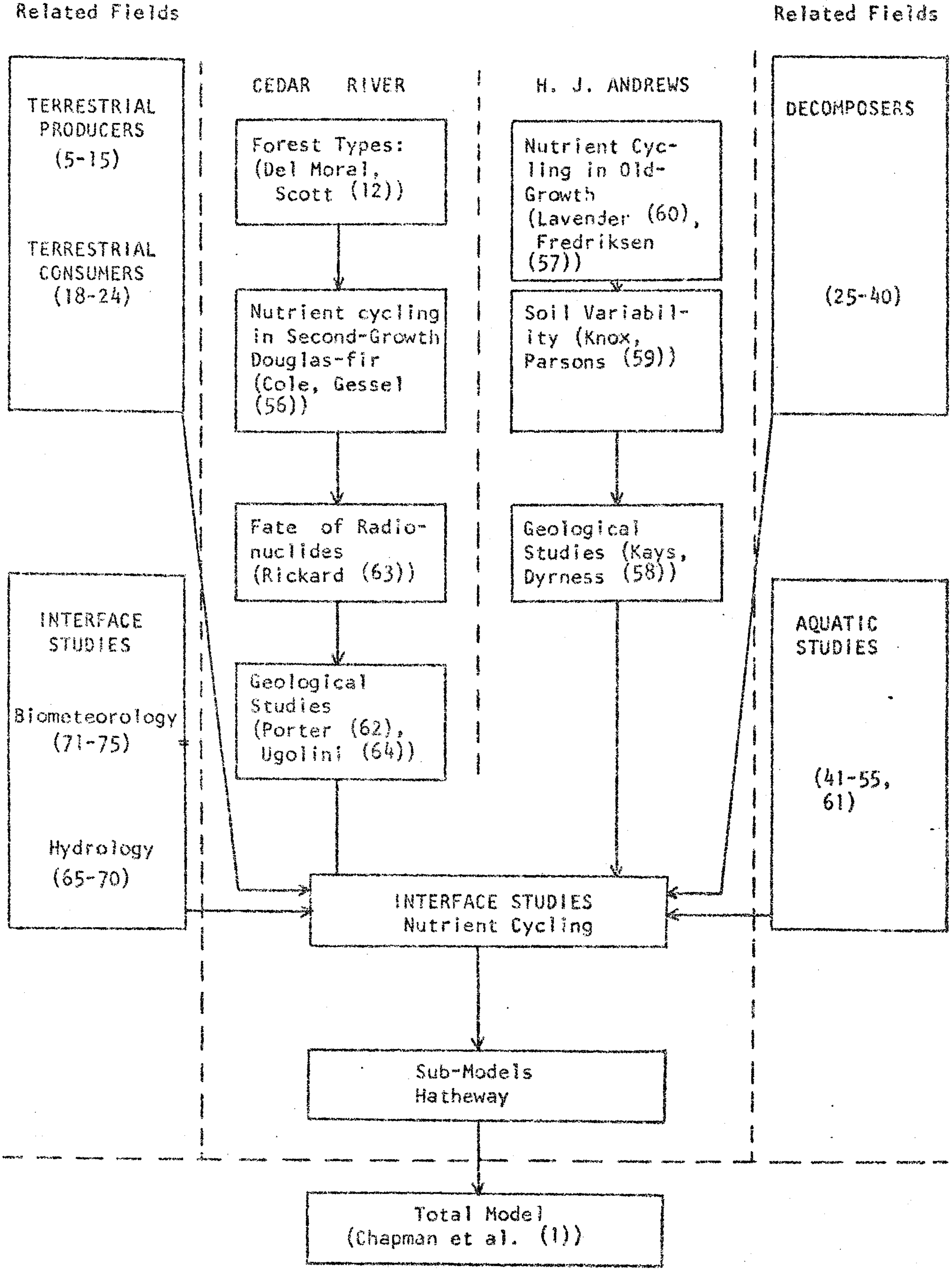
Van Cleve has computer plots and statistical analyses for data relating loss of weight, energy, and selected nutrient elements from birch and aspen litter to time. First-, second-, and third-degree polynomial equations were used and additional models are being tested. Zinke reported considerable progress in the data compilation of standing elemental balances in coniferous ecosystems.

Plans for year 2. Plans for nutrient cycling research (see Fig. 7.9) are concentrated on unit watershed programs at Findley Lake and the Thompson Research Center within the Cedar River drainage, and on watersheds 9 and 10 at the H. J. Andrews Experimental Forest in Oregon. Some of the effort in year 2 is directed to the completion of work begun in year 1 by coordinating sites. Specific plans for intensive sites are: (1) description of soils and geology, (2) measurement of nutrient capital of soil and forest floor, (3) measurement of nutrient return to the forest floor, (4) release and retention of nutrients in surface soils and forest floor, and (5) rate of nutrient transfer between terrestrial and aquatic systems. These work objectives represent only the work provided for under the nutrient cycling budget. Much of the nutrient cycling program is listed under other committees.

The general program indicated above is designed to provide information for coarse-resolution models for nutrient capital of components and rates of transfer between components of undisturbed systems. This work will provide a background for manipulations planned in year 3.

Specific proposals are part of an integrated research package at each intensive site. Description of soils and geology provides stratification for assessing soil nutrient capital and the potential supply of nutrients in geological

Figure 7.9 Diagram of Relationships between Proposed Studies: Interface - Nutrient Cycling. (Numbers refer to Proposals in Appendix - Section 8.2)



materials (Ugolini, Porter, Knox and Parsons, Kays and Dyrness). Measurement of nutrient capital of soil and forest floor will be provided by Knox and Ugolini. Lavender, Cole, and Gessel will estimate nutrient return from the forest to the forest floor. Moore, Cole, Gessel, and Riekerk will measure the release of nutrients from forest floors of the reference stands and unit watersheds. Moore's work will be integrated with Brown's work on subsurface flow through soils. The rate of nutrient transfer between undisturbed forests and the aquatic system will be determined by Fredriksen. Instrumentation for watersheds at two additional sites in the H. J. Andrews Forest for future validation work is provided for in this proposal. Rickard will estimate the residence time of materials from radioactive fallout in components of the terrestrial system.

Additional nutrient capital information will be provided by the biomass subcommittee. Lavender will compile nutrient capital for old-growth forests, and Newton will compile the nutrient capital of understory vegetation. The Terrestrial Producers Committee will coordinate primary production work with nutrient cycling studies at the Thompson Research Center (Cole and Gessel).

The nutrient cycling program in aquatic systems is described in the Aquatic Committee proposal. It is particularly related to studies in the Findley Lake watershed. Christman will conduct an analysis of biogeochemical relations in four lakes in the Cedar River drainage, including Findley. The relationship between nutrition and primary production in aquatic systems will be the responsibility of Welch, and studies of zooplankton consumption are provided for by Welch and Olson. A phosphorus balance sheet for lakes in the Cedar River drainage is planned by Sigurd Olsen. Donaldson and Stober will work on the enrichment of streams by salmon carcasses.

The Decomposers Committee will furnish estimates of nitrogen fixation input to terrestrial systems from mosses, lichens, and free-living organisms (Denison). Migration of particulate matter through the soil represents an important pathway and will be investigated by Riekerk.

7.3.7.2. Hydrology

The hydrologic cycle is inextricably linked to two other "physical" subsystems, energy and nutrients, upon which all the biological subsystems depend. The general description of the hydrologic cycle for a coniferous forest ecosystem has been understood for some time. The storage locations or compartments for water within the ecosystem have been generally described, as have the transfer functions relating to movement of water between compartments.

The greatest problems in applying this general model to a forest ecosystem center about quantification of the transfer functions which describe the rate of water movement between "compartments." The long range goal of hydrologic investigations in the IBP program is to prepare hydrologic models for coniferous systems in order to understand and predict liquid water movement. Accomplishing this task will help us understand the role of water as a carrier of nutrients and sediment, as a medium for aquatic organisms, as a significant sink for energy, and as an essential requirement for life processes. Further, it will help us to better understand the impact of man's manipulation of a coniferous ecosystem. It is obvious that the area of research touched by hydrology is broadly interdisciplinary and relates to the research proposed by the meteorology, nutrient cycling, aquatic, and terrestrial producer groups.

Progress in year 1. The hydrology aspects of ecosystem modeling have come into focus only during year 1 with considerable planning of a coordinated program (Brown). Field studies have been pursued in forest stand hydrology on the Thompson Research Center (Cole and Gessel). Data compilation and modeling of this work has been initiated. Similarly, modeling of terrestrial-lake (Fern Lake) unit watershed hydrology has been initiated (Hatheway and Male). The groundwork for modeling of extensive hydrologic data of the Andrews Experimental Forest has been laid (Rothacher and Brown).

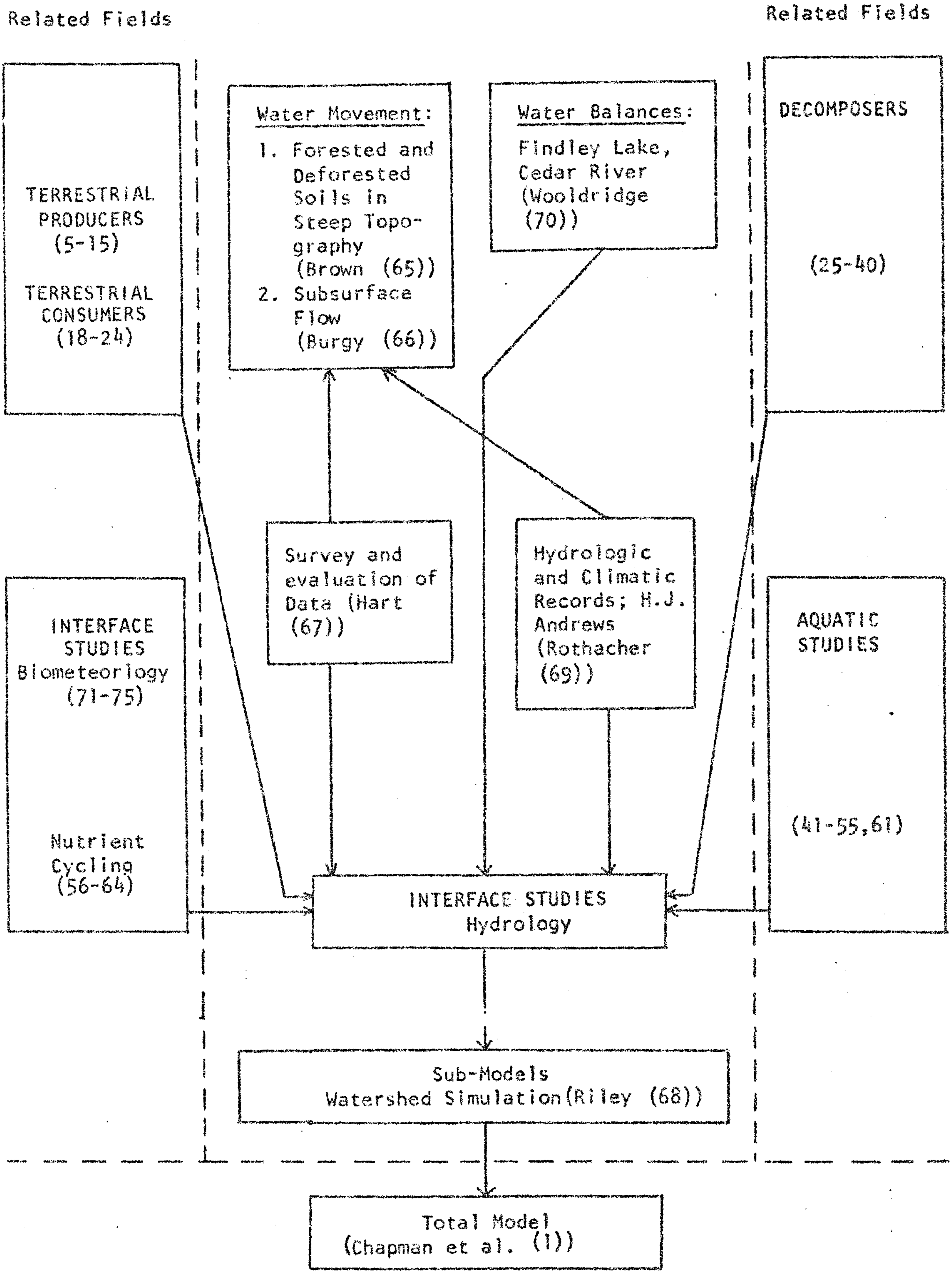
Plans for year 2. The primary goals of hydrology during the second year of research (see Fig. 7.10) are to study the process of subsurface flow in forest watersheds and to construct a hydrologic model for the H. J. Andrews Forest. The secondary objectives are to lay the groundwork for extending the Andrews Forest's hydrologic model to other sites within the Biome, and for the ecosystem manipulation phase of the Coniferous Biome study.

Studies of water movement in forest ecosystems are organized into three interrelated categories: subsurface flow processes, modeling, and data compilation. Subsurface flow is the primary mechanism of water movement in forest systems; it is also the least understood. Understanding nutrient movement through the forest system is contingent upon understanding the subsurface movement of water. Three subsurface flow studies will be undertaken simultaneously. Studies in California on set of highly instrumented watersheds will follow rainfall pulses through the soil-stream system using very-high-resolution records of rainfall, soil moisture, groundwater, and streamflow (Burgy). Subsurface flow and stream response will be related to edaphic flow at each of the intensive sites, and will provide additional data for subsurface flow modeling together with basic on-site data for concurrent nutrient cycling studies (Cole and Gessel, Brown). Process studies will be closely correlated with modeling efforts.

Modeling studies will incorporate basic data inputs from the intensive sites and from the process study in California in order to construct a comprehensive hydrologic model for the Coniferous Biome (Riley et al.). Other inputs will come from meteorology (evapotranspiration) and primary producers (transpiration). The investigators of Riley's group have been highly successful in modeling discharge and salt movement in agricultural watersheds. Similar techniques will be applied to investigating water and nutrient flow from forest sites. Modeling studies will also provide "feedback" information to the process studies in progress. Such information as data resolution requirements and guidelines from sensitivity tests about relative importance of various processes will provide valuable direction to research in progress.

Compilation and analysis of hydrologic data is a third important category of these integrated studies (Rothacher, Wooldridge). Analysis of data from the Andrews and Cedar River sites is necessary to provide data for the modeling efforts. Data on streamflow, soil moisture, and precipitation are also required by the other groups conducting studies at these sites (Aquatic).

Figure 7.10 Diagram of Relationships between Proposed Studies: Interface - Hydrology (Numbers refer to Proposals in Appendix - Section 8.2)



Further extension of the model after year 2 is anticipated. Thus a Biome-wide hydrologic data survey is proposed to ascertain availability and condition of data from the many experimental watersheds in the western forests (Hart). This survey will also be closely coordinated with the modeling study so that information about the types of data necessary, resolution, etc. may be used in selection of nonintensive sites for coordinated studies.

7.3.7.3. Meteorology

The growth of trees, or indirectly photosynthesis of a coniferous forest ecosystem, is related to evapotranspiration via the stomatal pathway. That is, in order for photosynthesis to take place carbon dioxide from the atmosphere must enter the substomatal cavity via the stomates. If the stomates are open to the entrance of carbon dioxide, they are also open to the escape of water vapor. In general, plants do not exercise stomatal control during daylight except under conditions of water stress. In addition, both photosynthetic and evapotranspirational rates are functionally related to the availability of energy and turbulent exchange of the atmosphere. Therefore the ratio of actual to potential evapotranspiration must be related to a ratio of actual to maximum photosynthesis and ultimately to growth.

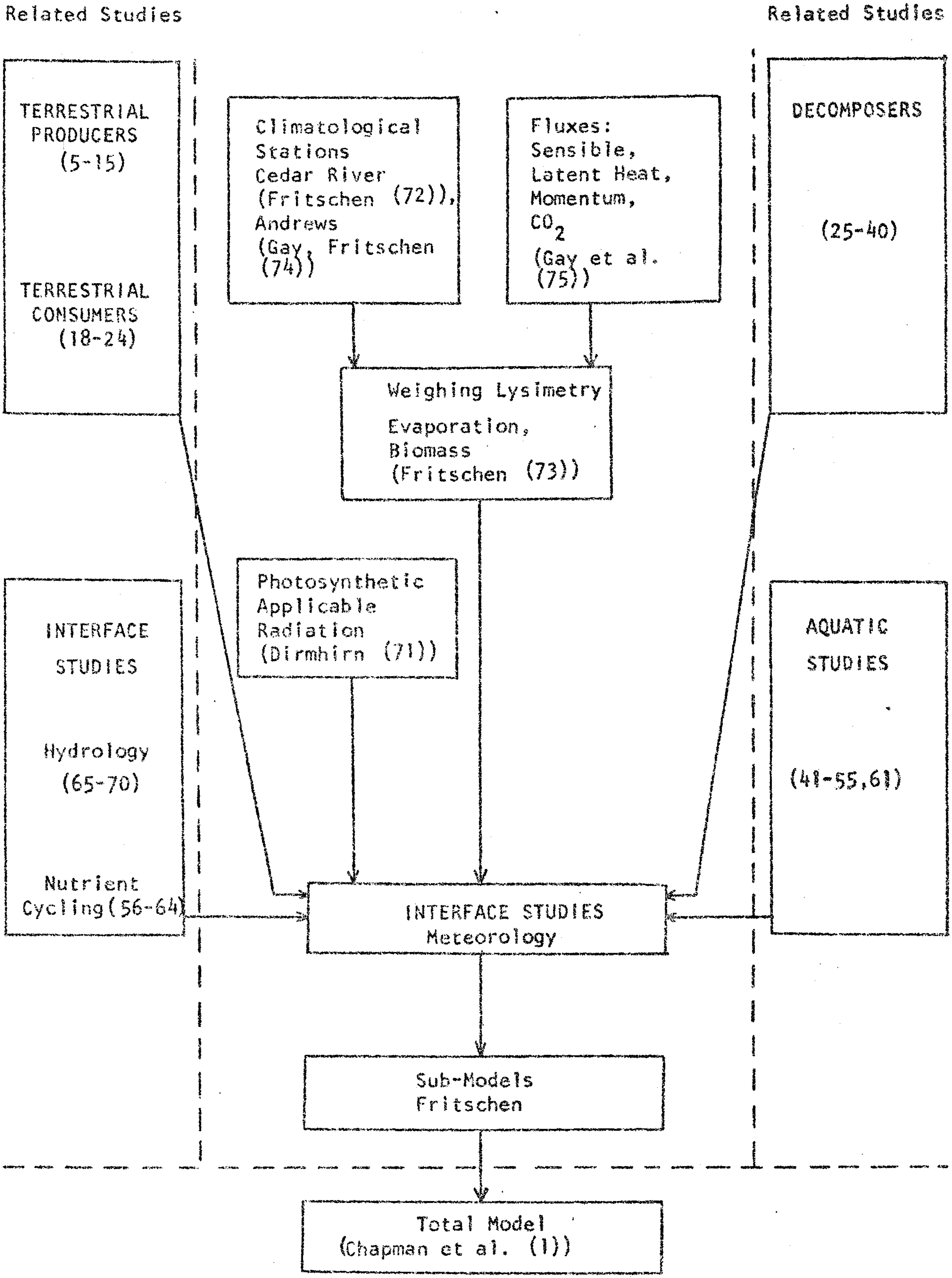
The understanding of photosynthetic and evaporational processes in relation to the determination of meteorological factors requires the measurement of short-period rates of the processes. Short-period rates of photosynthesis can be obtained by cuvette and meteorological techniques whereas short-period rates of evapotranspiration can be obtained by cuvette, meteorological, and lysimeteric techniques. The lysimeter is the only absolute method but it can be used only for short-period evapotranspiration rates at special locations. Cuvette techniques alter the environment and the results need to be translated to an area basis. Meteorological methods have been tested in agriculture and have been found to be adequate under certain conditions. Furthermore, they can be used to sample biometeorological fluxes at numerous sites. However, additional testing is required for forested conditions.

Progress in year 1. The planning of Biome-wide meteorological research for year 2 was accomplished in year 1. This research is described in "Assessment of sensible heat, latent heat, momentum, and carbon dioxide fluxes by meteorological methods and their evaluation" and "A study of the relation between radiant energy and photosynthetic applicable radiation." A preliminary pilot test of coordinated group research will be attempted during the summer of 1971 with non-IBP funding.

In year 1, a climatological station has been designed and will be installed at the Thompson Research site on the Cedar River watershed. The station consists of an automatic, battery operated, magnetic tape data logging system, a group of counters and integrators, and sensors. The major parameters to be monitored are solar and net radiation, air temperature and vapor pressure, wind speed and direction, precipitation, soil temperature, and heat flow. A similar station will be installed on the Andrews watershed in year 2.

Plans for year 2. The most promising avenues of research for the meteorological subcommittee in keeping with the Biome objectives (see Fig. 7.11) are to:

Figure 7.11 Diagram of Relationships between Proposed Studies: Interface - Meteorology. (Numbers refer to Proposals in Appendix - Section 8.2)



(1) test meteorological and cuvette techniques against a weighing lysimeter; (2) determine which meteorological model of flux determination would be most appropriate in forested areas; (3) determine the magnitude of the vertical fluxes of sensible heat, latent heat, carbon dioxide, and momentum in a forest canopy; and (4) determine the magnitude of horizontal fluxes of energy and air in relation to the vertical fluxes. In addition, the meteorological subcommittee has assumed the responsibility of providing detailed climatological data at each intensive research site (Findley Lake, Thompson Research Center, Andrews watershed No. 10).

A weighing lysimeter containing one 20-meter-tall Douglas-fir tree will be constructed in cooperation with primary production and nutrient cycling process studies at the Thompson Research Center (Fritschen, Scott and Walker, Cole and Gessel). The installation will be used as a standard to evaluate meteorological methods and field techniques as compared with tree physiological laboratory techniques.

When soil moisture is not limiting, evapotranspiration rates should be equal to the potential demand of the atmosphere. This will be verified by computing potential evapotranspiration from meteorological data using a modification of Penman's combination method. The energy balance equation will also be solved to determine if energy is extracted from the air mass to support the evaporation process or is used to heat the air mass. Knowledge of the consumptive use in relation to the time of year and meteorological demand would be useful in estimating the possible water yield increases as a result of manipulation of watersheds.

As soil moisture becomes limiting, a larger portion of radiant energy will be used to heat the soil, the canopy, and the air mass. At this stage, the moisture status within the soil and the tree will be related to the atmospheric demand. Plant control of evapotranspiration by stomatal closure will be determined with leaf resistance meters.

Evapotranspiration by layers within the canopy will be computed from the meteorological data using the Bowen ratio equation. The meteorological data will also be used to determine the diffusivities of heat and water vapor at different heights using the momentum balance approach. Knowledge of these transport coefficients is important to an understanding of the energy and material exchanges between plant leaves and air layers.

Meteorological models have several advantages for determining the fluxes of momentum and matter from natural surfaces. The flux of water vapor (evapotranspiration), for example, can be determined with meteorological models which are nondestructive, can be used continuously, or can be used for sampling at several sites. The instruments needed to sample the input variables can be constructed so that the models can be used with a great deal of mobility. Furthermore, assumptions concerning the wetness of the surface or the status of soil moisture are not required.

Meteorological models also have disadvantages. The most serious is the assumption that the fluxes are vertical (i.e., no horizontal advection). This assumption may not always be met under conditions of interest. The second disadvantage is that two of the models, the energy balance and the aerodynamic methods, require vertical gradients of input parameters. Vertical gradients exist in most ecosystems under forced convection conditions. However, in many localities free convection prevails more often than forced convection. The meteorological method which does not require vertical gradients and which will work under free convection conditions is the eddy correlation technique.

This study will be conducted in the area of the lysimeter installation proposed by the University of Washington. The tower established at the weighing lysimeter site will be used as one leg of a triangle of instrumented towers. The difference in evapotranspiration and sensible heat between the lysimeter and the meteorological models will give an estimate of horizontal advection at that point. However, this estimate applies to a single tree and it is necessary to know how representative a single tree is of a larger area.

An additional study of biometeorological interest is the modification of the spectral composition of light filtering through the forest canopy (Dirmhirn). The importance of the tree physiology will be investigated by coordination of light measurements with the proposed photosynthesis and microclimatological studies.

The above cooperative studies are all focused very intensively on one forest habitat of the Thompson Research Center. More general climatologic data will be collected by members of the meteorology group as a service for other researchers in the Biome. Two automated data acquisition systems will be operating in the Cedar River intensive site (Fritschen) and one in the Andrews Experimental Forest (Gay and Fritschen). Additional measurements of climatological aspects will be made by others in studies of environmental factors in terrestrial and aquatic systems (Dyrness et al., Burgner).