THE ORGANIZATION OF A STUDY OF A BIOLOGICAL SYSTEM

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ABSTRACT

Biological systems are complex and a multi-disciplinary approach is needed to provide the information essential for intelligent management of natural resources. A committee of scientists planning and directing research on the role of a forest insect in its ecosystem has proven to be a successful method of organizing a 'team' approach within a government research organization. This 'committee' approach is compared to the 'leader-oriented' approach to organization of research teams within government and university stituations.

INTRODUCTION

Traditionally, many biologists have been concerned mainly with characteristics of individual organisms rather than of biological systems such as populations, communities and ecosystems. However, in recent years more and more recognition has been given to the necessity for research into the operation of biological systems in order to solve complex problems facing mankind. Management of any system without a sound knowledge of its operating principles is obviously hazardous, thus research is needed to provide information for intelligent management of our natural resources.

The investigation of a complex system requires the integration of many talents in a co-operative approach if useful results are to be achieved in minimum time. The "team approach" is widely recognized as the best to solve complex research problems and is used in many disciplines. However, opinions differ widely on the best organization for team research. I have participated in a team approach to solving a complex forest entomological problem for a number of years, and this paper will comment on organizing and conducting the investigation of a biological system.

ORGANIZING FOR RESEARCH

I would like to emphasize that the organization of the team investigating a biological system must reflect the organization of the system. An important characteristic of the ecological system is that its parts form an intricate web of interactions; indeed, Watt (1966) defines an ecological system as "an interlocking complex of processes characterized by many reciprocal cause-effect pathways". Therefore, the mere division of aspects of a large and complex problem among a number of investigators does not constitute a team approach. Like the ecosystem the team must be characterized by an interlocking of thought and action in the development and operation of the investigation.

Two types of investigations can be recognized: problem-oriented and systems-oriented. Although the problem-oriented approach focuses its attention on a single organism or facet of the system while the system-oriented approach attempts to describe the entire system, the differences are more important on the theoretical than on the operating level. Since a system under investigation comprises an interlocking network of organisms and processes, the selection of a single problem or organism as the "target" does not prevent the

investigators from adopting a holistic approach to the ecosystem. Examples of this are available in the investigations of the spruce budworm problem in eastern Canada (Morris 1963), the western pine beetle in California (Stark 1966) and in the larch sawfly problem which I will now describe.

DEFINITION OF THE LARCH SAWFLY PROBLEM

The larch sawfly has long been recognized as the major factor affecting the growth of larch in North America. During the first half of this century extensive tree mortality and growth loss, attributed to this insect, were described and attempts were made to reduce these losses through the introduction of biological control agents. Chemical control experiments were also tried but were too expensive and too ineffective to be applied on a large scale. By the early 1950's it became apparent that the larch sawfly was the major obstacle to the maturing of large volumes of young tamarack, and fear of larch sawfly damage had led to the almost complete exclusion of this fast-growing conifer from forest planting programs. It also became apparent that without detailed knowledge of the population dynamics of the larch sawfly, there was no hope of developing an economic method of reducing the damage.

DEFINITION OF THE SYSTEM

The basic elements of the system which needed to be studied were: (1) larch, (2) larch sawfly, (3) other factors affecting the growth and survival of larch and (4) factors determining the abundance of larch sawfly and its impact on larch. Each of these headings, of course, includes a large number of interacting facets which determine the characteristics of the system.

ORGANIZATION OF THE PROGRAM

In 1955, as the results of a decision to consolidate larch sawfly research for Canada in Winnipeg, four scientists, each with different areas of special competence, began to plan the investigation. During the initial planning, and throughout the subsequent history of the program decisions have been made by a committee consisting of a varying number of participating scientists. Continuity of approach and dedication to the program have been insured by close involvement in the decision-making process. The committee decided that initially our resources would have to be allocated in three areas:

1. Application of existing techniques to the continuing collection of data on the larch sawfly and its environment.
2. Development or adaptation of techniques to extend the number of parameters measured in 1.
3. Experimental studies of the characteristics of the system components and elucidation of the paths of interaction between them.

These areas were considered necessary to produce the basic data for the analysis and description of the system which would lead to a model that could be used for simulation and optimization.

At the beginning of the operation, the greatest need was for the development of techniques. Although considerable research had been done on the larch sawfly, its parasites and its predators, little emphasis had been placed on sampling techniques. In addition to the development of sampling techniques for the larch sawfly, techniques for estimating the abundance and effectiveness of its mortality factors and the impact of larch sawfly on the growth and survival of trees had to be developed. Weather was recognized as an important, pervasive element in the whole system. Although meteorlogical equipment was available, such equipment had to be selected for its ability to measure parameters related to the system and adapted to operate in remote areas.

All three aspects of the initial program began simultaneously, but as standard techniques for collecting continuing data on the major elements of the system were developed, more time could be devoted to experimental studies. In addition, preliminary analyses, which are necessary to check on the data and to reveal new relationships, became an essential part of the program. In this respect, the decision to develop a highly skilled group of technicians to maintain the data-collection program was essential to allow the scientists enough time to experiment and analyse the data.

Throughout our operation, the assignment of specific projects to members of the group has been made on the basis of the priorities of the study and the abilities and interests of the individual. Additional specialists have been enlisted to study specific aspects of the problem and the assistance of others in the process of analysis is anticipated.

GENERAL COMMENTS ON ORGANIZATION

In considering the development of the larch sawfly project I have come to believe that several points need to be emphasized in the organization of a team approach to a complex problem.

1. The need for breadth and flexibility in approach and operation. The organization must draw upon the maximum range of knowledge and ability at the beginning and continually draw into its orbit personnel capable of extending its knowledge of the system. These people can be utilized full- or part-time for varying periods but will be essential to the attainment of the final result.
2. The need for continuity, both in maintaining the line of investigation and in building up a comprehensive body of information on the system.
3. The need for constantly reviewing the progress of the investigation toward its final objective, the synthesis of results into a meaningful description of the system which can be used for simulation and planning.
4. The need for material support and encouragement by the supporting organization, which is of course basic to the success of any program.

Differences in the type of organization may influence the extent to which these four needs are fulfilled. While the larch sawfly research team uses a committee approach within a government research organization, other systems investigations in forest entomology have been developed around a single leader, either within a government organization or at a university. Thus the team approach to the spruce budworm problem in eastern Canada, which produced an immensely useful description of this insect pest and its role in the spruce-fir forest community (Morris 1963), was conceived and directed by Dr. R. F. Morris within a research agency of the Canadian Government. Within universities, Dr. H. Klomp at the Agricultural University, Wageningen, Netherlands and Dr. G. C. Varley at Oxford University, England, have personally developed holistic approaches to the study of specific forest insects. These studies have made significant contributions to the knowledge of population dynamics (Klomp 1966, Varley 1967). Stark (1966) has described the organization of a study of a biological system within a university based on his work with the western pine beetle. He emphasizes the need for one or more senior researchers to plan and guide the efforts of associates and graduate students in studying portions of the problem and to build up their results into a comprehensive body of knowledge of the ecosystem.

With these examples in mind, some of the advantages and disadvantages of the type of organization of the team and their location can be examined in reference to the needs of the systems research listed above.

First, an organization with a dominant leader can be expected to show the maximum cohesiveness in the planning and operation of the program. This leader may also attract able subordinates to study specific aspects of the problem and draw upon them for ideas in planning and in analysis of the results. However, even strong leadership may have its weak points: the breadth and flexibility of an individual's approach to the problem is limited by his training and his ability to evaluate the varying viewpoints of his subordinates. The subordinates may also feel more involved and dedicated to their specific portion of the problem and less inclined to consider methods of studying the whole system. Continuity may also become a problem, through individual mobility or mortality, and replacement of a leader may be difficult.

The structure of the committee will greatly affect its success. Galbraith (1967:65) distinguishes between "representative committees" and those designed to test and pool information. A committee composed of members selected to represent special interests is severely limited, because a contribution to a decision by any one member can be made only at the expense of another member. When the committee is designed to pool and test information as a basis for making a decision, a synergistic effect often appears: the interplay of information and ideas between the members produces results greater than the simple summation of their individual contributions.

The ability of a committee to integrate a wide range of information in developing a logical approach to problem solving may also make it easier for the committee to obtain and maintain the usually large amount of support that is necessary to conduct systems research. Decisions are made only after proposed allocations of resources are examined in relation to the objectives from many viewpoints. A decision of an individual may be challenged by another higher in the hierarchy, and is too easily reversed. Such challenges to a committee decision are much more difficult, since the superior must be prepared to reverse the judgment of a wide variety of specialists acting jointly. The personal competence of the superior is unlikely to span the range of information available to the team and time prevents him from doing the massive job of probing that would be needed. Thus the greatest power of decision lies with the greatest breadth and depth of information, a group or committee rather than individual. As J. K. Galbraith (1967:67) succinctly describes the situation "Group decision, unless acted upon by another group, tends to be absolute."

The development of systems research in universities as opposed to governmental research organizations is a matter of serious consideration at the present time. In both areas a wide range of talents can be found and if these can be brought together, a program of satisfactory breadth and flexibility could be developed. However, as Stark (1966) observes, a university-based organization has difficulties in keeping the study flowing smoothly and in the right direction due to its strong dependence on the short-term efforts of graduate students in conducting research. Support for a sufficiently large staff of highly skilled, permanent technicians which can be devoted to collecting continuing data on the system may also be difficult to obtain. The weakness in continuity, however, is partially balanced by the depth of knowledge and intensity which may be directed by staff and students to the study of specific aspects of the system. In addition, while long-term support may be difficult to obtain, grant-supported research at the university is flexible and may get money much more readily for short-term studies.

In conclusion, I think that the best organization for the study of a complex biological system would be a committee of scientists, all active in the planning and operation of the study. Continual monitoring of the natural system, well-replicated, should be the realm of a highly skilled sub-professional team, working under the committee's direction. Continuity can be best assured by basing the study in a governmental research organization but the best over-all results would be obtained by including university scientists, both as members of the committe, and as associates who undertake experiments on special aspects of the problem.

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THE ECOLOGISTS' APPROACH [1]

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ABSTRACT

The present-day role of ecologists is considered, particularly with respect to other scientific disciplines, study of the environment, and resource management. To illustrate this role, a marsh ecosystem research program is discussed. Despite the pressures of human population and environment pollution, Miss Walker cautions against stress that might adversely affect the research process.

Ecology deals with the interaction of organisms and their environment, and is often referred to as environmental biology. The word "environment" covers a multitude of things, and includes organisms and their surroundings which are modified by them. The environment includes other organisms of their own kind and of other species. There are relationships, always adjusting and changing, between individuals within a population and with individuals of different populations. In fact, the interests of the ecologist extend into the areas of plant and animal biologists, taxonomists, physiologists, behaviourists, meteorologists, geologists, physicists, chemists, pedologists, and sociologists. Ecologists need to relate to all these and other established and respected disciplines. Ecology is a multidisciplinary science. It has to be to reach the heart of environmental biology. For many years ecology has been criticized for a lack of quantitative data and conceptual strength. This situation is improving, for modern ecology has shifted from the descriptive phase to the study of function. The modern ecologist quantifies his data wherever possible: he studies nutrient cycles, energy flow, functional niches, population growth. He draws increasingly upon statistics, chemistry, and physics to develop tools with which to probe into the ecosystem. Today it is essential that ecologists ally themselves with climatologists, soil scientists, ethologists, taxonomists, systematists, and geneticists.

With all due respect to the advances made in molecular biology, it is true to say that the most important current level of biological study is the organism and its environment. Even in non-biological circles, this is being realized. Man's impact upon his own environment is being felt more keenly day by day, and today Man, rather than nature, exerts the decisive influences on the shape of the future. Because of the increase in radioactive fallout, we have become conscious of nutrient cycles: because of loss of life from lethal doses of pesticides picked up through food chains, we have become increasingly aware of chemical poisons and other pollutants that are being cycled through ecosystems; because of increased urbanization, we are becoming more concerned about the need for open spaces and the need to protect environments. Constancy in environmental conditions generally represents, if not a good position, at least a non-deteriorating one, and we are suffering from deteriorating conditions on many fronts (Slobodkin 1968).

The future of human life on the earth demands more knowledge about the ecosystem than we yet possess, and for this we turn to ecologists. Edward Deevey (1968) has stated that

> Human societies are now so large, so complex, and use resources so rapidly, that they are in danger of drowning in their garbage. The problem is

1 Presented as an invitational paper at the Manitoba Entomological Society meeting, 1968.