

NATIONAL PARK SERVICE

HANDBOOK

NATURAL SCIENCES RESEARCH

RELEASE NO. 2

June 3, 1966

When the first four chapters of this handbook were released on July 27, 1965, the transmittal memorandum stated, "When the first 8 chapters have been received, this handbook will replace all previous directives concerning the natural sciences research program."

Chapters 5, 6, 7 and 8 are included in the present release; therefore, "all previous directives" including FO 6-64, dated April 10, 1964, have been replaced and the handbook directives are in force.

Chapter 5 discusses, and gives guidelines for, the writing of the Park Natural Sciences Research Plan. Plans for several parks have already been initiated, and Appendix A of this handbook will be an example Plan from one of these.

Chapter 6 discusses the RSP, the important programming document for natural sciences research projects. A new RSP form (10-224) for natural sciences projects is now in effect and replaces any and all previous forms. The form is now available and should be ordered on Form DI-1 in the usual manner.

Chapter 7 outlines the requirements and procedures involved in the Natural Sciences Proposal. The Proposal is the document, submitted by prospective investigators, that lays the blueprint for the proposed research. Extra copies of this chapter will be available from this Office for the use of any scientist wishing to submit a Proposal.

Chapter 8, Research Reports, prescribes various reports that are required in the administration of the Service's research program. Forms 10-225, 10-226, and 10-227, have been developed for several reports, and these are explained and exhibited in this chapter. A supply of the forms is now available and should be ordered on Form DI-1 in the usual manner.

Also enclosed is a new Table of Contents. Please remove Page ii, Release No. 1, July 1965, from your handbook and insert Pages ii and iii in its place.

Additional chapters and appendices to the Natural Sciences Research Handbook are anticipated for the future. For example, directives concerning the use of scientific plant and animal names; an outline of major terrestrial and aquatic ecosystems as a guide for community descriptions; a discussion concerning the uses and applications of research findings; and bibliographic references to important scientific source material, are all envisioned as being appropriate material for eventual inclusion.

After the enclosed material has been brought to the attention of all interested personnel it should be placed in the handbook. This transmittal sheet should be filed for future reference.

Additional copies of this release are available for your use, but requests should be based on actual requirements.


Assistant Director

Enclosure

Interior - Duplicating Section - Washington, D. C.

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THE PARK NATURAL SCIENCES RESEARCH PLAN

The purpose of the Park Natural Sciences Research Plan is to broadly outline the fields in which natural science research is needed to meet park requirements. In doing so it identifies pertinent investigations underway or already accomplished in the park, establishes general patterns for obtaining needed information, and indicates the broad content and dimensions of the natural sciences research program required for the park. It looks at the research problem as a whole.

An individual research project may apply directly to a particular management or interpretation problem. However, a specific problem, important as it may be on its own, is often related to other problems. Early insight into these relationships can, through advanced research planning, minimize duplication of effort and, indeed, produce more comprehensive conclusions.

The Park Natural Sciences Research Plan consists of four chapters, to which the following guidelines apply. (Appendix A at the end of this Handbook is an example of a Natural Sciences Research Plan):

Chapter I. Resource Preservation and Use Objectives

A natural sciences research program, responsive to the needs of park management and interpretation, must first take cognizance of the purposes for which the park was established and of the specific objectives toward which management and interpretive activities are oriented. The following documents establish general purposes: (1) The Act of August 25, 1916, establishing the National Park Service; (2) the "Magna Charta" letter of May 13, 1918, from Secretary Lane to Director Mather; (3) the "Road to the Future" letter of July 10, 1964, from Secretary Udall to Director Hartzog; (4) the March 4, 1963, Recommendations of the Secretary's Advisory Board on Wildlife Management; and (5) the enabling legislation for the specific park.

These documents define broad purposes; they must be translated into specific objectives for the preservation and use of the land, water, vegetation and fauna. For example, what interpretive

Chapter I. Resource Preservation and Use Objectives (con.)

themes and subjects will be stressed? What areas will be designated as wilderness, and thus preservation-oriented? What other features, ecosystems, specific species will be afforded special preservation or interpretive attention? What areas will be designated for heavy use development? What recreational use theory will prevail? Management objectives are specific, or as nearly so as current data permit, with regard to land use and to resource use other than for preservation. In a general way, they indicate the boundary lines for the mission-oriented research program.

Chapter I of the Park Natural Sciences Research Plan is a summary of these purposes and objectives, and usually requires only a few pages. It should be brief, though thorough and complete.

Management objectives derive, first, from important decisions about how and to what degree the park will be used and preserved, and are generally reflected in the Master Plan. All activities and offices of the Service are involved, the Superintendent and his staff most immediately. At a second level, management plans are expressed in terms of specific procedures concerning treatment of various resources--a wildlife management plan, a fire control plan, for example. Management objectives and resource management plans are based upon the best data and experience at the time. They are subject to modification as better information is developed. To provide this background is an important function of research.

Normally, at least the broad management objectives will have been developed before the research plan task force meets in the park to draft the Plan. The objectives will be examined by the task force as a basis for mapping out the research task, and for compatibility with known facts. For example, failure of chestnut to reproduce, formerly attributed to deer browse, but newly found to be caused by disease, would be of immediate use in modifying a deer management and control plan.

Chapter II. The Characteristics of Natural Resources

The characteristics of each significant natural resource in the park should be clearly detailed and explained. In addition to descriptions of the major ecosystems and their more important minor constituents, specific attention should be directed to such values as unique or rare organisms, unusual communities of organisms,

Chapter II. The Characteristics of Natural Resources (con.)

spectacular or scientifically important geological formations, centers from which postglacial migrations took place, and the like. In its total context, this portion of the Plan will constitute, to some degree at least, an appraisal of the condition of the important ecosystems of the park at the time that the Plan is drafted.

The statements concerning natural resource characteristics should describe the setting, factually and meaningfully, in which the research and management problems and opportunities exist.

Descriptions of the natural resource characteristics comprise Chapter II of the Park Natural Sciences Research Plan. The following conditions and resources should be described, whenever applicable, in sufficient detail to provide a clear and concise picture of each in relation to one or more park ecosystems:

- A. Geography. A description of the physical setting in relation to continental and provincial position, human population characteristics of the general area, etc.
- B. Climatology. A description of the climate in terms of precipitation, temperature and other factors, on annual and seasonal bases, including means, extremes, ranges, etc., and how these conditions relate to the ecosystem(s).
- C. Geology. A description of the regional and specific areal geology in terms of physiography, historical geology (including glaciation), structure, stratigraphy, petrology, etc.
- D. Soils. A general description of the soil types and their relationship to the ecosystems.
- E. Vegetation. A description of the various major species compositions of successional, climax, subclimax, preclimax and postclimax communities; of lesser communities such as bogs, swamps, mountain meadows, etc.; and, enumerations of specific plants that are unique, rare, or endemic.

The vegetation is an expression of the total environment. Faunal elements are dependent upon the vegetation.

Chapter II. The Characteristics of Natural Resources (con.)

Hence, classification of the various major park terrestrial ecosystems should be described here, using vegetation as the basis.

- F. Fauna. A description of the terrestrial fauna in relation to the ecosystems as described under vegetation. Major species should be discussed in relation to overpopulations, rarity, endemism, adverse animal-human relationships, important interspecies relationships, etc.
- G. Aquatic Resources. A description of the various aquatic ecosystems, in terms of major resident species and types, abundance, and distribution of aquatic habitats.

In their total context, each of the above writeups will reveal: (1) the best estimate of condition of the resource at the time that the area was first visited, or "discovered," by European man ("Pristine Condition"); (2) the changes in the condition of the resource brought about by the influence of man and civilization following the advent of "discovery"; and (3) the changes in the condition of the resource due to natural causes such as climatic shifts, postglacial uplift, recent volcanic activity, coastal subsidence, normal succession and the like. It is appropriate throughout this chapter to cite references--which are listed in the annotated bibliography (Chapter IV)--to authenticate statements made.

In summary, this chapter of the Plan describes the major and valuable natural resources of the park, resource changes that have taken place since "discovery," and, if known, causes for these changes.

Chapter III. Needed Research

After due consideration to the status of the natural resources, to the requirements of the management program, and to pertinent natural science research that has already been accomplished in and near the park, it becomes possible to determine approximately the kinds of research needed to solve management and interpretive problems.

Chapter III. Needed Research (con.)

The amounts of research already accomplished and the needs for additional research will vary from park to park. Normally, a certain amount of "basic" research is needed for all parks; for example, one important management objective in all parks is the preservation of naturally occurring species. This objective is impossible to achieve unless it is known precisely which species are present; basic inventories of plants, animals and rock types are absolutely necessary. Mandatory, too, is a knowledge of naturally occurring ecosystems, preferably their "pristine" condition, and what changes have occurred during modern times due to man's involvement with them. It goes without saying, that it is equally important to know the natural conditions which would now obtain through normal evolution and succession had not man interfered. If this information is not now known, research is required.

In addition to basic research, most parks need natural science studies of the more specifically mission-oriented type. For example, if there is a large ungulate population resident in the park without natural controls being present as well, the ungulate will almost certainly become overpopulous, and, in turn, seriously damage the vegetation by overbrowsing. Control methods must be developed. Research is almost always indicated to determine control methods. If a subclimax vegetation of outstanding value and significance is in danger of being lost due to successional changes, and if it has been determined that these natural changes are undesirable, research may suggest the means by which this loss can be prevented.

Next, it may be desirable to describe natural sciences research opportunities that exist in the park, but that have little obvious relationship to management or to interpretation. This merely calls attention to the opportunities that exist for researchers who may have personal or institutional research interests and needs, quite independent from those of the National Park Service. For example, a species of moss that has a high elevation and a low elevation form might provide an important research opportunity for bryologists interested in chromosome studies or other genetic-taxonomic problems. Such independent research is to be encouraged, even though it may have slight value to the interpretive program, or no apparent application to management. Even in investigations of this kind, however, the Service cannot afford to

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The Park Natural Sciences Research Plan

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Chapter III. Needed Research (con.)

predetermine negative usefulness before the data are obtained and integrated with other information. The immediate usefulness of research findings is not always predictable, and indeed, they are often cryptic until viewed in the context of the larger picture.

It is not often possible or desirable to describe all projects in detail far in advance. The Plan delineates, for the most part, only the general areas of investigation and the problem(s) that the research should attempt to solve. Later, within this framework, the requirements of individual projects can be better determined, the projects described in detail, and appropriate investigators selected. Together, the Service and the proposed investigators can then design the projects so as to develop the needed information. (See: Natural Sciences Research Handbook, Chapter 7.)

The format of the Natural Sciences Research Plan is not an inflexible one, and it will vary to adjust to individual park requirements. However, it should include a summary of research already completed that is pertinent to park management or interpretation problems (include references in Bibliography, Chapter IV). Then, for most parks, the chapter should be broken down according to subject matter as described for Chapter II. Under each subject heading there should be a section relative to the actual research needed. These sections can be presented as a series of statements each of which consists of two parts, (a) a brief description of the management or interpretive problem, and (b) a description of the research needed to provide a solution to the problem.

Chapter IV. Bibliography

The bibliography is very important, it is a compendium of the research that has been done in, or in close proximity to, the park. It should also include important references of a specific or general nature that closely relate to the natural resources of the park or its problems. To be really meaningful, each entry in the bibliography should contain a brief statement as to the nature of the investigation being reported and/or why it is important to consider.

Chapter IV. Bibliography (con.)

The bibliography must be kept up-to-date, since this document is the major bibliographic reference for natural science items for the park. Each entry shall be as follows, and arranged alphabetically by author.

Author's name (last name first). Year of publication.
Title of paper. Journal name, volume, issue, pages.
Publisher, publisher's location. Brief description of the research, when available.

In the right-hand margin of each page will be several vertical columns with the following headings, which represent major emphases of the publications:

Aquat.	Veget.	Clim.	Geol.	Zool.	Mgmt.
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--these being abbreviations for the following subjects: Aquatic Biology; Vegetation-Botany; Climatology-Meteorology; Geology; Zoology-Fauna; and Management. A checkmark (more than one when necessary) is placed in the appropriate column(s) after each bibliographic entry to denote the character of the reference. For extensive bibliographies, the listing may be subdivided into major subjects, the entries being listed alphabetically under Aquatic Biology, Vegetation-Botany, Climatology, etc. In this case the vertical column checkmark system can be used to denote secondary or parallel subject material contained in each reference.

Introductory Material

The introduction, prefacing the four main chapters, should identify the editor of the Plan, the members of the team that drafted the Plan, consultants, and others who contributed significantly. There should also be a brief statement that indicates the purpose of the Plan itself, with a reference to the Natural Sciences Research Handbook that contains the instructions and guidelines for its preparation.

A Table of Contents will be an essential part of the introductory material, since most of the Plans will tend to be lengthy.

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The Park Natural Sciences Research Plan

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Introductory Material (con.)

Introductory material will not form a chapter, as such, but can be labeled "Table of Contents," "Introduction," etc. Lower case Roman numerals should be used for pagination.

THE RESOURCE STUDIES PROBLEM (RSP)

The RSP (Resource Studies Problem), Form 10-224, is a most important document in the administration of the natural sciences research program. It is the primary programming document, comparable to the PCP. It is used to:

1. Identify problems or situations requiring research or technical advice.
2. Identify projects deriving from the Park Natural Sciences Research Plan.
3. Record and report research carried on independently by Service personnel.
4. Record and report research conducted independently by scientists, institutions, and other Federal agencies.

From the standpoint of the originator of an RSP, the most important function it has is to state the problem.

The RSP as a Device for the Statement of a Problem

The problem and the RSP usually originate in the park in connection with, or by virtue of, one of the following:

1. The requirements of the Natural Sciences Research Plan.
2. Current resource management needs.
3. Interpretive needs.
4. Planning and Construction as they involve:
 - a. Preservation of natural values.
 - b. Effects of developments on natural values.
 - c. Geologic and hydrologic characteristics of lands to be developed.
 - d. Knowledge concerning native plants for landscaping, etc.

NS

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

RSP

NATURAL SCIENCES RESOURCE STUDIES PROBLEM

Original and one copy of the completed form should be submitted to the Division of Natural Sciences Studies (RN), in the Washington Office with a copy to appropriate regional office. Refer to the "Natural Sciences Research Handbook" for additional instructions.

PARK	REGION
------	--------

1. Title of Problem (Brief Name)

2. Statement of Problem (Use continuation sheet if needed for further explanation)

CHECK ONE

3. ☐ Request for Service-supported research or advice.
4. ☐ Reporting independent research initiated, or to be initiated.

5. Submitted By (Name)	Title	Date
6. Superintendent's Recommendation <input type="checkbox"/> Approved <input type="checkbox"/> Disapproved	Signature	Date

7. WASO Review By (Name, Title, Date)

a. ☐ Needs no additional research: problem can be solved by using existing knowledge and/or techniques.

b. ☐ Needs research to obtain solution.

c. Recommendations:

d. Methods of Funding

☐ Resource Studies ☐ Other M&P ☐ D&C/PCP# ☐ Service Personnel ☐ Other

8. Est. Cost: \$ _____ Per year for estimated _____ years. Total Estimate Cost: \$ _____

9. Approved by Assistant Director, Resource Studies

(Signature)	(Date)
-------------	--------

10. RSP Number

				N			
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The RSP as a Device for the Statement of a Problem (con.)

The person submitting the RSP (item 5 on the form) may be anyone in any office in the Service who recognizes the problem. The RSP Procedure is as follows:

1. The problem is described on the RSP Form 10-224 and forwarded to Superintendent.
2. An RSP number is assigned (code letters of park + N + consecutive numbers in order; revisions will bear the same number as the original, with the addition of "a," "b," etc.).
3. RSP is signed by Superintendent, recommending approval.
4. Original and one copy submitted to Division of Natural Sciences, WASO, with a copy to Region.

All RSPs, whether or not recommended by the Superintendent, are to be sent to the Washington Office as above.

The submission of RSPs may be made at any time, but it is important that all RSPs be reexamined at least once per year to be sure that they are up-to-date and that the RSP package truly represents the research needs and activities in the park. This re-examination should take place immediately prior to January 15 of each year in order that the "Superintendent's Annual Research Report," due on that date, can be an accurate summary of the status of the RSPs and other park research matters.

Processing the RSP in WASO. The Division office in WASO will determine, by whatever means appropriate, whether or not the problem requires additional research for solution.

Professional advice will be sought for those problems that do not require further research. If the problem is such that existing knowledge is insufficient to provide a solution, research is needed. The Division office in WASO:

1. Recommends a research project under "Recommendations" in item 7(c).
2. Determines method of funding.

The RSP as a Device for the Statement of a Problem (con.)

3. Estimates the cost of the proposed project for budgetary or PCP purposes (item 8).

4. The Assistant Director, Resource Studies, approves the project by signing and dating item 9.

5. A machine copy of the completed RSP is returned to the park or other originating office. Additional copies may be sent, as appropriate, to other WASO Divisions, the Regional Office involved, Planning and Service Centers, etc.

Approval of the RSP by the Assistant Director indicates that the project will be placed in priority for activation as personnel and funds are available.

Research for which Park or Regional Funds are Available. Occasionally, particularly for less expensive research projects, park or Regional funds may be available for the investigation. If such is the case, Superintendents should so indicate on the face of the RSP under item 2, "Statement of the Problem." If the Superintendent already has a Natural Sciences Proposal from a prospective researcher (as defined in Chapter 7) it should be forwarded with the RSP to WASO. When such RSPs and Natural Sciences Proposals are approved by the Assistant Director for Resource Studies, assignments, agreements or contracts may be made immediately. However, approved RSPs and Proposals are required before Service support may be given to the project.

Project for which a Qualified Investigator is Available. Often, qualified investigators may have expressed interest in a project prior to the time that an RSP is submitted. Superintendents may suggest that this scientist be considered for project investigator under item 2 of the RSP. If the scientist has prepared a Natural Sciences Proposal, it should be forwarded to WASO along with the RSP. If he has developed a less formal plan of proposed research, a copy should be forwarded with the RSP, since it may aid the Chief Scientist in determining the qualifications of the proposed investigator.

The RSP as a Device for Proposing Independent Research Projects by
Service Personnel and Persons Outside of the Service

Many Service employees are capable of, and desire to do, research. Sometimes this is done on the employee's own time. Scientists outside of the Service may also wish to perform research in National Parks at no additional cost to the Federal Government. The RSP should be utilized to report the initiation of such research. The Service wishes to be aware of all independent research taking place within the parks because of the probability that such studies will yield results of value to the Service's management and interpretation programs.

If an independent project merely involves a few specimens or observations, with the majority of the project being carried out elsewhere, or if collections are being made simply for an institutional collection, the project need not be reported on an RSP form; but, such projects should be listed annually in the "Superintendent's Annual Research Report" (see Chapter 8).

When the RSP is used to propose, or report the initiation of, independent research, the form should be completed as usual, except that item 4, "Reporting Independent Research. . .," is checked, rather than item 3; and item 7(c) is filled in by the investigator, briefly summarizing the research project that he intends to carry out. Item 5, in this case, is the investigator's name.

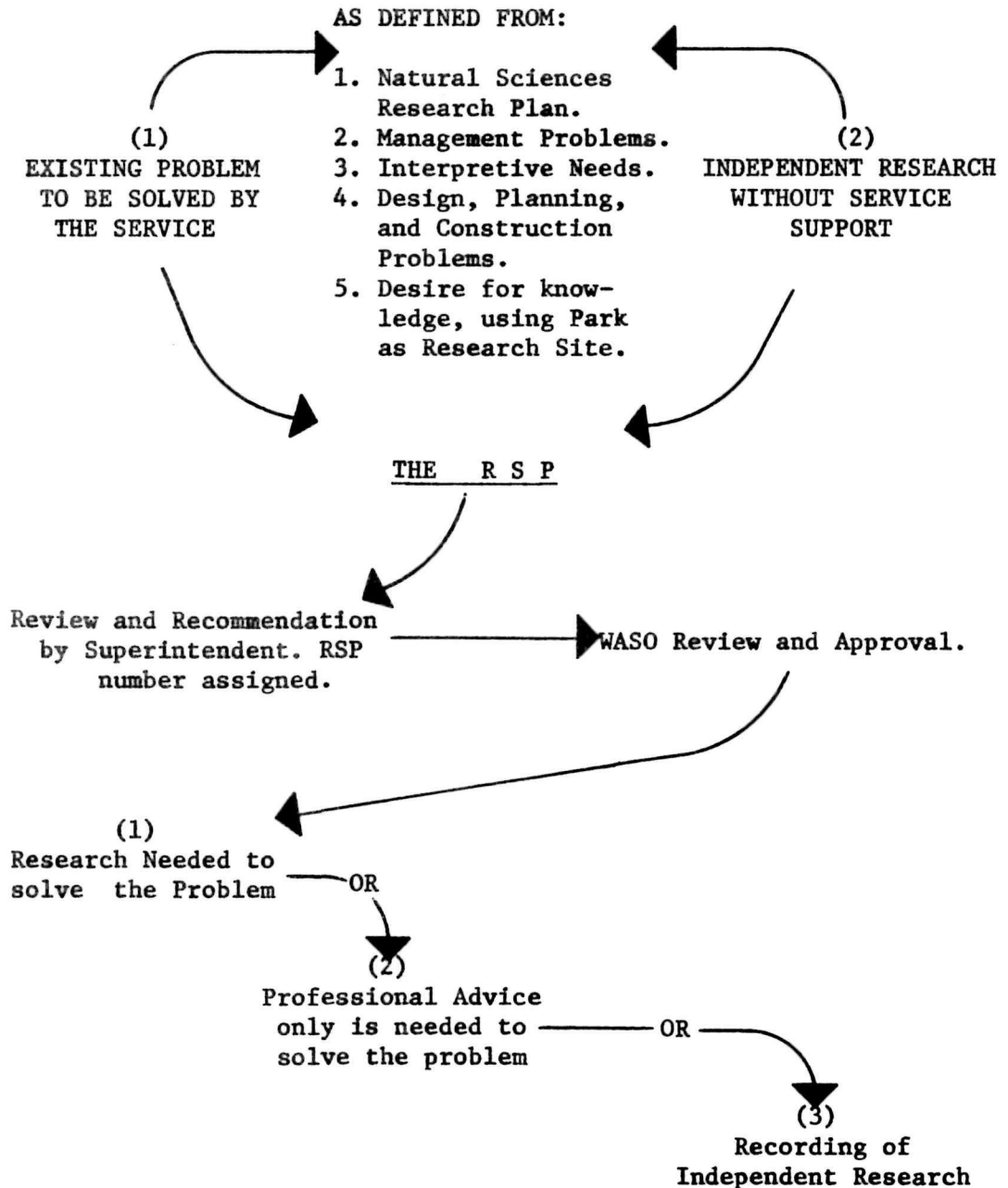
(Current collecting permit and collaboratorship requirements will be adhered to in addition to the RSP requirement.)

Concluding Remarks Concerning the RSP

It is important to remember that an RSP is required for each problem submitted for research support or for professional advice, and that an RSP is required to report the initiation of substantial independent research projects.

A summary of the RSP process is presented in the flow diagram on the following page.

Flow Diagram of RSP Process



THE NATURAL SCIENCES PROPOSAL

After reasonable assurance that funds are, or will soon become available for the proposed project, the Chief Scientist seeks one or more competent investigators from among Service personnel, other Government agencies, universities, etc., to prepare the research Proposal.

What it is

The Natural Sciences Proposal is a description of the job to be done, of how it will be done, of costs and time requirements, and of the purpose to be served. It is the "blueprint" of the investigative procedure to be followed.

Latitude in Choice of Format

Detailed step-by-step plans for the actual investigation should be spelled out in advance, recognizing that they may well be altered as the research proceeds. Often the precise direction of the next step will be dependent upon results obtained in an earlier phase of the study and the investigator must be in a position to make a judgment relative to the best course to pursue. The organization, quality, and other features of the proposal often give clues to the applicant's competence to execute the research and make such judgments as they become necessary. Before initiating a study, however, the scientist should have a sufficiently well-thought-out plan to permit delineation of the investigation's parameters and identification of the methods and techniques he expects to employ in achieving the research objectives.

Prescription of a rigid Proposal form is undesirable because it may hamper, or unduly assist, the individual's own efforts in planning and self-expression, and it may restrict the Service's opportunity for a comparative evaluation of submissions. The Service must clearly indicate the nature of the information required in Proposals, but permit maximum opportunity for individual initiative in expressing project concepts and proposed methods of project execution in narrative form.

How Many Copies to Submit

The original and nine copies (or 10 duplicated, mimeographed, or dittoed copies) of the Proposal should be submitted to WASO. Two copies are to be submitted to the Superintendent of the park at the same time. Additional copies may be required for Regional or Planning and Service Center offices; these will be requested by the Chief Scientist at the time he requests the Proposal from the prospective investigator.

What to Include

Proposals shall include adequate information concerning the following:

1. The Investigator. Name and organizational affiliation.
2. Title of the Proposed Study.
3. Description of the Research Project.
 - a. Summary of the Proposed Research (200 words or less).
 - b. The purpose of the study as understood by the investigator (200 words or less).
 - c. Detailed description of the work to be undertaken
 - (1) The objectives of the study; its expected significance and relation to similar or related work underway elsewhere or previously accomplished; supporting bibliography of pertinent literature.
 - (2) General plan of the work: description of the major lines of the investigation; the methods and techniques to be employed; and, where appropriate, the broad design of experiments.
 - (3) Outline, in the case of exceptionally complex and broad studies, of the various portions of the investigation, with identification of the individual who will be responsible for each portion.

What to Include (con.)

4. Research Personnel. List personnel, indicating qualifications, training, experience and list of pertinent publications of the principal investigator and any research associates, research assistants, etc., who will be professionally engaged in the project, together with the approximate per cent of time (academic or calendar year) which each expects to devote to it. The principal investigator will be responsible for direct supervision of the work and will participate, to some extent, in the conduct of the research irrespective of whether any reimbursement of his salary is received from Service funds.

5. Administration and Logistics of the Project.

- a. Include proposed starting date, expected duration, and logistic requirements of the project. The length of time for completion of a given phase of the project should be proportionate to its complexity, and ordinarily may extend to a maximum of three years. Usually, consideration for major support beyond the maximum three-year period should be based on the undertaking of an additional approved phase of the subject. In this case, the Proposal submitted for consideration of new support should be complete in all details and, in addition, should contain a reasonably comprehensive summary of the research accomplished with the earlier funding.
- b. Itemize major facilities and equipment already available for the project.
- c. Specify funds needed for project personnel salaries, by fiscal year. Salaries of non-Government scientists directly associated with the project may be considered as appropriate direct costs in proportion to the time each such individual expects to devote to the research. The proportion of this cost that shall be charged to Service research funds, and how much will be assumed by the institution or individual participating in the research, may vary widely, and will be established in the research assignment, agreement, or contract in accordance with the mutual interests and intended contributions of the respective participants.

What to Include (con.)

- d. Identify funds needed for project equipment, by fiscal year. Major items, including permanent equipment, shall be itemized and justified on the basis of their requirement in the research. Usually these will be limited to scientific equipment and measuring devices not already available for the project. Ordinary amounts of expendable equipment and supplies may be described in general terms, with estimated costs, but unusually large quantities and costs must be justified in detail. Typewriters, office furniture, air-conditioning equipment, motor vehicles, etc., ordinarily will not be approved for purchase with Service research funds.
- e. Travel Costs. The type and extent of travel and its relationship to the research should be specified in brief detail.
- f. Itemize other direct costs, such as equipment rental, aircraft rental, service charges, publications specifically related to the project, etc.
- g. Estimate funds needed to complete project reports. Costs of manuscript preparation, including necessary special arrangements for typing, drafting, photographs, etc., may be included. Requests for support of book or monograph publication usually will be considered as outside of and subsequent to the financing of the project itself. Approval will be dependent upon a professional evaluation of the completed manuscript as well as feasibility considerations.
- h. University or institution overhead charges may be permitted in accordance with existing Federal regulations covering this subject.

Assignments, Agreements and Contracts

After a Natural Sciences Proposal has been received and approved in the Washington Office, and funds are made available, an assignment, agreement, or contract (including Purchase Order) may be made immediately.

Assignments, Agreements and Contracts (con.)

An Assignment is made to National Park Service researchers. In this case, administrative clearances must be obtained from the investigator's supervisor. Arrangements should be made to provide "fill-in" personnel, as necessary, for those individuals whose normal duties are not primarily research activities.

An Agreement is normally made with other Federal or State agencies when personnel from such agencies are involved in proposed research projects.

A Contract is made with universities, colleges, and other institutions and, occasionally, with individual scientists.

Assignments, agreements and contracts will normally originate in the Washington Office. The Assistant Director, Resource Studies, will act as the Contracting Officer when contracts are made in the Washington Office. When delegated, contracts may be entered into at the park or regional level. In such cases, the Chief Scientist will normally recommend to the park or region the specifications which should be contained in the contracts. The intentions of the Natural Sciences Proposal and certain legally required clauses will form the substance of assignments, agreements or contracts.

RESEARCH REPORTS

This chapter discusses and provides guidelines for reports that are required for the administration of the natural sciences research program in the Service. There are three major reports as follows:

1. Superintendent's Annual Research Report, NPS(RN)-1, (Form 10-225) (Exhibit A), due in the Washington Office from each park on or before January 15th of each year.
2. Investigator's Annual Report, NPS(RN)-2, (Form 10-226) (Exhibit B), due in the park from each investigator (researcher) on Service-sponsored projects on or before January 1st of each year.
3. Final Research Report, due from the investigator upon completion of research project. (No form or exhibit; this chapter prescribes a format, however.)

In addition, Research Progress Reports from investigators are specified in Assignments, Agreements, and Contracts; Research Report Reviews (Exhibit C), are prepared by the Washington Office to transmit and interpret information from Final Research Reports to appropriate offices; and Professional Opinion Papers (Exhibit D), are prepared in the Washington Office in response to an RSP that does not require research.

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Research Reports

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Superintendent's Annual Research Report, NPS(RN)-1 (Form 10-225)

See other side of this sheet for Form 10-225. It faces the page containing instructions for filling it out.

Form 10-225
(April 1966)UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICESUPERINTENDENT'S ANNUAL RESEARCH REPORT
(Natural Sciences)RETURN TO: WASO (RN)
(No transmittal memo required)

Page 1 of 1 Pages

PARK Superb National Park	CODE S U P E
SUPERINTENDENT (Signature)	DATE January 1, 1967

RSP NO.	CATEGORIES AND TITLES	INVESTIGATORS AND INSTITUTIONS	CODE*					REMARKS
			A	B	C	D	E	
N-	CATEGORY A							
N-2	title	names of researchers and their institutions	1	1	7	61	95	
N-4	title	names of researchers and their institutions	1,6	4	10	63	100	Saltwater tech \$4,020/yr. 3 grad. students.
N-5	title	names of researchers and their institutions	3	4	?	66		researcher did not submit report; infor. incomplete.
N-	CATEGORY B							
N-1	title	names of researchers and their institutions	7	5	3	65	?	
N-3	title	names of researchers and their institutions	4	2	6	65	70	NASA-\$2,873,421/yr. USGS- 4 professionals.
N-	CATEGORY C							
N-I	title	names of researchers and their institutions	6	4	?	66	?	Blackwater tech (?).
N-I	title	names of researchers and their institutions	7	5	?	59	?	
N-I	title	names of researchers and their institutions	7	4	6	60	80	Bilgewater tech.
N-	CATEGORY D							
N-6	title	names of researchers and their institutions	1	4	0		0	
N-7	title	names of researchers and their institutions	1	1	0		0	
N-8	title	names of researchers and their institutions	3	3	2	67	0	Plan to initiates in March 1967.
N-								
N-								

* Place numbers in "A" through "E" blocks according to codes listed on reverse.

(DUE IN DIVISION OF NATURAL SCIENCES STUDIES (RN), WASO FROM EACH PARK ON OR BEFORE JANUARY 15 - SEE REVERSE FOR INSTRUCTIONS)

NATURAL SCIENCES RESEARCH
Research Reports
Superintendent's Annual Research Report, NPS (RN) -1 (Form 10-225)HANDBOOK
Chapter 8
Sample Form
Page 2a

NATURAL SCIENCES RESEARCH

Research Reports

Superintendent's Annual Research Report, NP&(RN)-1 (Form 10-225)

HANDBOOK

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Page 3

INSTRUCTIONS

SUPERINTENDENT'S ANNUAL RESEARCH REPORT

This report covers all natural sciences research for the calendar year ending December 31. It is due in WASO (one copy only—typed or legibly printed) on or before January 15 of each year. It is a list of research projects in the park, by categories as listed below. The investigator's Annual Reports should be stapled together with the Superintendent's Annual Report ON TOP. Whenever narrative statements are submitted with this report, such statements may be made as an addendum to the report rather than in a memorandum.. (Refer to the "Natural Sciences Research Handbook," chapter 8, for an illustration of a completed form.)

CATEGORY A: NPS-sponsored projects in progress, or completed during the year. (Each project listed for Category A is to be supported by the accompanying submission of an "Investigator's Annual Report" (Form 10-226), due from the project investigator to the superintendent on or before January 1 of each year.

CATEGORY B: Independent research, documented by RSP's. (Investigator's Annual Reports should also be obtained from as many investigators of Category B projects as possible, but these are not mandatory.)

CATEGORY C: Independent research not documented by RSP's; data from collecting permits, etc. Use a capital "I" in the RSP column, replacing the RSP number.

CATEGORY D: Proposed research, documented by RSP's, which has not been activated (for lack of funds, etc.).

For columns "A" through "E"—place numbers in "A" — "E" blocks according to the following codes. The other columns are self-explanatory.

COLUMN A: Funding Source (*may be more than one*)

1. NPS Resource Studies
2. Other NPS M&P
3. NPS Construction
4. Other Federal Agency*
5. State Agency (not university)*
6. University, College, Institution*
7. Personal

COLUMN B: Personnel (*may be more than one*)

1. NPS
2. Other Federal*
3. State Agency
4. University, College, Institution*
5. Individual--no affiliation
6. Other

COLUMN C: Status of Project (*use one number only*)

0. Proposed, but not started because of lack of funds
1. Proposed, funds available, but not allotted for some reason
2. Proposed, funds allotted, but actual work not started
3. Progressing, will continue for indefinite number of FY's
4. Progressing, will continue for 3 more FY's beginning next July 1
5. Progressing, will continue for 2 more FY's beginning next July 1
6. Progressing, will continue for one more FY beginning next July 1
7. Progressing, expected to be completed prior to next July 1
8. Field work complete, final report not submitted
9. Field work complete, final report in, awaiting approval
10. Project completed, including approval of final report

COLUMN D: FY That Project Began

Last two digits of year—55, 61, etc.

COLUMN E: Approximate Percent of Completion

(0—100) in actual work accomplished

* Specify exact source and amount of funds and/or personnel affiliation, if known, in "Remarks" column.

NATURAL SCIENCES RESEARCH
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Investigator's Annual Report, NPS(RN)-2 (Form 10-226)

See other side of this sheet for Form 10-226. It faces the page containing instructions for filling it out.

NATURAL SCIENCES RESEARCH
Research Reports
Investigator's Annual Report, NPS(RN)-2 (Form 10-226)

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Form 10-226
(April 1966)

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

INVESTIGATOR'S ANNUAL REPORT
(*Natural Sciences Research*)

This form is to be completed by the researcher and returned to the Superintendent of the Park by JANUARY 1. See reverse for additional instructions.

TO SUPERINTENDENT	PARK	REGION
----------------------	------	--------

1. Project Title

2. Name(s) of Researcher(s) and Institution(s)

3. Source(s) and Amount(s) of Funds Other Than NPS, if Any

4. Starting Date of Project	5. Percent Completion of Project to Date: _____	6. Est. Additional Time Required for Completion Beyond January 1st: _____ Years _____ Months
-----------------------------	--	---

7. Summary: (a) of progress; (b) of significant findings, if any, to date; (c) recommendations regarding future course, i.e., on basis of work so far, should it proceed as planned, be reoriented, expanded, reduced, time schedule and support level adjusted, etc.;

(Use Additional Sheets if Necessary)

8. Signature of Investigator	Date
------------------------------	------

9. RSP Number

				N			
--	--	--	--	---	--	--	--

NATURAL SCIENCES RESEARCH

Research Reports

Investigator's Annual Report, NPS (RN) -2 (Form 10-226)

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INSTRUCTIONS

INVESTIGATOR'S ANNUAL REPORT

(Natural Sciences Research)

This report is to be executed by ALL investigators (or project supervisors) of Service-sponsored projects; and by all independent investigators who INDICATE A WILLINGNESS to file the report. It summarizes project accomplishments; lists financial and completion expectations; and other administrative details that are needed for efficient administration of the research program.

It allows the investigator to summarize the information obtained during the previous "field" (summer) season, and permits him to anticipate his needs beyond the end of the current fiscal year.

1. BLANK FORMS will be sent to each researcher engaged in a going project on October 15 of each year.
2. REPORT FROM RESEARCHER--IN TRIPLICATE--due in the park superintendent's office by January 1 of each year. The superintendent keeps one copy.
3. SUPERINTENDENT'S ANNUAL RESEARCH REPORT (Form 10-225) and the original and one copy of the researcher's report are due in the Washington Office on or before January 15 of each year.

For further clarification, the following comments are offered:

- LINE 1 --- A brief title for the project.
- LINE 3 --- Optional, but useful to the Washington Office.
- LINE 5 --- Approximate percent figure is sufficient.
- LINE 9 --- Enter the RSP number--IMPORTANT for identification.

Research Progress Reports (no exhibit)

The form and content of research progress reports, when required, will be stipulated in contracts, assignments, and agreements. Report forms will be furnished to the investigator for this purpose.

Final Research Report (no form; no exhibit)

The investigator shall submit a final report upon the completion of the research project or a distinct phase of the study. A research project is not complete until all data collected have been analyzed and the findings included in the final report.

To facilitate its review and evaluation and to insure the inclusion of all elements of information, a final or major report shall be of a comprehensive nature and incorporate the following parts, when applicable: (1) Title; (2) RSP Number; (3) Author(s); (4) Date; (5) Abstract; (6) Contents; (7) Introduction; (8) Body of Report; (9) Discussion of scientific findings and conclusions with respect to the purposes stated in the Natural Sciences Proposal; (10) Literature Cited (or Bibliography); (11) Appendices; (12) Illustrations; and (13) Conclusions.

1. Title. The title should be descriptive, clear and brief. It should identify the subject matter and, normally, the park involved. It need not be exactly as stated on the RSP form.

2. RSP Number. Please place in upper right corner of title page. This number follows the project from the time of its conception to its completion in the final report. It is sometimes the only means by which the identity of a report can be positively established.

3. Author(s). The name, title and affiliation of the author(s) should follow the title. Authorship provides credit and responsibility for the research, discussion and conclusions.

4. Date. Date of submission of the report.

5. Abstract. The abstract is the factual summarization of the contents and conclusions of the report. It should include the

Final Research Report (con.)

salient facts discussed in the report, and the conclusions reached in relation to the research objectives. The abstract is the author's opportunity to state in a condensed style the contributions of the research project. It should be as brief as possible, yet cover the subject in clearly written style so that, standing alone, it tells the reader what the project was about, and what conclusions were made.

6. Table of Contents. Unless the report is short, a Table of Contents should follow the Abstract.

7. Introduction. The following elements should be included in the introduction: the purpose(s) of the investigation(s); conditions under which the study was conducted; the general plan of treatment of the subject; summary of previous work accomplished which relates to the project; acknowledgment of individuals who assisted with the project or participated in it.

8. Body of Report. The main body of the report describes the methods used in the conduct of the study, and presents the observations and data acquired from the investigations.

9. Discussion. Discussion, conclusions and summary of findings of the research project, with special attention to the purposes for which the study was made.

10. Literature Cited (or Bibliography).

11. Appendices (when needed). Contain supplementary supporting materials not contained in the main body of the report.

12. Illustrations. Photographs, maps, charts, graphs, and tables used as necessary to illustrate the subject matter may be presented at any appropriate place within the report.

13. Conclusions. Findings and conclusions of general interest to the scientific community. Recommendations may be submitted when appropriate or required. Recommendations of the investigator involving policy or specific management procedures will be covered by a special report, separate from the scientific report.

Final Research Report (con.)

The investigator submits the original and one copy of the Final Research Report via the Keyman to the Chief Scientist, or, if there is no Keyman, directly to the Chief Scientist in the Washington Office. The copy is retained by the Keyman. The investigator also submits a copy to the park where the research was undertaken. The Keyman and/or the Chief Scientist examines the report to determine that it does, in fact, constitute completion of the agreement or contract.

NATURAL SCIENCES RESEARCH
Research Reports

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Research Report Review (Form 10-227)

See other side of this sheet for Form 10-227. It faces the page containing instructions for filling it out.

NATURAL SCIENCES RESEARCH
Research Reports
Research Report Review (Form 10-227)

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Form 10-227
(April 1966)

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

RESEARCH REPORT REVIEW
(Natural Sciences)

PARK	REGION
1. Author(s)	2. Date of Report
3. Title of Report	
4. Publication Reference	
5. Brief Abstract	

6. Implications of Results, or Investigator's and/or Chief Scientist's Recommendations to the Service Based Upon Report Conclusions *(Use Additional Sheets if Needed):*

7. Copies of Report and Review to:			Reviewed By
a. Research Report File	d. _____	h. _____	Date
b. Park	f. _____	i. _____	
c. Region	g. _____	j. _____	
8. Application of Research Results <i>(List actions or programs initiated as a result of this research, values of research to the Service, etc. Use additional sheets if needed):</i>			

9. RSP Number

				N			
--	--	--	--	---	--	--	--

(SEE REVERSE FOR INSTRUCTIONS)

Release No. 2

April 1966

INSTRUCTIONS

RESEARCH REPORT REVIEW

1. When the Final Research Report is received in the Washington Office, acknowledgement is made by letter to the investigator as soon as possible.
2. A Natural Sciences staff member then reviews the report in depth, and abstracts the salient information onto this form.
3. The Chief Scientist may make recommendations, on this form, to the Service concerning the application of research results.
4. Copies of the completed form are transmitted to the park, region, and appropriate divisions at WASO. A copy of the Final Research Report is permanently retained, along with the review form, in the Natural Sciences Research Report File at WASO. Other copies of the Final Research Report are transmitted to those branches or divisions that have need for the research data, as well as to the region involved.
5. Park, region and/or other offices should notify the Division of Natural Sciences Studies in WASO of actions taken to apply these research results. The Division at WASO then makes notation of such action under item 8 on Form 10-227. This may take place at any time after the initial review has been made.

Professional Opinion Paper (Form 10-228)

The next page is a sample of Form 10-228, Professional Opinion Paper. Instructions for its use appear on the form itself.

NATURAL SCIENCES RESEARCH
Research Reports
Professional Opinion Paper (Form 10-228)

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Form 10-228
(April 1966)

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

PROFESSIONAL OPINION PAPER

Upon receipt in WASO of an RSP that does not require research to solve the problem, the Chief Scientist seeks the best professional advice available to him. (This may be obtained from one or more scientists or other professional persons from within, or outside of, the Service.) When sufficient information is available, the Chief Scientist approves a statement of professional opinion on this form. The completed form is transmitted to the Director, Regional Director, Superintendent, and other offices concerned.

TO: DIRECTOR		FROM: ASSISTANT DIRECTOR, RESOURCE STUDIES	
PARK		REGION	
1. Title (<i>As in RSP</i>)		2. Date of this Report	
3. Statement of Problem (<i>Use additional sheets if necessary</i>)			

4. Statement of Professional Opinion (*Use additional sheets if needed*)

5. Opinion By		Title	
6. Approved (<i>Chief Scientist</i>)		Date	
7. RSP Number			

				N				
--	--	--	--	---	--	--	--	--

APPENDIX A

NATURAL SCIENCES RESEARCH HANDBOOK



ISLE ROYALE NATURAL SCIENCES RESEARCH PLAN

AN EXAMPLE OF A PARK NATURAL SCIENCES RESEARCH PLAN

ISLE ROYALE



Natural Sciences Research Plan

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
Washington, D. C. 20240

ISLE ROYALE NATIONAL PARK
NATURAL SCIENCES RESEARCH PLAN

Edited by:

Robert M. Linn, Research Botanist,
Lowell Sumner, Research Biologist,
and George Sprugel, Jr., Chief Scientist,
Division of Natural Sciences

Approved:

Howard R. Stagner
Assistant Director, Resource Studies

March 1966

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INTRODUCTION

Planning for natural science research in the national parks requires thorough evaluation of past and present resource conditions in order to effectively supply park administrators with the information that they need for wise administrative decisions affecting the natural areas for which they are responsible. Such information is essential to the interpretation as well as to the restoration and management of park resources. It is essential, too, for the development of an overall Service natural sciences research program, for the establishment of funding priorities and for budget planning purposes. Finally, the information will be of certain usefulness to prospective researchers and to individuals responsible for developing and supervising research at the park level.

The purpose of this Park Natural Sciences Research Plan is to broadly outline the fields in which natural science research is needed to meet the above-mentioned park requirements. In doing so, it identifies pertinent investigations already accomplished or underway in the park, establishes general patterns for obtaining the additional needed information, and indicates the broad content and dimensions of the natural sciences research program required by the park.

This Natural Sciences Research Plan was prepared in accordance with the Service's Natural Sciences Research Handbook, which outlines in further detail the basic philosophy and the specific procedures to be followed in connection with the natural sciences research program.

Participants in the preparation of the Isle Royale National Park Natural Sciences Research Plan, or in the on-site discussions associated with its development, included:

C. E. Johnson, Superintendent, and staff, Isle Royale National Park, Houghton, Michigan.

Peter A. Jordan, Department of Forestry and Conservation, Purdue University, Lafayette, Indiana.

Louis A. Krumholz, Professor, Department of Biology, University of Louisville, Louisville, Kentucky.

Alton A. Lindsey, Professor of Plant Sciences, Department of Biological Sciences, Purdue University, Lafayette, Indiana.

Robert M. Linn, Research Botanist, National Park Service, Washington, D. C.

Murray H. Nelligan, Resource Studies Advisor, National Park Service, Northeast Region, Philadelphia, Pennsylvania.

Robert H. Rose, Research Geologist, National Park Service, Washington, D. C.

Kiril Spiroff, Professor of Mineralogy, Department of Geology and Geological Engineering, Michigan Technological University, Houghton, Michigan.

George Sprugel, Jr., Chief, Division of Natural Sciences, National Park Service, Washington, D. C.

Lowell Sumner, Research Biologist, National Park Service, Washington, D. C.

O. L. Wallis, Aquatic Research Biologist, National Park Service, Washington, D. C.

ABSTRACTPurposes and Objectives of Park

The primary purpose of Isle Royale National Park is the preservation of an undisturbed northwoods, northern lake, island wilderness, isolated from mainland influences by the waters of Lake Superior. It provides an outstanding opportunity for visitors to experience these wilderness qualities, and further provides an ideal outdoor laboratory for the study of natural communities and environments.

The major resource management objective is to maintain ecological conditions as nearly as possible like those that would prevail if man were not, and had not previously been, present. The interpretation of such natural ecological conditions is taken to be the primary objective of interpretive activities.

Resource Characteristics

Geography: Isle Royale is located in the northwestern quarter of Lake Superior, which is the world's largest body of fresh water. The island is about 45 miles long and up to 8 miles wide, constituting a land area of about 210 square miles. Its long axis trends southwest to northeast with many ridges and valleys parallel to this orientation. Two hundred and two lakes and ponds occur in the valleys.

Geology: Precambrian rock layers of over 1 billion years of age form the Isle Royale archipelago. These layers are the result of successive volcanism, sedimentation, uplift and erosion. From Cambrian Times to the initiation of the Pleistocene, erosion was the major force, reducing what must have been a towering highland. During the Pleistocene, several glacial advances composed of ice sheets a mile or more in thickness, ground, polished, scored and plucked the rock layers. Some glacial deposits were made by the ice, but Isle Royale emerged from the glacial era largely denuded of loose material. The postglacial lakes covered Isle Royale completely at first, then in successive stages the waters subsided to reveal the present islands, leaving ancient beaches stranded high on the ridge slopes. The thin youthful highly organic soils have all developed since subsidence of the postglacial lakes.

Climate: In general, the island's climate may be characterized as cool-moist summers and cold-snowy winters. Within this generality, those areas near Lake Superior are cooler and more moist than interior areas which obtain higher summer temperatures with greater water loss through increased evaporation, evapotranspiration, and runoff. The data so far collected and analyzed are sufficient only to suggest that additional macro- and micro-climatic data are needed in order to justly characterize the present climate of Isle Royale.

Vegetation: There are two major climax forest types on Isle Royale: the Boreal Conifer formation consisting largely of white spruce, balsam fir, paper birch, aspen, and mountain ash; and the Northern Hardwood-White Pine association of the Eastern Deciduous forest formation, consisting largely of sugar maple, yellow birch, and white pine. The Boreal Conifer formation occurs in proximity to Lake Superior as a result of the cool-moist lake water influence and the Northern Hardwoods occur in inland-upland areas where the lake influence is diminished.

Successional stands of paper birch, aspen, white pine and jack pine occur in many areas as a result of fires and windthrow. Some of these, particularly paper birch, white pine and jack pine are subclimaxes of long duration.

Northern bogs and swamp occur in most valley areas between the long parallel ridges. The bogs are found in every stage of succession from youthful to senescent.

Moose and beaver browsing pressures influence natural successional changes--often delaying the advent of climax, but, in turn, the timber wolf ameliorates these pressures.

Fauna: The Isle Royale fauna is an isolated one. This produces a faunal complex that lacks some mainland elements as well as containing unique forms which have evolved separately from mainland counterparts. Moose, beaver, timber wolf, snowshoe hare, red fox and red squirrel are the most abundant and important mammals. The wolf exerts a restraining influence on the moose and beaver populations--populations that have undergone wide numerical fluctuations in previous years when no timber wolf population was present. The browsers (moose, beaver and others) also exert significant pressures upon the plantlife; especially aspen, paper birch, mountain ash, balsam fir, and ground hemlock. These plants undergo decreases whenever moose and beaver populations explode, and increases whenever moose and beaver decrease. The wolf tends to ameliorate all of these fluctuations.

Lynx, marten, coyote and caribou were all present on Isle Royale until rather recent times. Causes for their disappearance are uncertain, although the coyote conspicuously disappeared as the timber wolf arrived and increased.

Most birds capable of sustained flight that exist in nearby mainland areas are found at Isle Royale. The most conspicuous birds are the herring gulls who occupy many offshore rocky island rookeries. There are only 9 amphibian and 3 reptilian species present in the park.

Aquatic Communities: The waters of Lake Superior are cold and clear, and support numerous forms of lake trout, whitefish, ciscoes and others. The sea lamprey has invaded these waters in recent years, depleting especially the commercially valuable lake trout.

Two hundred and two inland lakes on the main Isle Royale exhibit a variety of sizes and kinds--dystrophic, eutrophic, and oligotrophic.

There are 55 or more species and varieties of fishes in Isle Royale waters. Three of these (sea lamprey, rainbow trout and alewife) are exotic. The largest, most abundant inland lake fish is the northern pike. Others include yellow perch, walleye, lake trout, rainbow trout, brook trout and pumpkinseed.

Beaver, moose and forest fires all have important influences on the aquatic habitats, but most of these influences are as yet incompletely known or understood.

Needed Research

Isle Royale is almost unique among national parks in being effectively isolated from the majority of potentially serious, man-caused, modifying activities and conditions of surrounding areas. Moreover, the island is large enough to be, under these conditions of isolation, a self-regulatory ecological unit.

Unnatural changes have been few and comparatively superficial. Thus, in this park, it is possible to identify and document the current natural status of the park resources in advance of unnatural trends and developing situations which might adversely affect these resources if permitted to occur.

More than 30 "Problem-Research Needed" areas are identified in this first edition of the Isle Royale Natural Sciences Research Plan. These areas of inquiry are designed to obtain information essential to maintain, restore where necessary, and interpret the natural environments and ecological relationships of the entire biota, together with the associated primitive wilderness atmosphere.

PURPOSES AND OBJECTIVES OF PARK

H.R. 17005, providing for the establishment of Isle Royale National Park as an area " * * * set apart as a public park for the benefit and enjoyment of the people * * *," was approved by President Hoover on March 3, 1931.

The National Park Service Master Plan for the Preservation and Use of Isle Royale National Park identifies the park's primary contribution to be the preservation of " * * * an outstanding example of undisturbed northwoods lake wilderness--a vignette of primitive America." The Master Plan continues: "The Park provides an opportunity for visitors to experience the scenic beauty, the unique natural features, and the inspirational qualities of an island wilderness isolated from mainland influences by the waters of Lake Superior. It further provides an outdoor laboratory for research programs in the natural sciences that can be conducted satisfactorily only under protected and isolated conditions such as are found here."

Resource Preservation and Use Objectives

The Master Plan states, "The mandate of the National Park Service at Isle Royale is to conserve the Park so that the significant resources and values that visitors derive from it remain unimpaired, yet available, for the benefit and enjoyment of present and future generations." In interpreting the substance of other appropriate documents, management of the significant natural resources is understood to be oriented to: (1) assuring a minimum of man-induced interference with the natural processes associated with the evolution and maintenance of the park's wilderness features, and (2) restoration of the flora and fauna, insofar as is feasible and compatible with natural biological developments, to the state which obtained when European man first visited Isle Royale (probably in the early 17th century). The major portion of Passage Island is expected to be designated and managed as a natural science research area.

The major natural resources of the park are:

1. Aquatic - including inland lakes, appropriate portions of Lake Superior, streams, bogs and marshes, and the plant and vertebrate and invertebrate animal life found therein.

2. Animal life - including the very important wolf-moose complex, birds, and other terrestrial forms, all of which play a role in maintaining the ecological balance of the park.

3. Plantlife - including relict plant communities and all other earlier or current terrestrial vegetation so vital in determining the presence and welfare of the faunal elements.

4. Geological features - including visible structural and substrate evidence of the processes, other phenomena and materials associated with the geological development of the park and its present topographic and subterranean features, various mineral deposits, and soil characteristics.

The greatest value that visitors are likely to derive from a visit to Isle Royale is the experience of association with forest vegetation, animals and water in a completely natural wilderness setting. Similarly, the great scientific value of the park is the presence of the unspoiled wilderness conditions which permit the study of natural processes relatively uncontaminated by unnatural influences. Management procedures to preserve these values are quite compatible and, for the most part, can be restricted to managing of human activities such as to permit nature to take its course. The contributions of science through analyses of these natural processes will provide sound bases for determining the management steps which should or should not be taken in the event of natural catastrophic disturbance of the resource. Conversely, this knowledge will permit identification of actions which are needed to assist nature in its recovery from man-produced alterations of the environment.

Active management of natural resources on Isle Royale may be thought of as being largely oriented to taking positive action on the relatively few exceptions to nature in balance. However, the park offers exceptional opportunities for actively broadening and intensifying the visitor's wilderness experience by providing sound explanations in depth of the natural forces at work. The interpretive subobjectives associated with a goal of making Isle Royale the outdoor classroom for teaching an understanding of the north-woods lake wilderness ecosystem are many and varied.

In general, and aside from developing suitable methods for presenting the information to the visitor, the research objectives include establishing accurate knowledge of: the identity, distribution and life history of each terrestrial faunal and floral element;

the physical and biological characteristics of all aquatic ecosystems; the identity, origin and distribution of major geologic features; and, finally, the interrelationships between each resource element and the others.

Below is a more explicit and illustrative list of management objectives, based upon the purposes and objectives of the park:

1. To maintain ecological conditions as nearly as possible like those that would prevail if man were not, and had not previously been, present (Natural Ecological Conditions--NEC).

2. To maintain NEC of spruce-fir, sugar maple forests, and other ecosystems, allowing full play of natural ecological factors, and curtailing factors introduced by man and man's civilization.

3. To maintain NEC of animal populations, including the moose and wolf populations and their dynamic equilibrium, in such a way as to allow little or no interference from man, except, perhaps:

- a. if the north shore of Lake Superior should become hostile to wolf and moose populations and/or for their free immigration-emigration potential to and from Isle Royale, and
- b. if the entire wolf population of Isle Royale should, by circumstance or combination of circumstances, be threatened by an emigration that would, because of (a) above, not have reasonable chances of eventual correction by reverse emigration, then:
- c. management techniques to retain the wolf population upon Isle Royale, with least artificial appearances and results should be employed.

(The moose population, while subject to the same possibility, stands less chance of such circumstances occurring because moose do not band and travel together to the same degree as do wolves; hence, a mass migration of most or all of the moose is extremely remote.)

4. To reintroduce extirpated species when it can be definitely established that the species disappeared because of man and/or man's activities, when it can be determined that the ecosystem from which the species disappeared has not sufficiently changed to preclude

successful reintroduction, when it can be determined that the species being introduced will not adversely affect the ecosystems which have developed differently because of their extirpation, and, when it can be determined that species newly arrived by natural means will not be adversely affected.

5. To maintain the NEC of inland lakes and streams. Thus far, these are in reasonably pristine condition. Except at Isle Royale, there are few small lakes and streams in conterminous U.S.A. in which effects of past introductions and extirpations are not observable. Some of the fish fauna are unique to the lakes in which they are found.

6. To maintain the NEC of unique populations of devilsclub and thimbleberry. Their community and species ecology should be well documented so that their values to science and park interpretation will not have been lost should climatic and/or edaphic conditions change in such a way as to preclude the continued existence of these unusual populations. Devilsclub, especially, exists here in a very restricted environment, and will need special protection from human interference.

7. Interpret the Isle Royale ecosystems in sufficient detail so that park visitors will have a general but sound knowledge of how the natural environment operates.

A. GEOGRAPHY

Isle Royale lies in Lake Superior at latitude 48°N. , and longitude 89°W. , the northernmost point in the State of Michigan. The Ontario and Minnesota shores are about 15 miles away to the closest point. The island is, thus, slightly north and east of the center of the North American continent.

Isle Royale is about 45 miles long and eight miles wide at its widest point; the long axis trends roughly northeast to southwest. Several ridges parallel its long axis, extending into Lake Superior at both ends of Isle Royale in the form of many smaller islands. Thus, the park consisting of a number of islands is an archipelago. Between the ridges lie valleys containing many inland lakes, numerous swamps, and ponds (202 lakes are listed for Isle Royale by Humphrys and Green, 1962; of these, 162 are over one acre in area). Streams, mostly small, sluggish and sometimes intermittent, drain from them. Larger streams are few in number. The coastline is mostly rocky and rugged with some gravelly portions. Few sandy beaches are to be found. Many bays and harbors jut inland from Lake Superior; one, Rock Harbor, is approximately 14 miles long and, by virtue of anchorage and inshore depth, length and generally large size, and good protection from winds and storms, has been proclaimed the best natural harbor on the Great Lakes.

Much of the land itself is generally thin-soiled with numerous rock outcrops although valley areas and southwestern interior locations have deeper soils. There is an almost continuous and rather dense vegetation characterized by Boreal Conifers in near-lake areas and by Northern Hardwoods at inland locations. The climate is typically mid-continental, tempered by Lake Superior, so that summers are cool and moist, and winters cold and snowy. The fauna contains moose, wolves, beaver, snowshoe hare, and other northern animals.

Isle Royale is a wilderness island complex surrounded by the world's largest fresh-water lake, and, as yet, is relatively free from air and water pollution. There are no year-round residents and the grimmer aspects of civilization do not appear to be in attendance.

B. GEOLOGY

The Geologic History of Isle Royale

Precambrian History

Nearly everywhere on Isle Royale the Precambrian rock layers are exposed or are but a few inches below the soil surface. The Precambrian formation is, therefore, of great importance to the interpretive story and to the ecosystems themselves. Very little has been done to adequately define or describe the Precambrian of Isle Royale, although mine exploration drill cores from southwest Isle Royale were among the first evidences of the general Lake Superior geological history. The most comprehensive description of Isle Royale geology in relation to the general Lake Superior situation is that of Robert G. Johnsson, 1960, "A Natural History of Isle Royale National Park," pages 4-87, plus figures. Johnsson's description of the formation of the Lake Superior Basin is based largely upon the theory of Hotchkiss (1923). This theory has not been proven and is disputed by many geologists as not representing the true situation. The following discussion is largely based upon Johnsson's unpublished manuscript.

Three and one-half billion years ago the area now occupied by Lake Superior appears to have been a flattish, featureless plain, composed of basaltic lava rock layers of Keewatin times. No life forms had yet evolved from the sea to populate the land.

Subsequently, the Laurentian Mountains were formed by uplift and volcanism. They were reduced by erosion and this was followed by another uplift and more volcanism to form the Algoman Mountains. These, too, eroded and the remaining plains were invaded by the early Huronian waters--the Animikie Sea.

The middle Huronian was marked by the formation of a dome-like uplift, ellipsoidal in outline, caused by tectonic pressures from below. The dome elevated 4000 or 5000 feet above the surrounding plain, producing a highland structure that was subject to increased erosion. Finally, in the late Huronian, silica-rich (felsitic) lavas erupted from the dome's center, building a highland of volcanic mountains.

The felsitic highland eroded during the early Keweenaw, followed by another series of eruptions, of basic lavas, in the middle Keweenaw. Basaltic lavas spread out over the felsitic sediments, and erosion continued in its endless quest. Finally, the magmatic chamber was emptied of its molten material and the resultant empty chamber could no longer support the great weight of the overburden. The chamber collapsed; the dome gradually became a basin.

Either as a result of the warping of rock layers or as a result of lateral or other forces, faulting occurred along the northwest and southeast edges of the basin. The northwestern faulting resulted in a sharp dropoff along the southeastern edge of the Keweenaw Peninsula. Between these two major fault lines, the rocks dipped to the center of the Superior basin. The upturned and faulted edges of the basin form the present Isle Royale and Keweenaw Peninsula.

As mentioned earlier, the formation of a dome which later collapsed to form the Lake Superior basin is only one theory to explain the present situation. Other theories would omit the necessity of the dome-basin event and substitute relatively simple uplift to explain the Keweenaw fault to the southeast and the Isle Royale fault to the northwest. These uplifted edges would then contain the present Superior basin between them. There is some evidence on Mott Island, Isle Royale, to refute the dome-basin theory; pipe amygdulites that indicate lava flows toward the Superior basin, rather than toward the basin edges; crossbedded conglomerates that definitely indicate that deposition took place upon a lava bed already dipping to the southeast toward the present basin's center.

Also, on the Keweenaw Peninsula there are indications that the Nonesuch Shale, currently dipping to the northwest, was tilted subsequent to its formation, but prior to the formation of the Freda Sandstone. This tilting event occurred after the present Isle Royale layers were formed. If this is true, then it would seem necessary to explain Keweenaw Peninsula geology separately from the Isle Royale geology since their respective faulting and tilting must have occurred at widely different times.

The following is a statement by Spiroff (1965) presenting a slightly different view concerning the formation of Isle Royale:

"In the last stages of the Precambrian era there are evidences that there was a 'warfare' between the volcanic and sedimentary forces of nature.

"For a time there was a series of basic lava flows that poured out over the area, then the volcanic activity would stop and gravels and sands were washed over and covered the lava flows. Once again the volcanic activity was reactivated and flowed over the gravels. Thus, the activity was repeated many times.

"Due to the tectonic forces that created a crustal disturbance in the Lake Superior Region, a fracture zone developed to the north of the island and the island was elevated. The compacted sands, gravels and lavas were also cracked and fractured. Along these fractures many minerals were deposited, native copper being the most conspicuous, while in the gas cavities (visicules), greenstones (Chlorastrolites), Prehnite, Thomsonite and agates were formed.

"The area being on the surface was subjected to erosion and weathering; the rocks formed soil, but whether the island had been submerged again is not known, for glaciers have completely obliterated the story.

"How high were the hills, and how they looked will never be known, because the glaciers not only removed the soil but, also, the ice plucked, grooved, and polished the resistant rocks, completely changing the appearance of the island; the hard rocks formed ridges while the soft rocks formed valleys. In places the last glacier left a mantle of material from the Canadian mainland.

"When the ice melted, it formed a huge lake. As the lake was drained and became smaller the wave action cut beaches and deposited gravel banks on favorable exposed areas of the island and somewhat modified the topography by filling in the valleys."

There is, then, disparity of thought concerning the formation of the Lake Superior basin--disparity that can be resolved only after considerable research has revealed the true events.

Life in Precambrian Times

Living organisms have evolved to their present highly complex forms largely since Precambrian times. That life systems began during the Precambrian is a theoretical necessity, but not until recent years have techniques been devised to substantiate the theories.

Attention is directed to Barghoorn, Meinschein and Schopf's paper, "Paleobiology of a Precambrian Shale," Science 148:461-472, April 23, 1965. The authors investigated shales of the Nonesuch formation of late Keweenawan age (1046 ± 46 million years BP, based upon rubidium-strontium ratios) in the White Pine area of Northern Michigan just south of Lake Superior.

Their summary follows:

"Investigations have been made of crude oil, pristane, phytane, sterane-type and optically active alkanes, porphyrins, microfossils, and the stable isotopes of carbon and of sulfur found in the Nonesuch shale of Precambrian age from Northern Michigan. These sediments are approximately 1 billion years old. Geologic evidence indicates that they were deposited in a near-shore deltaic environment. Porphyrins are found in the siltstones but not in the crude oils of the Nonesuch formation--evidence that these chemical fossils are adsorbed or absorbed and immobile. This immobility makes it highly unlikely that these porphyrins could have moved from younger formations into the Nonesuch sediments, and the widely disseminated particulate organic matters and fossils in this Precambrian shale are certainly indigenous.

"The thermal stability of the Nonesuch porphyrins adds support to the concept of low-temperature emplacement of the copper minerals in the deposit. The concatenation of geologic, geochemical, and micropaleontological evidence strongly indicates that the organic matter, including the crude oil of the Nonesuch deposits, is an indigenous product of primary photosynthetic processes operating in Nonesuch time."

The Nonesuch shale formation does not occur on Isle Royale, and this evidence of life from the Precambrian may or may not indicate that similar evidence can be found in any of the Precambrian formations that do occur on Isle Royale; however, it does point up the fact that this new area of micropaleontology, and other new areas of inquiry as yet undeveloped, can bring forth knowledge and truth of inestimable value to science and mankind. To protect and conserve the basic materials for such future inquiry would be a monument to a farsighted conscience.

More Recent Geologic History

The previous discussion concerned mostly the formation of the Superior basin and its various rock layers. This formation took place over a period of nearly 1 billion years beginning about 1,200 million years BP (Before Present) in Keweenawan times and ending 500 million years BP in the early stages of Cambrian times. There seems little evidence for what may have taken place between this period of geologic activity in the Isle Royale area and the well-documented Pleistocene, beginning only 1 million years BP. The never-ending processes of erosion, of course, continued down through these long ages, reducing what must have been a tremendous highland area to the present relatively mild topography.

The Pleistocene Epoch

About 30 million years ago, earth atmospheric temperatures began to decline, culminating about 1 million years ago in the initiation of the several ice ages known as the Pleistocene Epoch. Ice accumulated to the north of the present Great Lakes area as a result of continuous snows and few periods of melt. The resultant glaciers covered the area at four different times during the past million years, each followed by a period of glacial deterioration. The most recent glacial advance, which had retreated by about 9,000 to 10,000 years BP, obliterated any evidence of conditions between the previous glacial advances. However, the interglacial periods of the Pleistocene lasted for tens of thousands of years; and, when these are compared to the present interglacial of only 10,000 years, it becomes reasonable to suppose that very well-developed ecosystems must surely have covered what is now Isle Royale during these times.

Direct evidences of the glacial advances over Isle Royale are numerous: glacial striae and grooving, formation of bog lake depressions, and depositions of glacial drift on southwestern Isle

Royale. The direction of glacial advances over Isle Royale and vicinity were generally northeast to southwest, in conformity with the landscape already present. While glaciation thus greatly augmented erosion, it may not have altered the general configuration of the island.

There is also evidence for glaciation during the Precambrian and/or early Cambrian (Murray, 1955; Schenk, 1965) but much remains unknown of this fargone period.

Postglacial Isle Royale

As the last glacial cover melted away, various "postglacial lakes" were formed along the glacial border. Glacial Lake Nemadji occurred just south of the present city of Duluth and drained southward through the St. Croix River to the Mississippi system. At this time, about 10,000 years BP, ice still covered most of the area now occupied by Lake Superior.

About 9,000 years BP, Glacial Lake Duluth lay in what is now western Lake Superior, still utilizing the St. Croix outlet. Isle Royale became icefree during the later stages of Lake Duluth, but the waters entirely covered it. As the ice further retreated, the St. Croix outlet was abandoned and a new outlet, the Au Train-Whitefish, was formed connecting Lake Duluth with the Post Algonquin Lake which occupied what is now Lakes Michigan and Huron, the outlet for these being via the Trent River in Ontario into the St. Lawrence Sea. It was at this time, about 8,000 YBP, that Mount Desor, highest peak on Isle Royale, began to emerge from the post-glacial waters. The Post-Duluth stages of Lake Superior clearly left their imprint as several ancient beach lines near the summit of Mount Desor.

During all time since glaciation the land of the upper Great Lakes has been rebounding in response to release from the great weight of the ice. The rate of rebound is rather startling: southshore Lake Superior is rebounding at about 7.8 inches per century; northshore Lake Superior at about 20 inches per century. In terms of Isle Royale, the northeastern end rises about 15.7 inches per century; the southwestern end about 12 inches per century. The differential uplift is the result of the more recent release from ice burden in the north as compared to the south. This rebounding and the formation of different postglacial lake outlets of the past 10,000 years has led to various stages of lake levels which have left ancient beach lines upon Isle Royale.

The Minong Stage [quoted from Johnsson (1960)]

"The retreat of the ice continued until a still lower outlet for the Michigan and Huron basins was opened by the northward moving glacier. Water drained through a lowland near the present site of North Bay, Ontario. From there it flowed into the Ottawa River and eventually discharged into the salt water embayment of the downwarped St. Lawrence Valley. The outlet was so low that only the deepest portions of the Michigan and Huron basins retained water.

"Lake Michigan, for example, dropped in level to about 350 feet below its present stage, and actually fragmented into two lakes. This lowest stage of the Michigan basin has been named Lake Chippewa. Lake Chippewa drained via the Mackinac Straits into a still lower stage in the Huron basin--Lake Stanley--which stood about 400 feet below the present level of Lake Huron.

"The waters of the Superior basin drained via the St. Marys outlet into Lake Stanley, and the Superior basin undoubtedly underwent a similar very low stage. This stage has been referred to as the Minong Stage because of its very prominent development on Isle Royale.

"The exact level of the Minong Stage is unknown. It would depend, of course, on the level of the St. Marys outlet at the time, for it was the outlet--then, as today--which controlled the level of the lake. Geologists consider it a reasonable estimate that the outlet, and hence the level of the lake, was at least 300 feet below its present height.

"The reader should be very careful at this point to keep the fact clearly in mind that while the St. Marys outlet was considerably lower at this time, so also was the rest of the Superior basin. The entire basin has been uplifted many hundreds of feet since Minong time, although not equally in all its parts. In view of this it should be easily understood that the shore built by the Minong Stage of the lake is not necessarily to be expected to occur below the present level of the lake. The fact of the matter is that it is found considerably above the present lake level.

"The Minong shoreline is exceptionally strongly developed on Isle Royale, and must therefore, have been produced by a very stable phase of the lake. The shore features show the effects of enduring and intense wave action, and one cannot help but be impressed by their magnitude. The Minong shore is easily the most strongly developed shoreline on Isle Royale, equalling and perhaps even exceeding the present shore in its degree of development.

"The park visitor may get some idea of this ancient shoreline by climbing the Greenstone Ridge on the Lookout Louise Trail. A half mile up the trail from its head on Tobin Harbor one encounters a veritable field of giant boulders and water-worn rocks. He soon comes upon the spectacular Monument Rock--a 70-foot sea stack of impressive aspect. It is undoubtedly the finest example of such a structure in all of the Great Lakes region. Directly behind it is a sea cliff of equal height, the weathering of which has added a profusion of boulders to the region about its base. The trail winds through the boulder-strewn area, passes beneath Monument Rock, and by means of a few small switchbacks climbs up the face of the sea cliff to follow its crest for a few hundred feet.

The Nipissing Great Lakes

"With the uncovering of the North Bay outlet the ice sheet retreated from further contact with the water bodies of the Great Lakes. As the ice retreated northward and away from the lake basins, upwarping of the land occurred rapidly in those regions just uncovered. The North Bay outlet was such a region and it rose rapidly during these times. Since this was the outlet which drained the three upper lakes, and since the outlet was the controlling factor in determining the lake level, as the outlet rose the lake levels in turn rose. The low stages of Lakes Stanley and Chippewa and the Minong Stage of the Superior basin were in this manner brought to an end. The uplift of the North Bay outlet continued until water levels of the three upper lakes became confluent at the same level, and one large lake

filled the three basins. This largest of the Great Lakes has been called the Nipissing Great Lakes.

"The water level of this gigantic lake rose to the height where water again began to spill out of the basins along their southern margins. The Chicago outlet reopened, draining via the Illinois and Mississippi Rivers to the Gulf of Mexico. The St. Clair-Detroit Rivers outlet (called the Port Huron outlet after the city of Port Huron) also reopened and discharged into Lake Erie. At the height of the Nipissing Stage, therefore, three outlets drained the lake--the North Bay, the Chicago, and the Port Huron.

"With the uplift of the North Bay outlet the water rose from the low Minong Stage to the much higher Nipissing Stage. The uplift of Isle Royale was, however, even more rapid than that at North Bay, and the island rose faster than did the water. The Nipissing strandline, therefore, formed below that of the Minong Stage.

"On Isle Royale the Nipissing shoreline is a pronounced feature, generally 40 to 60 feet above the present lake. Although nowhere as spectacular a feature as the Minong shoreline, it is nevertheless extensively developed and rather prominent. A fine example of this shore is encountered along both the Mount Ojibway and the Daisy Farm Trails just as they leave the Daisy Farm campground on Rock Harbor.

"The Nipissing Stage came to a close when erosion of the Port Huron outlet lowered the water level of the lake sufficiently to render the Chicago outlet inoperative. Erosion progressed more rapidly in the Port Huron outlet than in the Chicago outlet, for while the former drained over a channel of easily eroded glacial drift, the latter discharged over bedrock. With the falling lake level due to erosion of the Port Huron channel the bedrock-stabilized Chicago outlet and the severely upwarped North Bay outlet were soon abandoned. The upper Great Lakes now drained as they do today, via the

Port Huron outlet into Lake Erie, then over Niagara Falls into Lake Ontario, and finally by means of the St. Lawrence River their waters eventually reached the sea.

The Algoma Stage

"At the time of the close of the Nipissing stage the St. Marys outlet of the Superior basin was still sufficiently downwarped to allow the three upper lakes to remain confluent at the same level.

"Although the reason is still unclear, the downcutting of the Port Huron outlet halted sufficiently to allow a shoreline lower than that of the Nipissing Stage to be built. The shoreline is below the Nipissing shore but above the present shore. The momentary halt, generally believed to have been caused by channel shifting in the Detroit River within the Port Huron outlet, gave rise to the Algoma Stage of the upper lakes. Its shore, although not intense, is clearly seen in many locations on Isle Royale.

The Present Great Lakes

"Downcutting along the Port Huron outlet continued until the present time. It has now become somewhat stabilized even though still not draining over bedrock. The level of the outlet holds Lakes Michigan and Huron at 580 feet above the sea.

"The Superior basin, still completely to the north of the hingeline and undergoing uplift, has been raised above the level of the two adjacent lakes. The elevated St. Marys outlet, a bedrock channel, holds the level of Lake Superior at 602 feet, some 22 feet above the lower lakes. Uplift in this region, as has been mentioned, is still a dominant feature. We must conclude that, while the area is stable to casual observation, the Great Lakes are still in the process of post-glacial adjustment."

CHRONOLOGY OF THE LAKE STAGES IN THE SUPERIOR BASIN, BASED ON
RADIOCARBON DATES (from Johnsson, 1960; after Hough, 1958)

<u>Date (Years BP)</u>	<u>Lake Stage</u>	<u>Controlling Outlet</u>
0		
1000	Superior	St. Marys River
2000		
3000	Algoma	Chicago and Port Huron
4000	Nipissing	Chicago, Port Huron and North Bay
5000	Minon-Nipissing Transition	St. Marys River
6000	Minong	St. Marys River
7000	Post-Duluth	Au Train-Whitefish
8000		
9000	Duluth	St. Croix River
10,000	Ice Marginal	St. Croix River
11,000	Ice--Valders Advance	
12,000	Lake Keweenaw	?
13,000	Lake basin filled with ice of Mankato Advance	
14,000		

Soils

Isle Royale soils are mostly residual and thin with little profile development. Deeper soils with better defined profiles from podzolization, some containing glacial drift material, occur in southwestern island areas. Valleys contain alluvial accumulations from surrounding ridge slopes. The thin soils are highly organic in origin, especially in those areas where a spruce-fir climax situation has developed.

Insofar as we know, a complete systematic soil survey has not been made at Isle Royale. Although a Soil Conservation Service team visited the park in about 1951 and soil samples were taken, the park files contain no record of results. It would seem worthwhile to exert efforts to obtain this information if it exists.

One hundred and eighteen soil samples were taken from selected sites in 1955 (Linn, 1957). The purpose of this sampling was to determine soil moisture characteristics in spruce-fir forest areas, sugar maple forest areas, and transitional and successional areas. The data indicated that soils under spruce-fir retained much more moisture during rainless periods than soils under sugar maple. After 10 rainless days, spruce-fir forest 10-inch soil moisture levels exceeded the permanent wilting percentage by 64 percent; and after 10 rainless days, sugar maple forest 10-inch soil moisture levels exceeded the permanent wilting percentage by only 11 percent. Due to the organic contents of the spruce-fir soils, initial moisture content of the 10-inch soils (24 hours after nearly one inch of rain) was 130 percent of the soil's oven dry weight, whereas it was only 51 percent of oven dry weight in sugar maple soils. These data, of course, only give the barest suggestion that soil physical and chemical properties may be an important factor in causes of vegetational makeup; much remains to be done toward obtaining adequate soils knowledge on Isle Royale.

Summarizing Geology

Precambrian rock layers of over 1 billion years of age form the Isle Royale archipelago. These layers are the result of successive volcanism, sedimentation, uplift and erosion. From Cambrian times to the initiation of the Pleistocene, erosion was the major force, reducing what must have been a towering highland. During the Pleistocene, several glacial advances composed of ice sheets a mile or more in thickness, ground, polished, scored and plucked the rock layers. Some glacial deposits were made by the ice, but Isle

Royale emerged from the glacial era largely denuded of loose material. The postglacial lakes covered Isle Royale completely at first, then in successive stages the waters subsided to reveal the present islands, leaving ancient beaches stranded high on the ridge slopes. The thin youthful highly organic soils have all developed since subsidence of the postglacial lakes.

C. CLIMATE

Current Climatic Conditions

Based upon the Köppen Climatic Classification System (as modified by Trewartha, 1957), Isle Royale's climate is transitional between "Dbf" and "Dcf," where:

- D = Microthermal, snow-forest climates; coldest month below 32°F. (0°C), warmest month above 50°F. (10°C).
- b = Warmest month below 71.6°F. (22°C).
- c = Less than 4 months over 50°F.
- f = Constantly moist; rainfall all through the year.

In brief, Isle Royale's climate is characterized by long, cold, snowy winters and short, cool summers. By virtue of the ameliorating effect of Lake Superior, this pattern is modified by winter extending later into spring, and by autumn extending later into winter. Canadian Government data indicate a frost-free period of approximately 120 days annually for Isle Royale.

An accurate, comprehensive weather record for any part of Isle Royale is, unfortunately, nonexistent.

Temperature records are kept for Mott Island and Windigo Ranger Stations during the period May to November each year, and temperatures are recorded at the Ojibway and Feldtmann Fire Lookout Towers for times when the towers are manned. Virtually no winter, late fall, or early spring temperature data are collected in the park. Lack of winter temperature and precipitation data precludes annual means and distributions that are required for detailed climatic descriptions.

Cooper (1913) presents the following table of precipitation data from Port Arthur, Ontario--20 miles to the north of Isle Royale:

Monthly and Annual Mean Precipitation given in Inches for Port Arthur, Ontario, for the 20 years 1888-1907												
J	F	M	A	M	J	J	A	S	O	N	D	Ann.
0.67	0.58	1.0	1.6	2.2	3.0	3.8	3.0	3.3	2.4	1.2	0.5	23.0

As an example of the temperature regime differences between the two adjacent climatic types, Linn (1952) presents the following data from Marquette, Michigan (south shore of Lake Superior) and Winnipeg, Manitoba:

Comparison of Monthly and Annual Mean Temperatures and Precipitation between Marquette, Michigan and Winnipeg, Manitoba.

	J	F	M	A	M	J	J	A	S	O	N	D	Year
						<u>Marquette</u>							
T.°F.	16	16	25	38	49	59	65	63	57	46	33	23	41
P. "	2.2	1.8	2.1	2.3	3.1	3.5	3.1	2.8	3.2	3.0	3.0	2.5	32.6
						<u>Winnipeg</u>							
T.°F.	-4	0	15	38	52	62	66	64	54	41	21	6	35
P. "	0.9	0.7	1.2	1.4	2.0	3.1	3.1	2.2	2.2	2.2	1.1	0.9	20.2

These data do not characterize Isle Royale, but they probably characterize extremes within which its climate lies. Sorely needed, of course, are data from Isle Royale.

Summertime temperature, precipitation, and humidity data are available for several locations on Isle Royale. Little has been done to utilize these data, but a few summations have been made. The following maximum-minimum data for one month reveal slight climatic differences among the Mott Island--Windigo--Feldtmann Ridge stations (from Linn, 1951-Present).

MAXIMUM AND MINIMUM TEMPERATURES AND TEMPERATURE RANGES FOR 21 DAYSIN JULY 1951ISLE ROYALE NATIONAL PARK

	MAXIMA			MINIMA			RANGES		
	Mott	Windigo	Feldtmann	Mott	Windigo	Feldtmann	Mott	Windigo	Feldtmann
1	68	66	74	48	45	51	20	21	23
2	64	67	74	47	42	47	17	25	27
6	70	75	72	49	42	67	21	33	5
7	75	71	71	47	50	55	28	21	16
8	72	68	73	46	55	58	26	13	15
9	72	73	69	46	46	57	26	27	12
10	65	67	68	48	46	48	17	21	20
11	61	68	70	43	39	50	18	29	20
12	73	71	71	45	47	53	28	24	18
13	79	63	71	44	41	56	35	21	15
14	74	74	72	48	49	51	26	25	21
15	62	70	62	46	50	48	16	20	14
17	62	70	70	45	40	49	17	30	21
18	69	71	66	48	47	52	21	24	14
19	66	69	68	48	46	48	18	23	20
20	65	73	71	50	40	55	15	33	16
23	65	78	74	50	45	66	15	33	8
24	70	76	76	50	51	57	20	25	19
25	73	75	78	52	58	62	21	17	16
29	74	79	78	52	54	60	22	25	18
31	74	74	78	61	56	56	13	18	22
MEANS	69.1	71.3	71.7	48.2	47.0	54.5	20.9	24.1	17.1
EXTREMES	79	79	78	43	39	47			
						Diurnal	35	33	27
						Monthly	36	40	31

MONTHLY MEAN TEMPERATURES ($^{\circ}\text{F.}$) FOR THESE THREE LOCATIONS BASED UPON THE ABOVE DATA

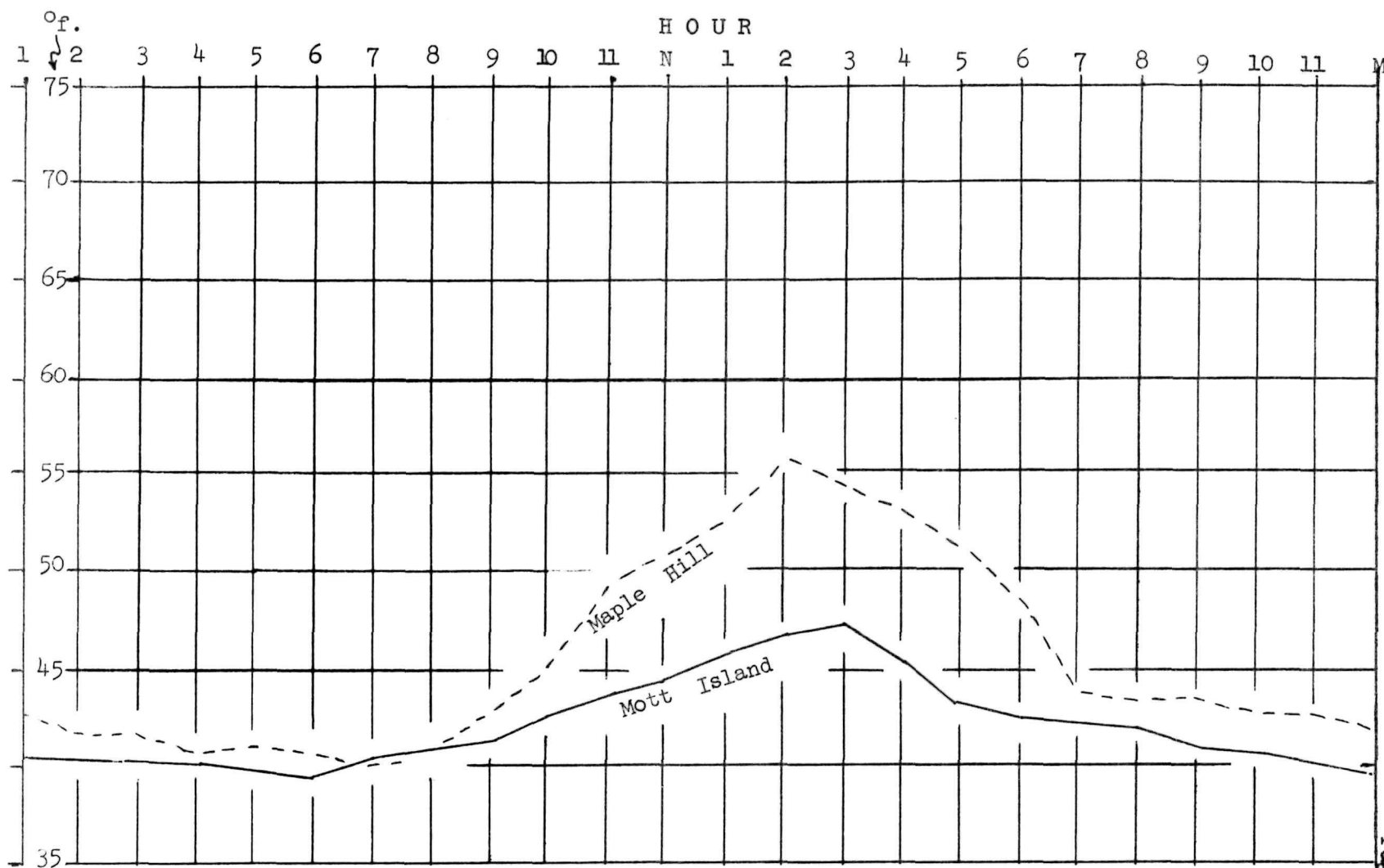
Mott	Windigo	Feldtmann
58.7	59.2	63.1

Note: Dates omitted (July 3,4,5,16,21,22,26,27,28,30) are so omitted because data from one of the stations in each case was not available for a variety of reasons.

The preceding data indicate that:

1. The Mott Island Station, closest to Lake Superior, maintains lowest summer temperatures.
2. The other two stations, however, are not sufficiently removed from lake influence to definitely show that inland temperatures have greater ranges and higher maxima.
3. The Windigo Station data reflect the cold air drainage effect. Windigo is almost entirely surrounded by hills from which cold air drains each windless night. This is especially true for winter temperatures which have been recorded as low as -28°F . for Windigo Station at the same time that -8°F . was recorded for Sugar Mountain--some six miles upslope from Windigo.

Data from six thermograph stations (three interior, two intermediate, one lakeside) during the summer of 1955, do indicate some wide temperature differences between lakeside and interior locations. The following graph shows hourly means for two-inch air temperatures, for 15 days in October 1955 at Mott Island and Maple Hill. The Lake Superior influence is apparent in that night temperatures are roughly equivalent and day temperatures are lower at Mott Island than at Maple Hill (an inland station):



Diurnal temperature progression, October 16-31, 1955. Hourly means for the two stations, Mott Island and Maple Hill.

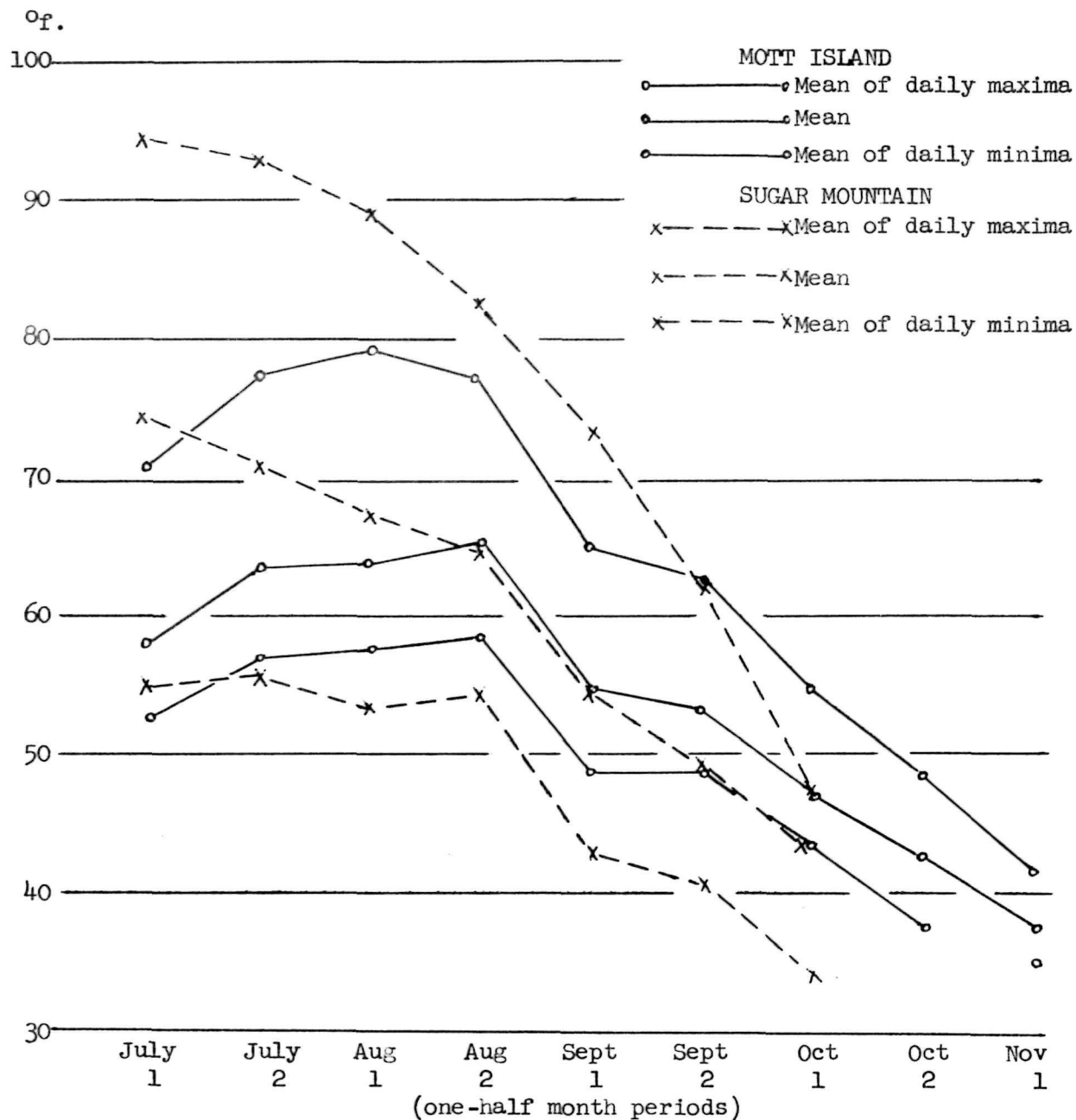
Spring temperatures near Lake Superior reflect the influence of cold winter water, while autumn temperatures reflect the influence of warmed summer water. Inland stations reflect this same influence, but to a much lesser degree.

The graph shown on page 21 presents means of daily maxima and minima for each one-half month period of two-inch air temperatures from July 1 to November 15, 1955, and also mean temperatures for each one-half month period based upon hourly temperatures for two stations, (1) Mott Island (lakeside) and (2) Sugar Mountain (extreme interior). This summation graph indicates:

1. Lakeside temperatures have a smaller range than interior temperatures.
2. Autumn temperatures of lakeside areas remain higher than interior temperatures.
3. Midsummer temperatures of lakeside areas are lower than interior.

In an attempt to explain the presence of two apparent climatic climaxes on Isle Royale, Linn (1957) constructed "envirographs" that illustrate temperature, vapor pressure deficit, angles of insolation, slope type, soil moisture values, and elevation. Linn's temperature data are from six thermograph stations at which 2-inch soil, 2-inch air, and soil surface temperatures were recorded during July, August, September and October of 1955. These temperatures were obtained to reflect "seedling climate" and are thus not comparable to weather station data. On page 22 is one of the envirographs, with necessary legend material.

2-INCH AIR TEMPERATURES ($^{\circ}\text{f.}$), JULY 1st to NOVEMBER 1st, 1955, for
MOTT ISLAND AND SUGAR MOUNTAIN.

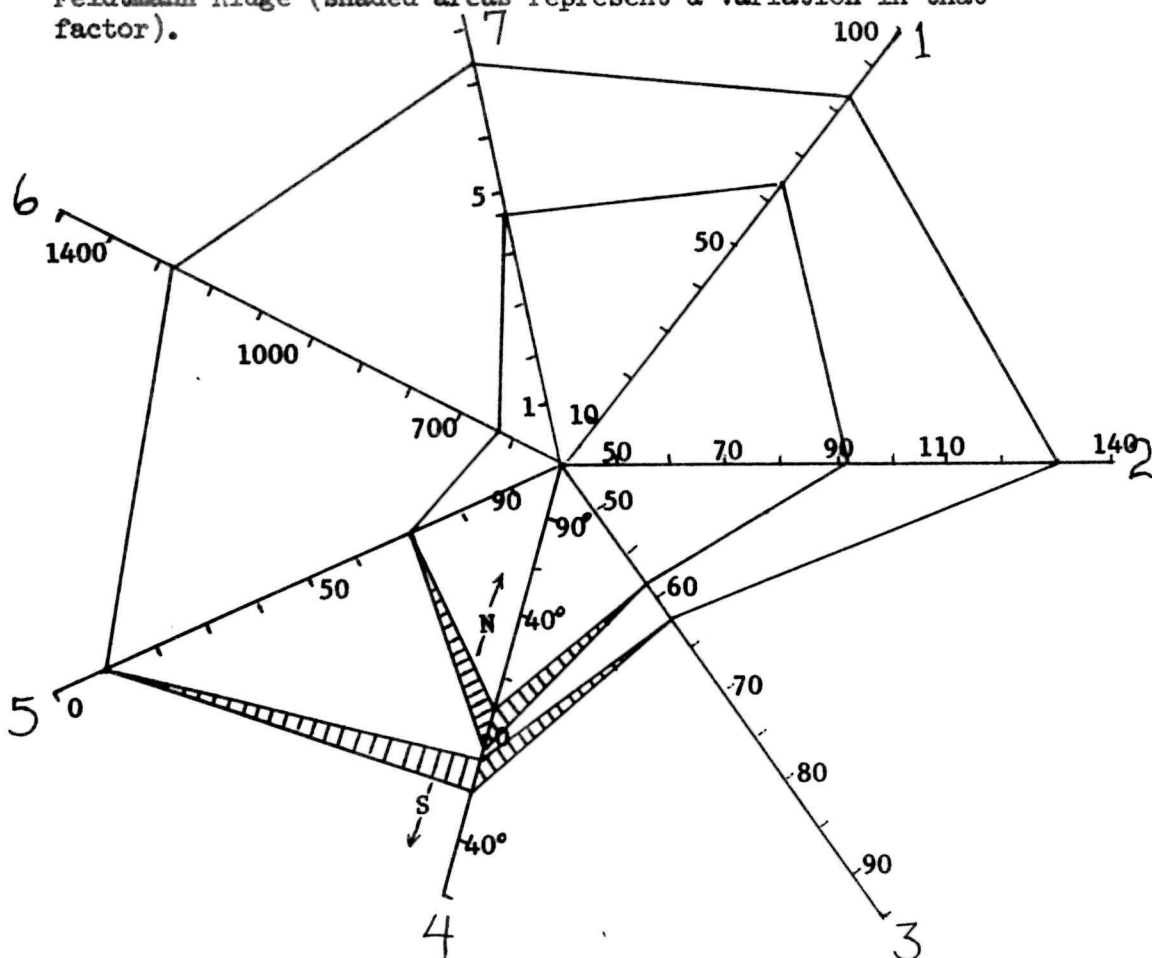


ENVIROGRAPH: The environments of Mott Island (inner figure) and Sugar Mountain (outer figure). (after Linn, 1957.)

Each radius is a gradient from coldest and/or wettest condition of the factor at radius' inner end to warmest and/or driest condition at its outer end.

Radii:

1. Angle of Insolation on June 21.
2. The maximum temperature (°F.), period of June to September 1955 (soil surface)
3. Mean temperature (°F.) of period June-Sept. 1955 (2-inch air)
4. Direction and degree of slope
5. Percentage available soil moisture at 2-inch soil level after 10 rainless days in July 1955.
6. Elevation (in feet) above sea level.
7. Mean of 43 5pm vapor pressure deficit values for Mott Island and Feldtmann Ridge (shaded areas represent a variation in that factor).



Summarizing Climate

In general, the island's climate may be characterized as cool-moist summers and cold-snowy winters. Within this generality, those areas near Lake Superior are cooler and more moist than interior areas which obtain higher summer temperatures with greater water loss through increased evaporation, evapotranspiration, and runoff. The data so far collected and analyzed are sufficient only to suggest that additional macro- and micro-climatic data are needed in order to justly characterize the present climate of Isle Royale.

Changing Climate and the Evolution of Vegetation

For reasons as yet unknown, there was a general decline in earth temperatures beginning about 30 million years ago. Before this decline began, northern Michigan and the Lake Superior region had a climate that was humid subtropical--that is, mean annual temperatures were about 20°F. higher than at the present time. Today, Isle Royale is in the transitional area between subarctic and humid continental cool summer. The humid subtropical climate--which marked the Superior region 30 million years ago--now exists throughout southeastern United States. Vegetation which lived as far north as Lake Superior 30 million years ago, and is now found there only in fossilized form, included hickories, oaks, magnolias, and even a palm or two.

Temperatures continued to decline during the next 29 million years. Therefore, the earth did not suddenly become frigid; rather, the cooling was gradual, with many variations along the way.

Vegetation gradually changed along with the gradual change in climate, and the ranges of different plant species migrated ever southward. The fossil record indicates that a forest much like that of today existed at the end of the Pliocene Epoch about 2 million years ago. But the decline in temperatures continued for another million years until spruce and fir, common on Isle Royale today, were growing well south of the Ohio River, and ice covered all of what is now the Great Lakes region.

The Glacial Epoch, or Pleistocene, lasted from about 1 million years ago until about 10,000 years ago. Actually, we are still enduring the general glacial period of the earth's history. The Glacial Epoch should not be pictured as continuously iced-over times. Rather, several glacial advances took place--each lasting

as long as 125,000 years--and each followed by an interglacial period--the longest of these lasting nearly 200,000 years. The last glacial advance, known as the Wisconsin Glacial, ended in this area about 10,000 years ago, and was followed by the present interglacial stage.

Each glacial advance tended to completely obliterate whatever happened in an area during the preceding interglacial stage. Therefore, little is known about glaciated lands during this time; but, considering that up to 200,000 years passed between glacial stages, it is probable that most glaciated lands were completely repopulated by plants and animals during each interglacial stage. This seems reasonable, because the mere 10,000 years of the present interglacial stage has been sufficient to allow the spread of plant and animal life all the way north to the shores of the Arctic Sea.

Our primary concern in tracing the climate and vegetation of Isle Royale starts with the present interglacial stage, beginning about 10,000 years ago. Isle Royale was still covered with the melt-waters of the postglacial Great Lakes. Close to 1,000 years would pass before these waters subsided enough to uncover Mount Desor, Sugar Mountain, Ishpeming Point, and other high points of present-day Isle Royale. From deposits in bogs at these higher elevations, it is known that a forest composed principally of spruce and fir followed closely at the heels of the melting glaciers and the subsiding lake levels. This period, called by botanists the initial spruce-fir period, lasted until about 7,000 years ago when, for some reason, earth temperatures increased slightly.

This temperature increase produced a warmer climate than exists at the present time; and, of course, it resulted in changes in vegetation. This vegetational change is recorded in the medium-depth deposits of Isle Royale bogs at higher elevations and in bottom deposits of bogs located at middle island elevations (200 to 300 feet above Lake Superior). That the bogs of mid-elevations should contain deposits of this vegetational change indicates that these elevations were above lake level at that time. Bogs at lower elevations (for example, on Raspberry Island), however, do not contain this deposit, which indicates that the lower elevations were still overlain by postglacial lake waters. The principal forest species during this time of increased temperature were pines, oaks, maples, yellow birch, hickories, and, in lesser abundance, spruce and fir. Of greatest importance were the pines--red, white, and jack--which have given the name "pine maximum" to this period in forest history. It lasted for about 3,000 to 4,000 years.

Then the climate turned cool again, and the spruce and fir returned in full force to Isle Royale. This second return of spruce and fir is recorded throughout the entire depths of bog deposits at lower elevations on Isle Royale, indicating that these lower elevations had finally emerged from postglacial lake waters sometime after the end of the pine maximum. This must have been between 1,000 and 500 B.C.

The present vegetation on Isle Royale is the result of these climatic changes occurring since the last glacial stage. The initial spruce-fir period saw the migration of spruce and fir onto the island; the pine maximum enabled pines, maples, oaks, and yellow birch to come in, at the same time drastically reducing spruce and fir; and, the end of the pine maximum brought back spruce and fir as the major forest species. Thus, pines, maples, oaks, and yellow birch still living in the warmer-drier regions of Isle Royale, may be considered as relics of the pine maximum.

During more recent times, climate has continued to change. In 500 B.C. temperatures dropped to a point nearly reaching glacial proportions, but this was short-lived and was followed by a warming trend that continued to about A.D. 1,100. Again, beginning about 1,200, temperatures began to drop, eventually producing what has become known as the "little ice age" which lasted from about 1650 to 1850. Since 1850, average temperatures have been increasing. That these minor fluctuations have had an effect upon Isle Royale vegetation cannot be denied; and the future will see, as has the past, a vegetation that changes with corresponding changes in climate. Moreover, as the vegetation changes, so will changes be noted among the animal populations which are so dependent upon plantlife.

D. TERRESTRIAL ECOSYSTEMS

VEGETATION

Perhaps the most conspicuous aspect of Isle Royale, aside from its topography and the water surrounding it, is the almost complete cover of forest. The island's vegetation is basic to all other life on Isle Royale--producing the food necessary to support all simple and complex trophic chains.

Lake Superior dominates the island climate. And thus it determines in large degree the vegetative patterns. The cold water surrounding Isle Royale cools the air immediately above the lake surface. This air flows over the lower lands of the island's periphery to produce cool temperatures all along the shoreline. Because cool air is incapable of evaporating large amounts of moisture from the soil, the shoreline is not only cool, but is also quite moist.

Farther back from the shoreline toward the central-uplands of Isle Royale, this cold water influence wanes; for this reason, the central-uplands area is, by comparison, warm and relatively dry. It is warm and dry, also, because the extensive southeast-facing slopes receive large amounts of the sun's radiation and because the ridge slopes accelerate drainage of ground moisture.

The two climates--one near the lake shore, the other at the island's center--have given rise to two forest types: the white spruce-balsam fir forest (or boreal conifer forest) along the shoreline and the sugar maple-yellow birch forest (or northern hardwood forest) of the central uplands.

Isle Royale is roughly triangular in shape. The island's narrow northeast end--the most acute angle of the triangle--is everywhere close to the lakeshore. Its forest cover is, therefore, mainly spruce and fir. The exception is a small stretch on the Greenstone Ridge where Mount Ojibway's vertical thrust leaves the shore climate below and allows an enclave of sugar maples.

To the southwest, the island is wider. Here the land influences of warmth and dryness support large expanses of hardwood forest in the upland, inland-most sections, with spruce and fir limited mainly to the lower elevations nearer Lake Superior.

The Boreal Conifer Forest

Upon further exploration of the spruce-fir forest, one finds that it, too, is composed of several different forest types; not necessarily because there is more than one climate, but because there are other factors (such as soil moisture) which determine forest composition. The major part contains white spruce, balsam fir, and paper birch. This combination exists where there are "average" or "medium" (mesic) soil moisture conditions.

Most of the spruce-fir lands have been burned over at one time or another during the past several hundred years. The first trees to establish themselves on burned-over forest lands are the pioneer trees, paper birch and aspen, whose seedlings and sproutings can survive in open sunlight. When these trees reach maturity, producing a shaded forest floor, their own seedlings grow rather poorly, while the seedlings of the spruce and fir are able to grow quite well. Holding this advantage, the spruce and fir seedlings mature, crowd out their competitors, and produce the climax forest.

All through the climax spruce-fir forest there are birch and aspen pioneer trees remaining from some previous subclimax stage--especially the paper birch because it is a relatively long-lived tree. There are also other trees, shrubs, and herbs: near shorelines, American mountain-ash can occasionally be found, forming an understory tree 10 to 25 feet high: thimbleberry, a shrub with large maple-shaped leaves and a fruit similar to raspberry often covers large areas, especially under a partial canopy of paper birch; alder, a tall shrub, quite often forms thickets near shorelines and swamp margins. Possibly the most abundant herb on Isle Royale is the large-leaved aster, which blankets much of the forest floor in the spruce-fir forest. Other common herbs include the Canadian dogwood (bunchberry), twinflower, fringed polygala, and yellow clintonia.

The devilsclub, a plant covered with thousands of thorns, has large maple-like leaves which have thorns along the ribs on the underside, and gets its name from the club-shaped cluster of flowers. It has a very restricted habitat: on the northeastern-most mile of Isle Royale near Blake Point, on the small islands fringing this area, on Smithwicke Island in Rock Harbor, and, on Passage Island four miles northeast of Blake Point. Although this species of devilsclub occurs nowhere else in the eastern United States, it does occur in the Pacific Northwest. Evidently this peculiar distribution is a result of the period when receding glaciers of the ice age

created a more or less uniform climate across this section of the continent. After recession of the glaciers, the climate of the northern prairie states became much too dry to support the devilsclub, thus separating the Isle Royale outpost from its far western counterpart. Thimbleberry is similar to devilsclub in this respect except that thimbleberry exists in the upper peninsula of Michigan as well as on Isle Royale.

Bogs

Wherever the topography produces a low area with little drainage, swamp conditions prevail on Isle Royale. If outflow is essentially lacking, and a fairly deep surface depression is present, a bog may be formed as the depression fills with water from the surrounding drainage. In this early stage it is known as a bog lake. Around the edge of this bog lake sedges grow very well in the still water and eventually form a mat over the water's surface. Lake John, not far from Saginaw Point, is a bog lake such as this.

In time, the sedge mat grows thicker and its older parts die off and settle to the lake bottom as new sedges develop. Finally this process fills the lake with dead sedge materials. In some bogs sphagnum moss begins to grow on top of the sedge mat. The living mosses and/or sedges eventually cover the old lake surface. In this later stage it becomes simply a bog, and is no longer referred to as a bog lake. The bog on Raspberry Island across from Rock Harbor Lodge, the Mott Island bog, and the bog along the McCargo Cover trail just north of the Daisy Farm are examples of bogs in this stage.

There are two major bog types on Isle Royale, with some bogs exhibiting characteristics of both. Sphagnous bogs are those in which: (1) the sedge, Carex limosa, forms the major part of the sedge mat; (2) there is little or no drainage; (3) sphagnum enters abundantly along with Labrador tea; and (4) black spruce and tamarack form the bog forest. Cyperaceous bogs are those in which: (1) the sedge, Carex lasiocarpa, is dominant; (2) there may be an active outlet; (3) sphagnum and Labrador tea do not enter abundantly; and (4) tamarack and northern white cedar form the bog forest.

Because the bog surface formed by the sedges and/or sphagnum moss is no longer a water surface, other plants such as sundew, pitcher plant, and vaccinium begin to grow here. The bog's edge, as a matter of fact, is by now so firm from its ages of accumulation

that moisture-loving trees, such as black spruce and tamarack (or larch), grow quite well and form a forested periphery around the bog.

Given additional time--say, several thousand years--this forested edge will expand until the entire bog surface is forested. As this takes place the surface becomes drier, permitting other forest trees (such as aspen, paper birch, and eventually white spruce and balsam fir) to exist here. Sometimes the only way to determine whether such an advanced stage has actually developed from a bog, is to determine the sphagnum moss and/or sedge content of the soil beneath.

Swamps

Swamps differ from bogs in that normally they are shallower and the water is generally moving from one end to the other. Because Isle Royale's topography is essentially a series of ridges and intervening valleys, swamps occupy large areas within the valleys where the slowly moving waters cover broad expanses.

Aiding the establishment of some swamps is the beaver, who builds extensive dams causing streams to flood over the valley bottoms. Often there are swamps with whole forests of dead, standing trees. Usually these are the result of beaver dams or series of dams, which have flooded the forested land. The trees, whose roots need oxygen, are drowned in this relatively sudden flooding.

The largest swamps on Isle Royale usually exist in their own right--the beaver playing only minor parts in their development. Such swamps are normally forested with either black spruce or northern white cedar-tree species that are adapted to semi-aquatic life. The two species are rarely found in the same locations because the spruce grows best in swamps which are slightly acid and the cedar grows best where slightly alkaline soils occur. The most extensive swamp on Isle Royale is located in the valley of the Big Siskiwit River, southwest from Siskiwit Bay between Red Oak Ridge on the north and Feldtmann Ridge on the south. This black spruce swamp extends unbroken along both sides of the river. It is, essentially, a pure stand of black spruce except in burns where alder exists as a subclimax community. In time, the alder will give way to the ever-encroaching black spruce.

A good example of a northern white cedar swamp is located on the northeast shore of Lake Richie, where the trail from Rock Harbor approaches the lake. Here the great old cedars form grotesque wilderness avenues under their contorted trunks, and the canopy above plunges the forest floor into deepest shade. Where enough open canopy exists in the swamp forest, there are skunk cabbages, and, as in the bogs, pitcher plants.

The Dry Conifer Forests

Just as there are segments of the boreal conifer forest marked by excessive moisture in bogs and swamps, there are also segments which are excessively dry. The major forest type exemplifying this is the jack pine forest. Jack pine occupies dry, rocky, south-facing slopes and also bluff tops which have been subjected to fire sometime in the past.

The cones of the jack pine are the secret of its success. They remain on the tree year after year, tenaciously containing the seeds within. Fire, or other intense heat, will force the cones to open, scattering the seed. If the seeds are not all destroyed, jack pine seedlings will germinate following the fire, giving rise to a new stand of this forest type. Sometimes temperatures on the open hill-sides become remarkably high in midsummer and may force jack pine cones open. As more jack pines germinate and mature, the forest becomes cooler owing to the increased shade. Eventually the cones cease to open in any great quantity in such areas and, since the forest floor is now cooler and more moist, spruce and fir seedlings are better able to grow. This, of course, brings to an end the temporary jack pine forest and establishes in its place the typical spruce-fir type. Because the process is extremely slow, even our great-grandchildren may not detect much change from today's jack pine stands on Isle Royale.

The Northern Hardwood Forest

Because the climate in the interior-upland parts of Isle Royale is warmer and drier, a different forest type occurs. The northern hardwoods seem to be much better equipped to live in this area than are the boreal conifers, though small enclaves of conifers do occur. The best example of the northern hardwood forest on Isle Royale is the large expanse of sugar maple forest extending along the Greenstone and Red Oak Ridges--and in valleys and on smaller ridges between them--from Mount Desor southwestward to within a mile of Washington Harbor. This is probably the largest tract of undisturbed,

unaltered forest on Isle Royale. Upon entering this forest from the conifer forest at lower elevations, the change is so great that one gets the feeling of having been suddenly shifted to another and remote part of the continent. The general appearance of the sugar maple forest is one of openness, with an unbroken canopy of sugar maple. However, this forest is not homogenous and it, too, is subdivided--based upon soil moisture, degree of slope, and depth of soil. Within this northern hardwood forest are areas with differences in moisture due almost entirely to topography: gently rounded slopes facing south are driest; cove slopes, small valley bottoms, and north slopes are most moist; and on level areas and gently rounded ridge tops average moisture (mesic) conditions prevail.

Most of the ridge tops along Greenstone and Red Oak Ridges are areas of average moisture conditions. The northern hardwood trees here are mostly sugar maple, with a fair scattering of yellow birch. The trees are large and quite old, but their trunks are not especially tall and there is a slight tendency for limbs and upper trunk parts to be contorted a little more than would seem natural. Perhaps this observation is only a result of comparison to the unusually straight conifers of the spruce-fir forest.

The most remarkable aspect of this mesic hardwood forest is the great abundance of sugar maple seedlings and saplings from one to four feet high. In some areas there are 75 to 80 of these per square yard, producing an extremely dense undergrowth. Many of these are 15 years old or older, but they remain stunted for a number of years in response to the dense shade produced by mature trees. If, for some reason a large tree dies, the saplings beneath suddenly begin to grow taller in response to their release from shade. Those that grow fastest overshadow the others with their increased foliage. When this happens, the less vigorous saplings are again inhibited by dense shade. This not only halts their growth, but usually the change is so great that they slowly die. Thus, survival of the fittest quietly holds forth. Because of the dense growth of seedlings and saplings, there is little room for shrubs and herbs. However, the lesser plants are not entirely absent and occasionally one finds trillium, yellow clintonia, and twisted stalk.

The ridges on which this hardwood forest grows are beset with finger-like ravines extending upward from the valleys below. Runoff moisture from the ridges seeps into these ravines (or coves) and thence downward to the valleys. They are, therefore, areas where greater soil moisture is available to the forest vegetation. In

response to this condition, northern white cedar, balsam fir, and white spruce grow in the ravines and valley bottoms along with the sugar maple. Another result of the additional moisture appears to be the presence of fewer yellow birch trees here than in the mesic hardwood areas.

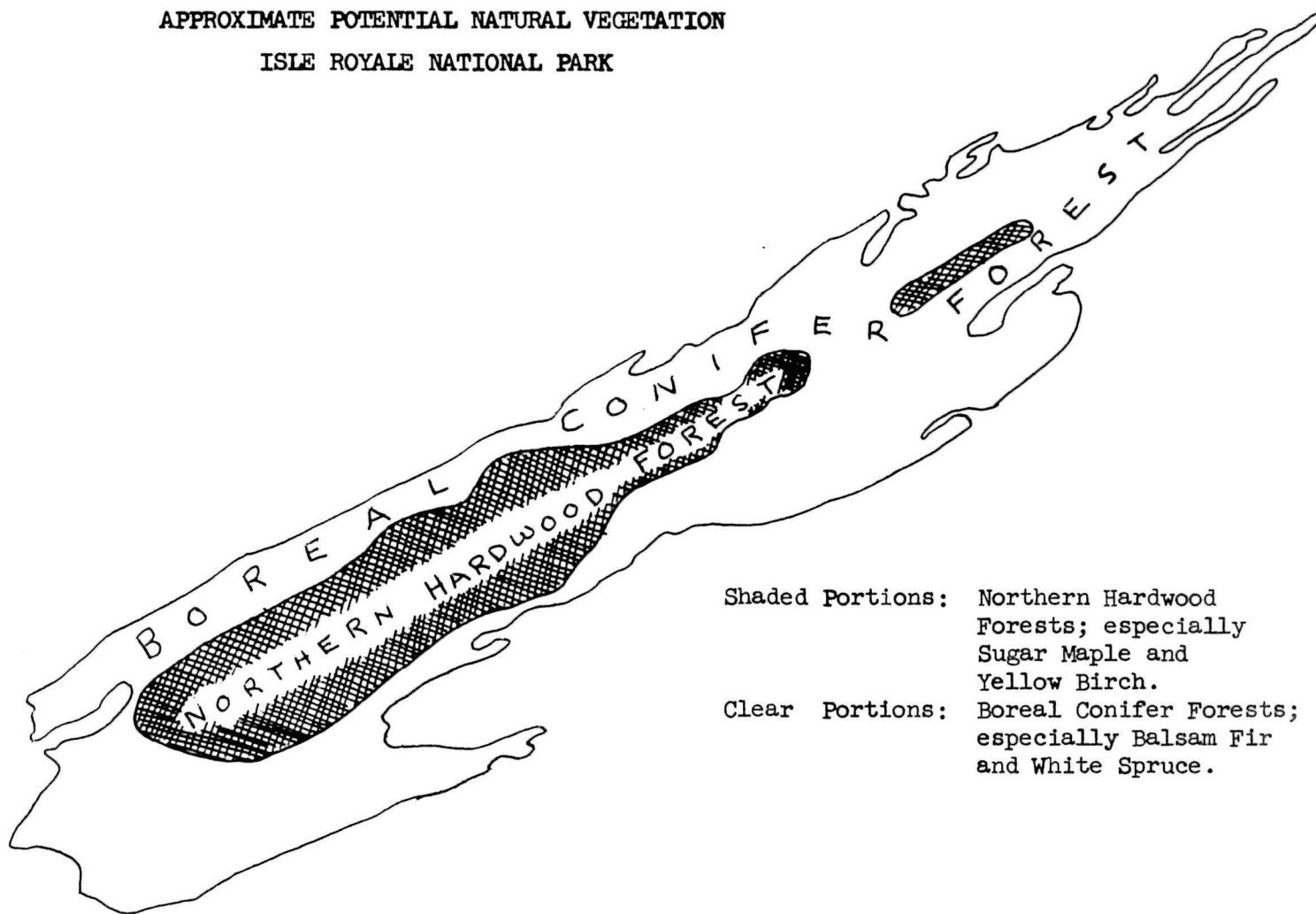
Between the ravines along the south side of the Greenstone and Red Oak Ridges are slopes of a different nature--convex slopes. The drainage of soil moisture from these slopes takes place toward the valley below and off to the sides toward the ravines. This, combined with intense radiation from the sun on the south-facing slopes, produces Isle Royale's driest and warmest forest site which is dominated by sugar maples almost to the exclusion of other species. Northern red oak grows well on these dry hillsides, but it does not persist for long in the mature forest. It is much too dry for either spruce or fir, and probably so for yellow birch.

Towering above the maple forest are a few white pines. Some of these old trees are as much as four feet in diameter. Their presence is testimony to times past--before the sugar maple and other hardwood forest species had become dominant. Sometime, say 1,000 years ago, fire may have swept through what is now the maple forest. Assuming that the climate was about the same then as now, paper birch, white pine, and several lesser species began to repopulate the forest. White pine, being better suited to this warmer, drier section of Isle Royale, fared best, producing a magnificent pine forest. In time, if maple seed were present, sugar maples began to grow under the pines, finally maturing and preventing the sun-requiring pine seedlings from further growth. After the maple had thus assumed dominance, pine grew only in open areas where there was a source of pine seed, as well as soil and soil-moisture conditions conducive to its growth. The pine, needing all of these favorable conditions, is today a comparative rarity in the maple forest.

Our original assumption, that 1,000 years ago fire swept this area, is strictly for the purpose of relating the general story. That fire did sweep this forest is not a proven fact. In any event, it has probably been a very long time since the last fire of any great size. However, in central Isle Royale along the Greenstone Ridge, just northeast from Lake Desor and southwest from Chickenbone Lake, an extensive area (approximately one-third of Isle Royale) was burned over in 1936. This area probably had been burned over a number of times earlier, and white pine had had good opportunity to grow here. Today there are many old stumps and snags, some

standing, some fallen, of white pines that died in this latest fire. Also, where the fire for some reason missed a clump of trees, living white pine may still be seen in abundance. Forest succession, in time, will again establish white pine in this area. Then, if fire is absent for a sufficiently long time, sugar maple and yellow birch will form an understory, shade out the pine seedlings, and finally form the climax forest.

APPROXIMATE POTENTIAL NATURAL VEGETATION
ISLE ROYALE NATIONAL PARK



Shaded Portions: Northern Hardwood
Forests; especially
Sugar Maple and
Yellow Birch.

Clear Portions: Boreal Conifer Forests;
especially Balsam Fir
and White Spruce.

Vegetational Changes Due to Fire

Fire, through both natural and unnatural causes, has been a more or less common occurrence on Isle Royale. The first white man copper-mining ventures on the island occurred in about 1843 and continued in irregular fashion through to the 1890's. The original land survey plats and notes by William Ives in 1847 indicate the approximate extent and location of recent burns at that time. Most of these burnings are noted to have occurred in the vicinity of Rock Harbor and Conglomerate Bay--areas in which the early copper mines were located. For example, in Ojibway Township (T66N,R34W), seven recent burns were noted on the plat; however, in Desor Township (T64N,R37W), where mining did not commence until much later, only one small burn is noted along the shore of Siskiwit Bay.

Today evidence of fire is common from east of Lake Desor to near the northeast end of Isle Royale, especially along the Greenstone Ridge where plant succession following fire is extremely slow. There are reports (or "stories") handed down by local residents of large fires occurring in the 1860's. The following is quoted from Linn's (1951-) Log, page 46: "This story was related to me by Peter Edison, a fisherman on the Old Lighthouse Peninsula and a guide for many years on Isle Royale. He has been on Isle Royale during the summer months since 1916. Twenty years ago (about 1930) he (Peter Edison) knew a French-Indian prospector who was then 80 plus years of age. This prospector when young had found (Peter believes) a vein of silver near McCargo Cove and had returned to rediscover this vein. He was surprised to note that vegetation was so dense, because, when he was young, the earth had been scorched down to the rock and mineral soil. Peter says that an English syndicate was responsible for the burn and that the area burned extended from Thomsonite Beach on the north and the head of Siskiwit Bay on the south to the northeast end of the island. It is peculiar to note that the 1936 and 1948 burns extend northeastward from this same line indicating susceptibility of burned areas to fire." Subsequently, Linn (1951-), page 105, attempted to correlate growth ring data from white pine stubs on Mount Ojibway with living white pines in the Red Oak Ridge-Sugar Mountain area in order to date the fire that killed the Mount Ojibway pines. These pine stubs and fallen trunks are still observable on Mount Ojibway. This project has never been completed; the meager data merely indicating that the 1860 fire may, indeed, have taken place.

The largest fire actually recorded in recent history is the 1936 burn described earlier. This fire started in the area

immediately adjacent to the head of Siskiwit Bay where pulp log harvesting had been in operation for several years. Whether the fire originated by lightning or human carelessness has never been demonstrated, but the existence of much slash left on the forest floor of that area certainly added fuel to what became a holocaust. The fire burned a large section in this area and spot-fired to the area south of Lake Desor, from which it spread northeastward along the Greenstone and other ridges to a point just south of Rock Harbor. From this central area the burn spread to the Lake Superior shore north of Lake Desor and in the area between Siskiwit River and Lake Whittlesey. Again in 1948, a large fire developed to the south of Lake Desor which confined itself to an area already burned in 1936. Since 1940 about 40 small fires have occurred in addition to the large 1948 burn. All were suppressed by the Service, so that large fires did not develop.

For the 11 years from 1954 through 1964, 28 fires occurred in Isle Royale National Park (NPS, 1954-1964, Individual Fire Reports).

These fires can be summarized as follows:

Date	Name of Fire	Size (acres)	Type	Cause
July 13, '54	Siskiwit Bay Fire	4.0	brushy	Lightning
July 30, '54	Big Siskiwit Fire	0.004	brushy & swampy	"
July 14, '54	Washington Creek	0.9	swampy brush	"
July 16, '54	Lookout Louise	0.001	open forest	Smoker
Aug. 30, '56	Richie	0.001	open forest	Smoker ?
Aug. 25, '57	Chickenbone	0.002	open forest	Visitor
Aug. 14, '58	Chickenbone Campsite	Negligible	open forest	"
Aug. 10, '58	Rescue Fire (not applicable)			---
Aug. 12, '58	Siskiwit Lake Fire #1	N	birch-aspen forest	Lightning
Aug. 12, '58	Chippewa Harbor Fire #1	1.0	jackpine & brush forest	"
Aug. 11, '58	Huginnin Ridge	0.07	forest	"
Aug. 9, '58	Washington Harbor	N	forest	"
Aug. 9, '58	Little Siskiwit River	N	forest	"
July 14, '59	Little Siskiwit River	0.16	forest	"
Aug. 12, '59	Locke Point	N	S-F-birch forest	"
June 30, '60	Rock Harbor Lodge	N	open forest	Visitor
Aug. 16, '60	Passage Island	N	open-forest- grassy	"
Sept. 2, '60	Three Mile Campsite	N	S-F forest	"
July 26, '61	Minong Ridge	0.006	forest	Lightning
Aug. 12, '61	Hastings Island	N	birch, open & brush	Visitor
June 19, '62	Ekmark (not applicable-building fire)			---
June 30, '62	Mount Franklin	N	open, brushy	Visitor
July 11, '62	Belle Isle	0.2	open, grassy	"
Aug. 6, '62	Hidden Lake	0.1	S-F forest	Lightning
Aug. 27, '62	Mount Siskiwit	0.07	S-F birch forest	Visitor
June 5, '64	Beaver Island	0.1	grass	"
June 26, '64	Richie Snag	0.01	forest	Lightning
Sept. 7, '64	Desor North	0.01	forest	"

N - Negligible

Man was responsible for causing 12 fires totaling approximately 0.380 acres for the 11-year period. Of these 12 fires, five occurred in open forest, two in closed forest, two in open forest and brush, and two in grassy situations.

Lightning, during the same 11 years, was responsible for 14 fires totaling 6.264 acres. Of these, 10 were in closed forest, three were in brush areas, and one was in a forest and brush situation.

These data indicate that naturally occurring fires are responsible for about $16\frac{1}{2}$ times the area burned by fires resulting from man-caused factors. This may be at least partially the function of more difficult access by fire fighting crews to natural fires than to fires caused by human carelessness which occur predominantly in open situations along trails and in campgrounds. Also significant are the number of natural fires occurring in closed forest situations as compared to man-caused fires. It would appear that closed forest situations attract as much or more lightning as open situations and/or the closed forest situation better supports fire once it has been ignited by lightning.

Since all of these fires were suppressed before they could develop to their ultimate potential, it seems impossible to determine the exact role of fire in the natural ecosystem of Isle Royale. However, we know that fire is a naturally occurring factor of the ecosystem and that the suppression of naturally occurring fires has introduced a man-caused change of unknown magnitude in the forest structure.

The Sequence of Vegetational Changes Following Fire

Wherever fire has burned the vegetation and the organic soil components along ridges, subsequent rains have usually eroded soil remains into the valleys below. This and other situations that leave exposed rock surfaces, result in the necessity for succession to begin in its primary stages. Soil is only very slowly accumulated on such surfaces, resulting in many years of successional vegetation (often centuries) before climax vegetation is established. Mount Ojibway, Ishpeming Point, Mount Siskiwit and much of the remainder of the Greenstone Ridge, parts of Minong Ridge, Red Oak Ridge, and some of the lesser ridges are experiencing this primary succession, in various stages, following past fires.

Areas in which fire has been less severe may not have lost much soil, and, in some instances, even standing trees have been missed by the fire and they have acted as seed sources to repopulate the surrounding land.

Valleys between the ridges, of course, are many times too moist to support intense fires. Thus, even when valley forests are burned, soils are not lost (though they may be changed) through burning and erosion; in fact, eroding soil from surrounding slopes increases the soil deposits in valleys after each such fire. Charcoal and potash are also washed into the valleys along with the eroding soil. The net effect of this is that valleys possibly gain fertility following fires; the resulting vegetation usually developing rapidly into a lush forest. When lakes occupy valley bottoms they are also recipients of these materials, but there appear to be no data that reveal possible effects on lakes and aquatic life of these added materials.

A mosaic of successional vegetation on Isle Royale has developed from the various intensities of fire, the different times at which fire has occurred in different places, the varying topography upon which fire has occurred, the differences in the available seed sources following fire, the differences in soil depth and fertility following fire, the differences that slope, exposure and microclimate inflict upon successional vegetations, and so forth. Fires have produced this mosaic; the absence of natural fires, or the suppression of them, would serve to ultimately clothe Isle Royale with climax vegetation except for the small areas of wind damage and other minor forest destruction. Such a monotypic climax situation would certainly be unnatural in view of the fact that at least 14 lightning fires occurred in the years 1954 through 1964.

The absence of natural fires has additional consequences beyond the mere fact that "natural ecological conditions" depend upon them. Windfall of trees on Isle Royale is a continuous process, especially since soils are typically so thin. More or less regular burning of sites maintains a low accumulation of windthrown trees; but the absence of fire allows continued accumulation of forest floor fuels leading to ever higher potentials for highly destructive fires. The occurrence of such fires are more likely to destroy the organic portions of the soil and set vegetative succession back to the primary stages. Fires occurring at the more frequent natural intervals, tend to reduce fuel accumulations and hence return the environment to a stage of succession where soils are not so likely to be initially absent. Moreover, roots and stumps of paper birch and aspen

would probably succumb to intense fires fed by high accumulations of forest floor fuels, whereas the roots and stumps of these species are likely to survive less intense fires.

Viewed as an ecosystem in which each organism's life is inextricably woven into and among the lives of its coinhabitants, the successional stage to which a forest stand is reverted by fire is an immensely significant event. If the soil organic portion of the ecosystem is lost through fire, succession begins anew upon the bare rock or other residual mineral material. Shrub and forest regeneration in this case will require decades or centuries to occur. In less intense fires where the soil organic material is not destroyed, secondary succession in which paper birch, aspen, hazelnut, and other successional trees and shrubs become established follows with little delay. Within a decade of light burning, these species furnish browse for moose, beaver and snowshoe hare.

Vegetational Changes Due to Insects

Vegetational changes brought about by insects on Isle Royale are either few and slight, or are largely unknown.

However, the larch sawfly (Lygaechematus erichsonii Hart.) may be responsible for the present low frequency of larch (Larix laricina) compared with the relatively great abundance of this species in 1847 (Ives) and in 1910 (Cooper). Bogs normally contain a few scattered, sickly-looking larch of small size, with only occasional stands of larger individuals such as are located near the northeast end of Mott Island. That there was once much greater representation for larch on Isle Royale than at present, must be noted as a vegetational change probably due to insect infestation.

The spruce budworm (Cacoecia fumiferana) has occasionally multiplied to epidemic proportions throughout most of the boreal forest of North America. On Isle Royale it caused extensive damage to balsam fir in 1930 (Brown, undated). Many of the trees which were infected at that time survived--the attack being recorded as crooked trunks where lateral branches replaced terminal growth. How many trees succumbed to the attack has not been determined nor studied; however, the abundance of balsam fir in the present forests of Isle Royale would seem to indicate that no great lasting effect has incurred from spruce budworm within recent years.

Vegetational Changes Due to Mammals

Any major change in the faunal components of an ecosystem is likely to effect some change in the vegetational components. Vegetational changes have been rather dramatic in response to the natural mammalian adjustments which have taken place on Isle Royale during the present century.

The disappearance of the caribou by the mid-1920's must have relieved grazing pressures to which lichens had been subjected. However, we do not know the extent to which the original pressures obtained or the effect of the release from this pressure.

During the studies by Cooper in 1909 and 1910, moose had not yet become established on Isle Royale. Brown (undated) stated that, by 1930, moose were responsible for the near disappearance of ground hemlock (Taxus canadensis) on all but the offshore islands and Passage Island. The ground hemlock situation reflects the continued moose pressure on this species over the more than 50 years just past. Even offshore islands now contain only fragmented remnants of this plant. On Passage Island where moose have never become established, the ground hemlock is still abundant.

Moose also utilize balsam fir for winter feeding. In times past when the moose population was high, balsam firs were subjected to intense browsing pressures. These pressures resulted in high browse-lines on the larger trees and clipped tops of seedlings and small saplings. Rarely under these circumstances could a balsam fir reach maturity; the resulting forest composition tended to favor white spruce and paper birch. The browsing pressures were somewhat relieved when moose starvation occurred and when the 1936 burn area reached a stage of succession that provided an abundance of birch, aspen, hazelnut and other moose browse species.

With the establishment of wolves on Isle Royale in the late 1940's, and the subsequent development of a wolf population of 20+ individuals, the wildly fluctuating moose population became relatively stabilized so that much less pressure is currently being applied to browse species at any one time. Even so, the distribution of the moose population sometimes results in heavy browsing of balsam fir and other species in certain localities. It is expected that the current Purdue University studies on moose ecology will produce data to indicate the patterns, if any, concerning intensely browsed areas--where and why they exist.

Brown (undated) and Koelz (1929) both reported that in 1929 and 1930 moose created extensive damage and changes to bog vegetation by reason of trampling and churning. Water lilies and other aquatic plants are eaten by moose--water lilies to the greatest extent because of their high palatability. However, aquatics evidently form only the "salad" in the moose diet (Cain, 1962a).

Beaver activities have also produced vegetation changes in many areas. Beaver impoundments have created ponds or extended the boundaries of existing lakes, swamps or bogs. When enlargement of bog areas by beaver-damming takes place, sections of bog mat may break loose and form "floating islands" (Veirs, 1963). Aquatic vegetation may also be increased when beaver ponding creates extended lake boundaries (Cain, 1962a).

Forest areas in close proximity to populations of these animals may be altered by beaver activities as much or more than the aquatic habitats. Beavers are fond of aspen, mountain ash and paper birch, among others, and these species tend to disappear, whereas spruce, fir and pines tend to obtain dominance in such "selectively cut" areas. Since the beaver competes, to a degree, with the moose for these same species, beaver population cycles, moose population pressures, and wolf predation upon both moose and beaver, are all major factors of a complex trophic web: aspen + paper birch + mountain ash + beaver + moose + wolf. There are other factors in this web, many of which are incompletely or not at all understood.

Summarizing Vegetation

There are two major climax forest types on Isle Royale: the Boreal Conifer formation consisting largely of white spruce, balsam fir, paper birch, aspen, and mountain ash; and the Northern Hardwood-White Pine association of the Eastern Deciduous forest formation, consisting largely of sugar maple, yellow birch, and white pine. The Boreal Conifer formation occurs in proximity to Lake Superior as a result of the cool-moist lake water influence and the Northern Hardwoods occur in inland-upland areas where the lake influence is diminished.

Successional stands of paper birch, aspen, white pine and jack pine occur in many areas as a result of fires and windthrow. Some of these, particularly paper birch, white pine and jack pine are subclimaxes of long duration.

Northern bogs and swamp occur in most valley areas between the long parallel ridges. The bogs are found in every stage of succession from youth to senescence.

Moose and beaver browsing pressures influence natural successional changes--often delaying the advent of climax, but, in turn, the timber wolf ameliorates these pressures.

FAUNA

Isolation

A primary governing circumstance in the occurrence of animal life on Isle Royale is the formidable 15-mile barrier presented by Lake Superior against free migration to and from the island by most terrestrial animals, and some birds. Thus, many species common to the mainland are absent, including bear, deer, porcupine, raccoon, fisher, skunk, badger, bobcat, chipmunk and ruffed grouse.

Other species that have made the crossing are not necessarily better equipped to do so except that they are nonhibernating species that could have traveled over the winter ice between the island and the mainland, or in some cases, may have been accidentally carried over on ice expanses that became detached from mainland shores. These species include the moose, wolf, red fox, mink, weasel, snowshoe hare, beaver, muskrat, red squirrel, deer mouse, and lynx; also, the marten, coyote and caribou, which for other reasons, are no longer present.

Most birds of the Canadian mainland that are capable of sustained flight, particularly the strong migrants, occur here, as do five species of bats.

The amphibians and reptiles exhibit a similarly erratic distributional pattern.

A circumstance of major importance to research is the isolation factor on Isle Royale which results in a greater simplicity and definability of ecological relationships between species than is the case on the mainland. This facilitates discovery of basic ecological relationships and principals whose complexity elsewhere has thus far defied analysis.

Wolf-Moose Relationship

One of the most significant animal relationships on the island, by virtue of its far-reaching and profound effects on vegetation and lesser fauna, is the fluctuating balance between moose and wolves.

This predator-prey relationship at the apex of the ecological pyramid has been studied intensively since 1958, revealing that populations of about 800 moose and 23 to 28 wolves recently have

achieved, and appear to be maintaining, a classic predator-prey balance which it has seldom been possible to illustrate outside of ecological texts.

This ecological chapter began some 10 or 15 years after the turn of the century when the moose arrived on Isle Royale and the woodland caribou began to disappear. The exact year of the moose arrival is not known, but by 1920 they were firmly established and after 1927 the caribou vanished. Moose are excellent swimmers and it is not inconceivable that the first animals swam across to the island. But they may have walked over from the Canadian mainland on winter ice, which, in some years, becomes thick enough to make this possible.

Until the late 1920's or early 1930's the moose had plenty of food and no natural enemies, with the result that their numbers increased steadily. Eventually, however, overpopulation and malnutrition became the enemy. Aspen, birch and balsam fir, as well as aquatic plants of the bogs and swamps, were severely reduced; and smaller aspens, birches and balsams were almost completely cleared from the forests.

The deterioration of the Isle Royale moose range attracted much outside attention and concern. The Michigan Conservation Department tried to control the exploding population by live-trapping moose and shipping them elsewhere in the State but, as is usual with such projects which attack the periphery of a population problem, the effort failed to significantly reduce the Isle Royale surplus.

The crest of the population rise was reached about 1930, when Adolph Murie estimated it at between 1,000 and 3,000 animals. Then began the rather rapid decline that usually occurs when a population exceeds the reduced food supply. Under such conditions, death occurs not necessarily through starvation, for stomachs may be full to the end, but from exposure, particularly during the difficult winter months, aggravated by severe malnutrition. Equally significant for the fate of the population at such times is the drastically curtailed breeding success (failure to mate, failure to conceive, resorption of fetuses, etc.) which results from the malnutrition and from the social stresses caused by overcrowding. The decline is believed to have been further aggravated when an outbreak of spruce budworm occurred in the balsam fir, an important winter food of the moose.

By 1936, the moose had declined to about 200 head, and in that same year fire denuded about one-third of the island of available browse. The fire, although an immediate disaster for the moose in their struggle for food, created an extensive ecological subclimax area which a few years later became covered with a low growth of birch, aspen, cherry and willows--thus creating a new and abundant source of food. By 1945, the moose population had increased again to about 500 animals on its upward spiral--limited, as before, only by the availability of food which, for the time being, was abundant.

In 1948, it was estimated (but probably not as accurately as today) that there were some 800 moose in the park, and, once more, the available food proved insufficient to maintain the increase. As the second moose die-off was underway in 1948, timber wolves were found to be on the island. Evidence from moose hair found in wolf droppings, from examination of moose carcasses and, in recent years, numerous detailed observations of actual attacks, demonstrate that, from that time to the present, the wolves have effectively preyed on the moose. The moose population has stabilized since 1948 at an estimated 800 individuals (as of 1965). This figure is considered to contain a possible error, in either direction, of 200 animals, but detailed studies of the vegetation show that a healthy balance now exists.

Intensive research, initiated in 1958 by Dr. Durward L. Allen and his associates of Purdue University, has revealed that a healthy, adult moose can rarely be taken by wolves, provided the moose elects to stand and fight. It is the aged, crippled, diseased or very young moose that generally elect to run. Unless those that run are very fleet, they are caught and pulled down. The continuing research program shows that, as a result of wolf predation, the incidence of diseased and debilitated moose has been reduced since 1948; a healthier herd has been created, with a high reproductive rate and an increased frequency of twinning. In turn, the island's forests and shrub understory have been relieved of the intense moose pressure which had been such a serious threat. It is clearly of vital importance to the natural biotic unit which is Isle Royale, that the moose and the timber wolf be maintained in their natural relationships in order to insure the integrity of the forest.

Ecological effects of the reduced moose pressure undoubtedly extend to many lower levels of the pyramid, benefiting an unknown number of plant and animal species, but most of these relationships still remain to be identified and explored. Nevertheless, it can

be assumed that the key role played by the wolf at the apex of the ecological pyramid is essential--directly in some cases, indirectly in others--to the continued well-being of a large number of the island's interdependent plants and animals.

Wolf-Beaver Relationship

Another relationship currently being revealed involves the beaver. Even in summer, moose remain the principal source of food for the wolves, but at that season the moose are supplemented somewhat by beaver which then comprise 10 to 15 percent of the total wolf diet.

In the past, Isle Royale's beaver also experienced wide population fluctuations, owing to their tendency to multiply beyond the carrying capacity of their habitat. The beavers colonize new areas, thrive in the absence of population restraints until their natural resources approach exhaustion and then decline.

Current research by Purdue University scientists has not yet fully demonstrated that the wolves have stabilized beaver populations at a level which permits the vegetation as well as the beaver to flourish, but this appears to be a possibility. As the beavers use up more and more of their food and building supplies, they have to travel ever farther from the protection of their ponds and canals. This renders overcrowded beaver populations more vulnerable to capture in proportion to their overuse of their resources, and should tend to stabilize them below a self-defeating level of resource consumption.

Faunal Influences Originating Within the Park

1. Fire suppression. Suppression of natural fires, which are essential for plant successional stages required by moose and other wildlife, has been one of the most potentially far-reaching forms of human interference (see Vegetation section).

2. Park visitor developments. So far, such developments have been handled with restraint and with a minimum disturbance to flora and fauna. A possible exception is the public campground now proposed for the south side of Feldtmann Lake. This would be situated in or close to the only wolf denning area so far discovered in the park.

The trail recently constructed to Feldtmann Lake from Washington Harbor has not in itself presented a serious threat to the continuation of normal wolf reproduction because it has not encouraged prolonged human occupancy and intensive explorations of the lakeshore. But development of a public campground would do just this, and thus could permanently upset the ecological pattern of the area.

3. Trapping by residents of the island before establishment of the park, has been considered to be the cause of the disappearance of the lynx and marten, but their apparently simultaneous disappearance from Sibley Peninsula on the Canadian mainland raises the question as to whether unidentified climatic factors may have been in fact responsible. More concerted attention should be focused on this question to determine whether the disappearance was a part of the unfolding natural ecological story, or a man-caused disruption which should be corrected.

4. Natural changes brought about by the normal interplay of the island's undisturbed ecology are listed here for the sake of completeness, and because further studies are required to achieve a better understanding of them--but no interference with such natural changes appears warranted within the foreseeable future:

The coyote was present from about 1900 to 1956 but apparently was exterminated by the wolf. The incompatibility between these two species has been repeatedly demonstrated elsewhere in North America.

The disappearance of the caribou after 1927, a decade or so following the arrival of the moose, parallels the widespread phenomenon of replacement of caribou by moose which has occurred in Alaska and Canada since the early 1900's. In Alaska, at least, extensive man-caused fires have destroyed the vast caribou lichen ranges of primitive times and replaced them with moose browse. So far, recorded dates of fire occurrences on Isle Royale do not appear to closely coincide with the replacement of caribou by moose; thus, further investigation is required to determine the cause of this replacement on Isle Royale, and to learn whether it was a natural or a man-caused event.

The continuing natural evolution of wolf, moose, beaver, snowshoe hare, forest, bog, and swamp successional relationships and stages are described elsewhere.

Faunal Influences Originating Outside the Park

1. Bald eagle populations virtually throughout the United States, except in Alaska and southern Florida, are seriously threatened by agricultural pesticides such as DDT, which are progressively concentrated in the tissues of aquatic organisms lower down in the eagles' food chain. By the time these concentrations are passed along to the eagles, they are high enough to significantly reduce the fertility of the parent birds, and (by introduction of the pesticide into the eggs) the survival rates of the few young produced. Isle Royale's eagle population has suffered the same fate as those elsewhere.
2. White-tailed deer were introduced by the Michigan Department of Conservation in 1906. They persisted until 1936 but, as in other regions, could not indefinitely withstand heavy moose competition in a severely browsed environment.

Summarizing Fauna

The Isle Royale fauna is an isolated one. This produces a faunal complex that lacks some mainland elements as well as containing unique forms which have evolved separately from mainland counterparts. Moose, beaver, timber wolf, snowshoe hare, red fox and red squirrel are the most abundant and important mammals. The wolf exerts a restraining influence on the moose and beaver populations--populations that have undergone wide numerical fluctuations in previous years when no timber wolf population was present. The browsers (moose, beaver and others) also exert significant pressures upon the plantlife; especially aspen, paper birch, mountain ash, balsam fir, and ground hemlock. These plants undergo decreases whenever moose and beaver populations explode, and increases whenever moose and beaver decrease. The wolf tend to ameliorate all of these fluctuations.

Lynx, marten, coyote and caribou were all present on Isle Royale until rather recent times. Causes for their disappearance are uncertain, although the coyote conspicuously disappeared as the timber wolf arrived and increased.

Most birds capable of sustained flight that exist in nearby mainland areas are found at Isle Royale. The most conspicuous birds are the herring gulls who occupy many offshore rocky island rookeries. There are only nine amphibian and three reptilian species present in the park.

E. AQUATIC ENVIRONMENTS

Included within the park are the waters of Lake Superior for a distance of approximately 4.5 miles from shore. Much of this water is extremely deep, extending to depths of over 500 fathoms. Isle Royale's outline is broken by numerous channels, bays and harbors. Several, especially those located on the northeast end of the island, are long and narrow, coinciding with the valleys between the ridges. Prominent of these is Rock Harbor but others include: Amygdaloid Channel, Robinson Bay, Duncan Bay and Tobin Harbor. Largest of the bays is Siskiwit Bay which is more than 13 miles long and 3 miles wide. It is enclosed by Houghton Ridge and a chain of long, narrow islands. Washington and Grace Harbors are prominent on the western end of Isle Royale. Todd Harbor is located on the north.

The abundance of lakes, bog ponds and swamps give evidence of the imperfect drainage of Isle Royale. From them drain small streams which flow generally toward the ends of the island with a few flowing through narrow cross valleys which have resulted from faulting. Although the majority of the streams are small, outstanding exceptions are found in Washington Creek and Grace Creek flowing to the west; Big Siskiwit River, Little Siskiwit River, and Siskiwit River entering Siskiwit Bay; and Tobin Creek draining into Tobin Harbor.

Lakes and ponds vary in size from tiny beaver ponds and bog ponds to the largest lake on the island, Siskiwit Lake, which covers over 7 square miles. More than 160 lakes have areas which exceed one acre. In addition there are numerous smaller ponds.

With the retreat of the glaciers and the gradual emergence of the island above Lake Superior, water filled the readymade basins. Other lakes were created in situations where wave action built bars across the ends of channels. A still further change in elevation between the island and Lake Superior by only a few feet could change existing long, narrow channels on the northeast end of the island into independent lakes separated from Lake Superior. Pickerel Cove and Duncan Bay are prominent examples of such situations.

The lakes of Isle Royale are "born to die" like all other lakes as aquatic vegetation gradually develops and encroaches upon the open water surface and sedimentation is accelerated. Lakes in all stages of evolution from the very young to the very old are readily found in the park. This successional process is most evident in the small ponds and lakes sheltered from winds and having little outflow.

Adolph Murie pointed out in his evaluation report on Isle Royale (Murie, 1935) that, "In few places can one find the life history of a bog so well illustrated. There is the open lake with no marginal vegetation, the lake with marginal vegetation of varying widths, the lake with a false bottom and grown up in water lilies, and many other stages, leading finally to the filled in bog grown up in cedars and black spruce."

Cooper discusses the succession of a bog lake in considerable detail. He used Amygdaloid Lake, on Amygdaloid Island, as an example of the lake in which bog plants are gaining first foothold; two ponds (now known as Hidden Lake and Moose Lake) near Tobin Harbor to illustrate lakes which are partly covered by aquatic vegetation and are being filled in by bog edges; and the basin on Raspberry Island to demonstrate a completely covered bog.

The successional process is much less evident in the deeper, larger and exposed lakes such as Siskiwit and Feldtmann. Action of waves and ice retard the establishment of aquatic vegetation, except in the more sheltered coves.

Beaver Ponds

Lakes of Isle Royale received initial studies by University of Michigan scientists in 1904 and 1905. Investigations were limited to a few lakes; namely, Sumner and Desor. The most intensive investigation was made by Walter Koelz (1929) when he studied 38 lakes in connection with research on their fishes. By damming of creeks and swamps, beavers are continuously creating new ponds and small lakes or enlarging smaller preexisting bodies of water. Lake Ojibway is an example of a tiny pond which has been enlarged by beaver activity to a lake measuring over a half-mile in length. When abandoned by beavers, their ponds are gradually filled in by vegetation and the successional process is hastened.

Lakes

Lakes of Isle Royale probably fall conveniently into the following three groups according to physical, chemical and biological characteristics: (1) dystrophic lakes; (2) eutrophic lakes; and (3) oligotrophic lakes.

1. Dystrophic Lakes. These lakes are characterized as having water brown in color and containing high concentrations of nutrients, organic matter and humic materials. The pH of these lakes is usually

low indicating that they are highly acid. Dissolved oxygen content is extremely low. Such lakes on Isle Royale have bog borders and soft bottoms. They usually have depths of less than 5 feet and are rarely as deep as 10 feet. They range in elevation from some of the lowest bodies of water on the island to Lily Lake, the highest. Examples of such lakes are: Akmeek, Wallace, Sumner, Lily, Theresa, Mud, Sholts, and Stickleback, in addition to numerous smaller unnamed lakes.

Isle Royale bog lakes contain few kinds of fishes, usually six or less species. Although the brook stickleback occurs in nearly all of them, the finescale dace, the northern redbelly dace, and the northern fathead minnow are the most characteristic fishes of boggy situations on Isle Royale.

2. Eutrophic Lakes. Eutrophic lakes are the most numerous type on Isle Royale. Generally, they are 10 feet or more in depth, but possess extensive littoral zones which favor an abundance of rooted aquatic plants. Their waters are warm, highly organic and rich in nutrients. Plankters may be abundant. In size, lakes of this type range from Feldtmann Lake, one of the park's largest to Wagejo, a small pond.

Common fishes in the eutrophic lakes include pike, yellow perch, blacknose shiners, white suckers, golden shiner and spottail shiner. The number of species found in these lakes may range from two to eight and thus is intermediate between the numbers found in the bog lakes and in the deep lakes. Coregonids (whitefishes, herrings, ciscoes) are not present in the eutrophic lakes of the park.

3. Oligotrophic Lakes. The deep, cold, clear-water lakes represented on Isle Royale by Siskiwit, Richie, Desor and Sargent Lakes, are low in nutrients and organic matter and are classed as oligotrophic lakes. Extensive littoral zones are lacking in these lakes and, consequently, populations of rooted aquatic plants are small. Plankters are relatively scarce. Eventually, after a long period of time, these lakes may evolve to a eutrophic stage.

Hubbs and Lagler determined that oligotrophic lakes on Isle Royale contain the highest number of species of fish. In fact, the average number of species is more than twice that found in the eutrophic lakes although the number of individuals per species may be fewer. Siskiwit has 17 species; Richie, 11; Desor, 11; and Sargent, 9. The unique coregonids present in the four lakes are

distinguished, at least by average differences, from their Lake Superior relatives.

Fish Fauna

The fish fauna of the lakes and streams of Isle Royale and the adjacent waters of Lake Superior is composed of at least 55 forms. All are native to park waters with the exception of the sea lamprey, rainbow trout, alewife, and smelt which have reached park waters through natural dispersal from introductions made in other portions of the Great Lakes. Of these nonnative fishes, only the rainbow trout is known to have entered waters on the island.

A few plantings of nonnative fishes have been made in island waters but it is doubtful if any of the plantings were successful. Consequently, the natural ecological condition of the Isle Royale fish fauna is believed to remain virtually unaltered by the introduction of nonindigenous species or strains.

The unique significance of the park's fish fauna was reported as follows by Dr. Carl L. Hubbs, then Curator of Fishes, Museum of Zoology, University of Michigan, in correspondence with Director Newton B. Drury, February 7, 1942:

"The fish fauna of the island has a number of distinctive features. Many of the mainland types are lacking. There seems to be at least three endemic subspecies of minnows. It has not been demonstrated that any of the game fish, such as brook trout, are in any way different from those of other regions, but we can have no assurance that they are exactly the same. We do know that some of the deep water coregonid fishes of the lakes are confined to the island . . . Isle Royale presents an unique opportunity of preserving for posterity a sample of the aboriginal fish population."

Of special interest is the fact that at least eight fishes found on Isle Royale are endemic forms, not found elsewhere.

The endemic Siskiwit Lake cisco, Coregonus bartletti, was initially taken off Teakettle Island in Siskiwit Lake in 100 feet of water on August 21, 1929, and described by Walter Koelz. Drs. Hubbs and Lagler report that the variability of this species is perhaps due to hybridization in the past. The period of isolation probably approaches 5,000 years, because Siskiwit Lake lies 57 feet above

Lake Superior. Since the cisco inhabits deep water, the species probably has remained completely isolated. It is unlikely that either it or its ancestor penetrated into the lake through the outlet.

The coregonids found in Siskiwit, Desor, Sargent, and Richie Lakes are distinguishable, at least by average difference, from their Lake Superior relatives.

Based upon specimens collected in Lake Desor on September 10, 1929, Koelz described as unique the Lake Desor whitefish, Coregonus clupeaformis dustini. Distinguishing features are the large mouth and slender form. Hubbs and Lagler speculate that these characteristics may well be adaptations to this subspecies' fish-eating habits which have been enforced by the paucity in Lake Desor of the normal whitefish food, molluscs and crustaceans.

The Siskiwit Lake whitefish, Coregonus clupeaformis, ssp., although it has been isolated only since Lake Nipissing time, appears to be unique to Siskiwit Lake and, according to Drs. Hubbs and Lagler, apparently has become subspecifically differentiated from the Lake Superior whitefish. Koelz collected specimens in August 1929.

Ciscoes found in Isle Royale lakes seem to be differentiated from one another, from forms present in inland lakes elsewhere, and from the Lake Superior form. The Sargent Lake cisco, Coregonus artedi sargenti, is considered by Hubbs and Lagler to be a distinctive race. The type specimen was secured from Sargent Lake, September 19, 1929, by Walter Koelz who initially described the form.

Lake Desor cisco, Coregonus artedi, ssp., evidently represents a distinct subspecific endemic form, but its exact taxonomic status has not been determined.

The most notable differentiation, reports Hubbs and Lagler, is perhaps that of three minnows which occur in Harvey Lake: Harvey Lake pearl dace, Margariscus margarita koelzi; Harvey Lake blacknose shiner, Notropis heterolepis regalis; and Harvey Lake fathead minnow, Pimephales promelas harveyensis. They were collected by Walter Koelz on September 1, 1929, and later described as unique subspecies by Hubbs and Lagler. These investigators noted that in other park waters representatives of these species have remained scarcely or much less modified from typical forms. It appears that the differentiation of

the Harvey Lake forms is due to isolation rather than to any peculiar ecological conditions which prevail in the lake. The Harvey Lake fishes have been isolated from other waters only since emergence from Lake Superior during postglacial times. The outlet is so small and, in part, so steep that it has probably been a barrier to further invasion by minnows from Lake Superior since that time.

Most of the other park fishes exhibit no specific differences but several display unique characteristics. It is significant that speciation appears to have taken place in certain fishes of Isle Royale lakes because the fishes have been isolated for not more than 9,000 years.

Other species also may have become more or less differentiated on Isle Royale. Hubbs and Lagler point out, for example, that the populations of walleye in Chickenbone, Whittlesey, and Dustin are very peculiar in appearance and may represent local differences. Furthermore, there are indications that ecotypic subspecies or races of ciscoes and herrings, Coregonus artedii, and the lake trout, Salvelinus namaycush, occur along the Lake Superior shores of Isle Royale.

Origin and Distribution of Fishes on Isle Royale

The means by which the types of fishes now found on Isle Royale reached the island has been the subject of considerable speculation by many, including A. G. Ruthven, Walter Koelz, Carl L. Hubbs, and Karl F. Lagler, who have made detailed studies of this fish fauna.

The fish fauna apparently is limited in numbers of families and species represented because of the northern latitude and the isolated position of the island in a large cold lake. The occurrence of each species in the Isle Royale fish fauna is primarily attributable to incursion; secondarily, to survival or differentiation. Like other parts of the Great Lakes region, Isle Royale was populated with fishes during and after the melting of the last continental ice sheet.

Ruthven (1909:329) and Koelz raised the question of how fishes which originated in quite different habitats could span Lake Superior to reach the island. Koelz remarked: "A journey of twenty-five miles across a depth largely over 600 feet, in water that for most of the year is near freezing, is hardly to be expected from fish that do not regularly grow larger than three inches and prefer to live on warm shoals." Considered are fishes such as the creek chub,

pearl dace, finescale dace, northern redbelly dace, golden shiner, blackchin shiner, northern mimic shiner, blacknose shiner, fathead minnow and logperch.

Several theories are advanced to account for the arrival of such fishes on Isle Royale:

1. Transported by fortuitous means such as being carried as eggs or at other stages by birds, high winds, with or without aid of rafts.

2. Followed smaller watercourses on a land bridge or on the bottom of Lake Superior when and if it was exposed during the evolution of the Great Lakes. Neither seem probable from existing geological evidence.

3. Fishes may have, or have had, greater powers of dispersal across deep waters than is generally recognized. Since any fish in the latitude of Isle Royale are forced to live in icy water for several months each winter, their ability to survive for a considerable length of time in Lake Superior is to be expected. Crossing from the mainland may have been very rare events, but thousands of years have elapsed since the Lake Superior basin became filled with water.

4. Lake Superior may have interposed a less formidable barrier against the invasion of fishes from the mainland during a warm post-glacial period.

George Stanley's survey of the Pleistocene geology of the island in 1930 leaves no reason to believe that any fish could have reached the island by any means other than swimming from the mainland across the intervening channel, no matter how wide, deep, and cold it may have been.

It is improbable that all fish immigrants to Isle Royale have survived. It may be assumed that there has been at least local extirpation, particularly of the cold water, clear-water pioneers. Thus, most of the inland lakes were no doubt at first occupied by coregonids (the whitefishes) which have vanished in all but the four largest and deepest lakes.

Isle Royale lakes were created as the island rose and the waters of the Great Lakes receded. Initially the lakes on the islands were not abruptly and completely isolated and thus contained

a variety of fishes. Outlets connecting the inland waters with Lake Superior contained more discharge and they were not immediately blocked by impassable barriers. At present, however, the outlets of most Isle Royale lakes appear to be too small or obstructed to serve effectively as channels by which fishes can ascend to the lakes.

Lack of suitable habitat and ecological conditions or the changing of original conditions have resulted in the survival of the more adaptable forms.

Higher Isle Royale lakes harbor glacial Great Lakes fishes as relicts. Lake Desor, for example, has 11 fish species partly because of its large size and varied habitats. The gradient of the outlet permitted entry of many species. The highest lake--Lily Lake--has three typical northern bog water forms which entered by the outlet or are relicts dating from the ancient origin of the lake.

Richness of the Isle Royale fish fauna decreases with increasing elevation. At the higher elevations, there are fewer waters and less varied habitats. Many species which reached waters adjacent to the island at a later time were able to enter the lower waters. As outlet streams to many of the upper lakes had become smaller and intermittent, they provided restricted access.

Distribution of the fishes appears also to be somewhat scattered as though chance played an important role in dispersal and survival of the fishes entering lakes on the island. Twenty-four fish species are known to occur in not more than one lake each. Eight forms are found in only two lakes each. In general, the larger, as well as the lower lakes, have the highest number of species--Lake Superior has 38 forms, Siskiwit Lake has 17 forms, and Lakes Richie and Desor have 11 each.

Introduced Fishes

The sea lamprey, the rainbow trout, the alewife, and the smelt are the only fish species present which are not native to the park. The rainbow trout is the only nonnative fish found in streams on the island. Planting of fishes into waters on the island has been limited to the stocking of 4,500 brook trout in Tobin Harbor, Big Siskiwit River, Little Siskiwit River, and Rock Harbor in 1932; 10,000 brook trout in Tobin Harbor and Rock Harbor in 1941; and the release of 5,000 brown trout in three streams in 1941. Sometime

prior to 1935, Mr. Frank Warren is reported to have planted walleye fry in Richie Lake and Moskey Basin of Rock Harbor. Fortunately, none of these planted fish are believed to have survived to contaminate the natural indigenous fish populations.

For a number of years, eggs were taken from lake trout in the Lake Superior waters off Isle Royale by the State of Minnesota for propagation in the Fish and Wildlife Service (formerly Bureau of Fisheries) hatchery at Duluth. Subsequently some of the resultant fry were released into Isle Royale waters. In addition, whitefish have been stocked in the Lake Superior waters near the island.

Use of the Fishery Resources

Sport fishing is permitted on the lakes and streams on Isle Royale and in the waters of Lake Superior adjacent to the island. Commercial fishing is conducted in the waters of Lake Superior but is not permitted in inland lakes or streams on the island. The National Park Service has complete management jurisdiction over the fishery resources on the island, but in the waters of Lake Superior regulation of fishing is under the control of the State of Michigan.

The principal sport fishes include the pike, yellow perch, walleye, lake trout, rainbow trout, brook trout and pumpkinseed.

Pike and Perch. The most abundant and widespread species are the pike and the yellow perch which are in 28 and 29 lakes respectively and also the inlets of Lake Superior. In some waters the pike reportedly are thin and in "poor condition," apparently as a result of overabundance of fishes in relation to the relatively poor food supplies. Nevertheless, Isle Royale is frequently referred to as the "pike capital of the country." In abundance, the pike is the No. 1 sport fish of the park. The perch is also abundant. Koelz reported that perch were so numerous in Forbes Lake that the lake was locally called "Perch Lake."

Trout. Few waters of Isle Royale appear to be highly ideal for trout. The nonnative rainbow trout is found most abundantly in Washington Creek during the spring when it runs in from Lake Superior to spawn. It is also found in the lower end of the outlet stream from Siskiwit Lake. The extent to which the rainbow trout is established in these streams as a resident form is not known.

In Lake Superior the brook trout is called a "coaster." Coasters migrate into several park streams to spawn during the fall and frequently are caught near the mouths of the streams. The degree to which the upstream movement of brook trout is limited by barrier falls and bog waters is not known. In addition, resident brook trout are found in Washington Creek, Grace Creek, Little Siskiwit Creek below the falls, Benson Creek, Tobin Creek, Desor and possibly others.

Brook trout have been reported from Desor, Hatchet and Siskiwit Lakes but the current status of the species in these lakes is not known. The inclusion of Lake Desor stems from the record of a single specimen found in the lake near the head of the outlet. In Hatchet Lake, near the mouth of the outlet, Koelz (1929) took 11 brook trout, but Robert Nord was unable to locate any brook trout in the lake during his 1961 survey. It is doubtful that conditions in these lakes are suitable for permanent residence by brook trout. During periods of favorable water conditions, it is possible that the brook trout may ascend from Lake Superior to Lake Desor and Hatchet Lake.

The lake trout is found only in Siskiwit Lake in addition to the waters of Lake Superior.

Walleye and Pumpkinseed. Chickenbone, Whittlesey and Dustin Lakes are the only lakes which contain walleye and the distribution of the pumpkinseed is restricted to Richie and Mason Lakes.

The Invasion of the Sea Lamprey. In the course of its rapid spread through the Great Lakes after its initial entry into Lake Erie through the Welland Canal, the sea lamprey finally reached Isle Royale in 1946. A 9.5-inch specimen was taken from a 10-pound lake trout by a commercial fisherman near Rock Harbor on August 15, 1946. Since that time many lake trout and other species of fishes in Lake Superior within the boundaries of the park have fallen victim to this parasite and the subsequent decline of the commercial fishery at Isle Royale, previously discussed, resulted.

There was concern that the lamprey might migrate into park streams for spawning purposes. In June 1955, the Bureau of Commercial Fisheries conducted a survey of 12 streams on Isle Royale. No evidence of sea lamprey use was found. A reexamination of four of the streams in mid-August of that year again did not provide any indications of the presence of the lamprey.

A check of all the important streams on Isle Royale was made again in September 1960. During the course of these investigations, no spawning beds, lamprey larvae, or ammocoetes were observed. Special attention was given to the outlet stream and tributaries of Siskiwit Lake because of fear that the sea lamprey might have invaded this lake. Although occasional but unconfirmed reports have been received that lake trout caught from Siskiwit Lake bear lamprey scars, the falls in the outlet are apparently sufficient barriers to keep the lamprey from ascending into the lake. It is possible that an indigenous lamprey may occur in the lake, since they are found elsewhere in the Great Lakes region, but so far native lamprey have not been recorded from Isle Royale. Again in 1962, during a resurvey of the streams and channels of Isle Royale, no lamprey larvae were found. The presence of the sea lamprey was evidenced in 1949 when 0.57 percent of the lake trout taken from the Isle Royale waters of Lake Superior bore lamprey scars. The percentage of scarred fish increased during the subsequent years at an accelerated rate. The first indication that the lamprey control operations were resulting in a reduction of lamprey populations in Lake Superior occurred in the fall of 1961 when the incidence of scarred trout was encouragingly low.

The effects of the continued predation by sea lamprey upon the fishery resources of Lake Superior is of especial concern to the Service as it relates to the continuance of sport and commercial fishing for lake trout in waters adjacent to the island. As the predicted recovery of the lake trout fishery materializes, the Service will be mindful of management measures and regulations developed to protect the lake trout fishery for sport and commercial fishing purposes.

Research activities in Lake Superior by the Bureau of Commercial Fisheries are directed toward learning more about the limnology of the lake and about the life history and taxonomy of the various species of fishes. Special emphasis is placed on commercially significant species, but other species are studied as well, because it is recognized that each plays an interdependent role in the ecology of Lake Superior. Much of this work has been done in waters adjacent to Isle Royale.

Relationship of Moose to Aquatic Vegetation

In the process of feeding along the edges of the lakes, moose consume considerable amounts of aquatic vegetation and break loose sections of the sedge mat. Koelz, during his 1929 investigations of the lakes of Isle Royale, observed that the eradication by the moose of the higher aquatic plants undoubtedly had serious consequences upon the fish life. These plants are important in affording certain species with food and shelter.

Using historical accounts and scientific studies conducted prior to the arrival and buildup of the moose populations as an index (Adams, 1908; Cooper, 1913) and comparing these conditions with the situation in 1930, Brown (undated) remarked upon the absence of aquatic plants, particularly the water lilies in lakes such as Summer and Moose. He also commented upon the damage to the sedge mats of the bog lakes caused by the movement of the heavy mammals over the fragile shorelines.

Murie (1934) made similar observations and suggested that the destruction of certain summer foods (such as some of the lake plants) probably had more serious effects on the plant and animal interrelationship than the destruction of winter foods. For instance, a reduction of water plants may have a rather direct deleterious effect on the fish fauna. He remarked that he found that water lilies were practically gone and only an occasional plant was found; and that no doubt the lakes were formerly a source of much summer food which had become greatly depleted.

Hubbs and Lagler also concluded that aquatic vegetation was probably more abundant before it became heavily browsed by moose. The minnows, including the unique forms in Harvey Lake, occupy lakes which contain considerable aquatic vegetation.

So little is known about the exact life history of many of the minnows in Isle Royale lakes that it is difficult to evaluate the impact that a reduction or disturbance of the aquatic plants may have upon these native fishes.

Effect of the Fires Upon Aquatic Environments

The effect that forest fires on Isle Royale have upon the aquatic life is not known. The removal of the vegetation undoubtedly resulted in considerable silting and alteration of the chemical content of the water in individual lakes.

Nord, who studied Hatchet Lake in 1961, raises the question of the possible effect that the 1936 fire may have had upon populations of brook trout which formerly were reported from this lake.

Influence of Beavers Upon Fish Distribution

Adams (1908) reported that in 1905 the beaver in all probability had been extirpated from Isle Royale. The routes of travel and several of the stations established by the University of Michigan survey were in localities where beaver are now present. It is difficult to believe that the animal was extirpated because today beaver are abundant in streams, lakes and swamps. The damming of these watercourses and the creation of new ponds may have an effect upon the distribution of the fishes on Isle Royale by limiting upstream movement and by creating new types of aquatic habitats.

Summarizing Aquatic Environments

The waters of Lake Superior are cold and clear, and support numerous forms of lake trout, whitefish, ciscoes and others. The sea lamprey has invaded these waters in recent years, depleting especially the commercially valuable lake trout.

Two hundred and two inland lakes on the main Isle Royale exhibit a variety of sizes and kinds--dystrophic, eutrophic, and oligotrophic.

There are 55 or more species and varieties of fishes in Isle Royale waters. Three of these (sea lamprey, rainbow trout and alewife) are exotic. The largest, most abundant inland lake fish is the northern pike. Others include yellow perch, walleye, lake trout, rainbow trout, brook trout and pumpkinseed.

Beaver, moose and forest fires all have important influences on the aquatic habitats, but most of these influences are as yet incompletely known or understood.

NEEDED RESEARCH

A 15-member committee of the First World Conference on National Parks pointed out in 1962 that, "Few of the world's parks are large enough to be self-regulatory ecological units; rather, most are ecological islands subject to direct or indirect modification by activities and conditions in the surrounding areas."

Isle Royale, though indeed an "ecological island," is almost unique among national parks in being effectively isolated from the majority of potentially serious, man-caused, modifying activities and conditions of surrounding areas. Moreover, the island is large enough to be, under these conditions of isolation, a self-regulatory ecological unit.

Unnatural changes (i.e., those resulting from human interference with the island's self-regulating mechanisms) have been few and comparatively superficial. Thus, in this park, it is possible to identify and document the current natural status of the park resources in advance of unnatural trends and developing situations which might adversely affect these resources if permitted to occur.

From the foregoing chapters, the overall outlines and objectives of the Service's research plan for Isle Royale National Park emerge. Such research shall be designed to obtain information necessary to maintain, restore where necessary, and interpret the natural environments and ecological relationships of the entire biota, together with the associated primitive wilderness atmosphere.

Determinations of the degree and kind of human interference with original natural conditions shall rest on the assumption, except where further research indicates otherwise, that natural conditions prevailed in Isle Royale National Park up to the early 17th century. While this Plan is devoted to research in the natural sciences, it is obvious that historical research is needed to determine the locations and extents of past human interference, to the degree that such interference may have affected natural ecosystems in the park; and firm facts concerning the past fire history, if available, would be very valuable in determining the true value of some communities--Mt. Ojibway, for example.

Owing to the fortunate and almost unique circumstance that the original ecology is virtually unimpaired in this park and, at the present time, requires little more than further elucidation and understanding, management and interpretation find themselves in

need of the same basic information for application to and support of their respective programs and responsibilities.

There is immediate usefulness for administration, interpretation, planning and protection in classifying the salient natural resources of the park according to a few major categories. Such categories indicate the position of the park, resource-wise, in the National Park System as a whole; they may also be used to identify fragile or unique features that require special attention and/or protection.

However, such a summary of major categories must not obscure the underlying fact that all of the park resources are ecologically interrelated so that neglect of any resource or component eventually may adversely affect all of them.

In reality, allowing the natural processes associated with these resources to unfold while their built-in checks and balances function with an absolute minimum of human interference--preferably none at all--constitutes a contribution to science and education which the national parks are uniquely fitted to present.

The following problems and research needs reflect the meager extent of current ecological and management understanding of the park resources, and their protection and interpretive needs. The list should proliferate as understanding increases and research brings into sharper focus the outlines of resource situations which are only dimly glimpsed at present.

Practical considerations will make it impossible at times to arbitrarily establish priorities among these research needs on a strictly logical basis. It might be ideal to first determine original natural conditions in a park in order to better understand current situations. However, in actuality, where unnatural situations have been long neglected, they cannot further be deferred without approaching a potentially irreversible stage--corrective action can be of little avail if too long postponed. In such cases, management requires prompt application of the best scientific knowledge and planning. When an adequate research program is underway, such emergency situations should tend to phase out of the program, and research should concentrate on identifying and correcting unnatural situations before they reach an acute stage.

Through circumstances beyond control of the Service, competent investigators may be available for studies of current, urgent

situations at a time when investigators of the original natural conditions cannot be located. On the other hand, there is usually some overlap between execution of the four research and management steps outlined in the Leopold Report, and this can mitigate the situation; comprehensive studies inevitably draw comparisons between ecological conditions now and in primeval times.

A. GEOLOGY

Much of the geological story of Isle Royale is based on studies conducted on the mainland in the United States and Canada. The needs of the present and future are for research within Isle Royale National Park itself.

Generally, geological knowledge is basic to an understanding of plant-soil-parent material relationships, drainage patterns, special edaphic conditions and the like. Moreover, such basic knowledge can be vitally important to the planning and construction of developed areas and to the interpretive program.

The geological history of the formation of Isle Royale--the lava flows, sedimentation, erosion, glaciation--is of continuing interest to park visitors. Indeed, the geological story is reported to be the most important interpretive problem in the park. Perhaps this is partially explained by the fact that rocks are exposed to view along so many of the shores and ridge slopes. In any event it would seem reasonable from this standpoint alone to take a more active part in determining the finer points of Isle Royale's geological history.

PROBLEM: The geological forces and events that produced Isle Royale and the Lake Superior basin have only been theorized upon; there is no widespread agreement among geologists on this point. Moreover, Isle Royale itself has never been geologically surveyed using modern methods and principles as bases for the survey. Suffering from this lack of knowledge are the following:

1. Understanding of soil types and their bearing upon different vegetative stands.
2. Nutritive and toxic soil substances and their roles in vegetation, fauna, aquatic life distributions.
3. Adequate explanations of geological history of Isle Royale to the visitor.
4. Wise planning of construction sites and developments.

Drainage and ground water patterns are not adequately enough known to assure sound planning of sewerage systems and potable water supplies (other than from Lake Superior).

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RESEARCH NEEDED: At least one major research project is envisioned, several smaller projects which may be logical parts of the major project if other circumstances permit.

Geological mapping of Isle Royale: Greatest among the needs in the realm of geology is a good geologic map of the park. The Geological Survey is prepared to produce such a map on a cooperative basis. The projects listed concerning the sedimentary rocks and their stratigraphy and relationships to adjacent igneous formations can be a phase of the study essential in producing such a geologic map. The map and its associated narrative should include:

1. The lava flows, sandstones and conglomerates, accurately plotted.
2. Their strike and dip recorded.
3. The fracture pattern.
4. The contacts.
5. The sedimentary features as cross bedding, etc., that show direction of sedimentation.
6. The amygdaloidal zones, showing oxidation, flowage, mineralization.
7. The shape of the ridges--glacial grooves, scratches and gravel banks.
8. Depth and type of soils; samples gathered for tests.
9. Rock samples for detailed petrographic study: texture and composition.
10. Explanation of surface and subsurface drainage patterns; type and amount of water held in the subsoil, distribution, quality and quantity of subterranean water, etc.

RESEARCH NEEDED: A comprehensive study of the composition and structure of the igneous rocks of the Isle Royale archipelago. This study should embrace the collection of rock specimens and their detailed petrographic analysis.

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A study of this kind would disclose the lateral and vertical variations in mineral content and texture of all of the exposed igneous formations which would, in turn, disclose data as to probable sources, directions of flow and related information.

RESEARCH NEEDED: The stratigraphy and structural relationships of all sedimentary formations to one another and to the adjacent igneous rocks of the area. These may disclose some new knowledge concerning the preglacial geology of Isle Royale that has not yet come to light.

RESEARCH NEEDED: The roles of preglacial, glacial and postglacial erosion in producing the present day topography and configuration of Isle Royale and associated islands of the archipelago. We know that erosion of these three stages has exercised a profound influence on the existing landscape of the area, but this cannot be expressed in quantitative terms on the basis of available information.

RESEARCH NEEDED: The geomorphology of the Isle Royale archipelago. Much is known about this subject based principally on work done around Lake Superior's borders. What is needed is an intensive study based on observations and investigations within the area. This project is closely related to others in this list and may be accomplished as phases of other projects if planned in advance.

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B. CLIMATOLOGY

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PROBLEM: Available data from operating weather stations on Isle Royale have not been compiled and statistically treated. Therefore, no comprehensive weather record is available for the park for even that period of the year when weather data are gathered.

PROBLEM: Weather station data do not exist for late fall, winter and early spring periods of the year. Therefore, annual precipitation and temperature totals, means and cycles for Isle Royale are completely unknown. Without this basic knowledge, analyses of vegetation, wildlife and aquatic life, successions thereof and their relationship to climatic conditions cannot be fully understood.

RESEARCH NEEDED: At least one, preferably two, regulation U. S. Weather Bureau instrument shelter complexes, containing at least maximum and minimum thermometers and rain and snow gauges, should be operated on a continuous year-round basis. The type of data should be comparable to data obtained at other official weather measurement stations in the Lake Superior area. It may be necessary to utilize automatic and/or telemetering instrumentation to gather these data if the stations cannot be manned during winters.

PROBLEM: There is sufficient evidence to indicate that a climatic gradient occurs on Isle Royale, extending from northeastern lakeshore areas to southwestern inland-highland areas. However, there is not adequate data to characterize this gradient and variations within the gradient. This knowledge is prerequisite to most biological research needs in the park.

PROBLEM: Plant and animal distributions are governed in a very large way by microclimatic patterns. With few exceptions, these patterns are totally unknown for all sections of Isle Royale.

RESEARCH NEEDED: Microclimatic study of typical Isle Royale situations such as:

1. Lakeshore areas of northeast, central and southwest Isle Royale.

2. Ridgetop areas.

3. Inland valley areas (including streams, lakes, swamps).

(This could conceivably be combined with an appropriate vegetation survey or phytosociological study.)

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C. BOTANY

The work of Cooper (1913) was a pioneering effort in describing the forest ecology of Isle Royale; his work was, and continues to be, a classic study. Most of his work, however, was done in the northeastern areas of the park, and it was completed previous to the existence of moose and wolves in the ecosystem. Brown (undated) gave a general description of the island's vegetation in 1930, but did not dwell on specifics. Linn (1957) described mostly only the Boreal Conifer-Northern Hardwood transition and some of the general causes for it. There is no definitive work which describes in detail each vegetation type--its phytosociology, edaphic and soil moisture relationships, microclimate, and the like. Before the vegetation can be understood, such studies are mandatory.

PROBLEM: There is no vegetation map for Isle Royale which includes a complete description of each vegetation type shown. The need is for a map which shows each type, whether successional or climax, and is supported by sufficient ecological data to permit identification of the probable climax vegetation for each area. Such a map with attendant ecological studies would furnish valuable information basic to wildlife surveys and studies, to fire prevention planning, to construction programs of all kinds, and to the interpretive program.

RESEARCH NEEDED: Vegetation ecology studies:

1. A modern vegetation map, utilizing those maps already available.
2. Phytosociological studies of each vegetation type.
3. Vegetation-edaphic-microclimatic relationships (see proposal for climatological studies to be undertaken and combined with this).
4. A map of 1847 vegetation based upon original land survey.
5. Study of fire occurrences and their causes, based upon National Park Service fire records at Isle Royale, and from field evidences of past fires.

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6. Succession studies in burns and other areas, continuing or adding to information developed by Cooper (1913). An important aspect should be the effect of moose and beaver upon the course of succession.

PROBLEM: In the construction of campgrounds and other development areas, which vegetative type can be expected to best withstand the human impact involved: Which can least withstand it? Which type would be most desirable from the visitor's point of view? What native plants can be utilized to greatest advantage in plantings for new building sites and other landscaping purposes?

RESEARCH NEEDED: Vegetation-Human Impact and Use Studies in developed areas: Studies in current heavily used campsites and other areas receiving intensive use, to determine which plants are most easily disturbed and which native plants survive.

PROBLEM: Although bogs are common on Isle Royale, they have not been intensively studied. Their ecology is not well-known, are there several "types" and how much do these types intergrade? Also, what role is played by the moose and beaver in bog ecology? Can bogs be preserved in the face of visitor use--use that permits trampling of bogs? How can provision be made for visitors to see a bog without destroying it?

RESEARCH NEEDED: Bog ecology studies:

1. Determine the different bog types--water exchange rates, chemical and physical properties of the water and underlying parent material, plant species involved and their interrelationships, successional rate, etc.
2. Determine least disruptive means of exhibiting bogs. (See also: Aquatic Biology Research Needed--"External Influences on Aquatic Habitats").

PROBLEM: Little or nothing is known concerning the life histories of several rare and/or endangered plant species on Isle Royale. Devilsclub and thimbleberry represent two species which are extremely rare east of the Rocky Mountains. Thimbleberry is common on Isle Royale; devilsclub is very restricted to a narrow environment. Tamarack

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has suffered larch sawfly infestation and has decreased in abundance over the past few decades. Ground hemlock has been nearly extirpated by the moose. Life histories and environmental requirements of these species must be well-known if the National Park Service is to be prepared to meet future threats to their existence on Isle Royale.

RESEARCH NEEDED: Life history and environmental requirement studies (in priority order based upon degree of rarity): (1) devilsclub, (2) ground hemlock, (3) tamarack, (4) thimbleberry. These studies may be done in conjunction with the vegetation ecology studies, at least insofar as utilizing microclimatic and edaphic data in determining suitable habitat types for these species.

PROBLEM: White pine blister rust was introduced into North America in about 1900 and since that time it has spread throughout the northern states to the west coast. Blister rust, *Cronartium ribicola*, is a fungal disease (Basidiomycetes) producing pycnial and aecial stages on white pine, and uredial and telial stages on currants and gooseberries of the genus *Ribes*. It currently infects a number of white pines at Isle Royale and may seriously interfere with natural succession in those areas where white pine is a dominant subclimax species.

RESEARCH NEEDED: Determine the abundance of *Ribes* spp. in areas where white pine constitutes an important segment of the vegetation. Determine what *Ribes* eradication procedures would be necessary and effective in these areas, the distance from the pines in which *Ribes* would need to be eradicated to offer protection, etc., so that an administrative decision can be made concerning the feasibility of white pine blister rust control.

PROBLEM: From time-to-time, serious outbreaks of forest insects and diseases occur in practically all forest types. When the entire continent of North America was in a pristine ecological condition, such outbreaks might have occurred without destroying an entire forest type; but with today's conditions it may be folly within the confined limits of remaining natural areas, to permit insect and disease populations to explode. On the other hand, many insect populations, and perhaps disease organisms as well, tend to increase to high levels for short periods of time before plummeting into comparative oblivion. If

such population cyclings are interfered with in an attempt to reduce initial impacts of population explosions, there is some evidence that the population, while it may not reach extreme heights, maintains a moderate level with little or no decreases for many years. Thus, over long periods of time, greater damage to forest tree species may occur if man attempts to control such insect outbreaks. Assessment of such damage is dependent upon the type of value (lumber production, esthetic, natural area, browse production, etc.) for which the forest is being managed.

RESEARCH NEEDED: Intensive, long-term studies involving careful analyses of the population dynamics of many forest insect and disease organism species under a variety of environmental conditions are needed. Only through consideration of such background knowledge can decisions be made concerning forest insect and disease control; and only by the use of this kind of knowledge can we expect public support of the control measures taken or not taken. The forest tent caterpillar and spruce budworm, as well as other typical northern forest destructive species should be included in such studies. Research is needed also to permit development of more information relative to proper control methods and procedures, should it become necessary to control any insect or disease population.

PROBLEM: Caribou disappeared from Isle Royale during the 1920's. The major support for caribou is the lichen vegetation of an area. To determine the possibilities for the reintroduction of caribou, information is needed concerning available lichen food material for this species.

RESEARCH NEEDED: Determine kinds and amounts of lichen species occurring in the park and determine how many caribou could be supported by the available lichen flora.

PROBLEM: Moose and beaver depend upon aspen to a large degree. Specifics of aspen reproduction and genetics, however, are largely unknown for Isle Royale.

RESEARCH NEEDED: A survey and study of aspen reproduction on Isle Royale, the attendant pressures from moose and beaver, the potential of aspen to reproduce with and without browsing pressures, and the similarities and/or differences between Isle Royale and mainland aspen.

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<p><u>PROBLEM:</u> The lower plant groups have not been intensively studied at Isle Royale. Cooper (1912) collected and identified mosses and described moss communities; Conklin (1914) produced a list of liverworts, and Povah (1934) described the fungi of Isle Royale. The park herbarium contains a collection of fungi, and several packets of lichens were added by Dr. Clifford M. Wetmore several years ago. These represent preliminary studies, however, and considerably more should be known about the taxonomy and ecology of these lower group species in order that a greater emphasis can be placed on them in the interpretive programs and to permit a better understanding of their role in the ecosystem.</p> <p><u>RESEARCH NEEDED:</u> Ecological and taxonomic surveys and studies of the Thallophytes and Bryophytes.</p>	REL RSP	RSP
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D. ZOOLOGYAnimal Resource Management

Isle Royale is one of the few national parks in which the animal resources have been so little disturbed that (with a few exceptions as noted) they continue to exist in close to the original natural state, presenting a vignette of primitive America. Consequently, management here will consist primarily of closely watching--and learning from--the natural course of events, but of refraining from interference that would disrupt the very processes which have, on this island, a unique opportunity to continue to achieve their own ecologically and esthetically acceptable, continuously dynamic equilibrium.

Exceptions to this hands-off type of management may be made in order to reintroduce native animals now absent from the park, provided research demonstrates that they disappeared as a result of human interference. The marten may be in this category, and perhaps the caribou, but this will remain in doubt until more is learned about the causes for their disappearance. The lynx (or bobcat) appears, from recent reports, to be again (or still) here; the coyote, having disappeared owing to natural causes, would not be a candidate for reintroduction.

The bald eagle, probably the park's most threatened species, clearly is in need of protective management--if and when effective measures may be devised for cleansing the entire Lake Superior environment of its pesticide pollution.

Interpretation of the Natural Environment

The entire natural ecosystem story of Isle Royale National Park, and the principal findings of practically all of the resource studies related thereto, and covered by the present resource study outline, are potentially of highest interest to visitors, and require only that the many interrelated themes be interpreted and presented by adequately trained interpreters.

Visitor Use and Impact: Facility Placement

The Isle Royale National Park Master Plan recognizes the paramount importance of maintaining, for the use and enjoyment of the people, the unique natural resources of the park in an ecologically unimpaired condition. Consequently, visitor use and impact are being, and will always need to be, judiciously planned to conform with this purpose and objective.

At the present time the only development whose impact on the ecology of the island might be questioned is the campground proposed for Feldtmann Lake.

Unusual Opportunities for Animal Research

Of comparable significance to the developing science of ecology, and of high potential interest to visitors and students, are many additional relationships at Isle Royale which offer unusual opportunities for study: The ecological requirements and survival ability of the red fox, which has withstood the coming of the wolves, in comparison to the coyote which has not, the ecological status of the snowshoe hare, whose peak populations exert a profound effect on the vegetation, while its cyclical fluctuations in population raise questions of great scientific importance; the reasons for the scarcity of the lynx, which should be able to thrive on the hares but in recent decades has not; the ecological factors that keep the red squirrel population in bounds (in contrast to the moose) despite the absence of its arch-predator, the marten; the possibility of a nonhostile commensal relationship between such relatively large and high evolved social animals as beavers and muskrats; the ecological riddle involved in the apparent disappearance of marten, caribou and lynx from the Sibley Peninsula on the Canadian mainland simultaneously with their disappearance on Isle Royale (perhaps a minute remnant of the lynx population survived).

PROBLEM: Interrelationships on Isle Royale between wolves at the top of the ecological pyramid, moose and beaver at the next level, forest, swamp and bog components, and indirectly, a wide spectrum of biota at all levels, are almost unique in North America by virtue of their insulation from disrupting outside influences, their nearly pristine condition, and their ecological self-sufficiency, whereby they constitute a dynamic, self-regulating system. This system constitutes a living outdoor laboratory of tremendous value to science, education, and through the interpretive program, to visitor enjoyment and appreciation. The pristine condition of the system renders active management at this time largely unnecessary, but management has an important stake in the opportunity to learn how a park's ecological system can maintain itself in the absence of undesirable interference.

RESEARCH NEEDED: Since the island's biology knows no artificial categories and subject boundaries, projects up to

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now included under the original ISRO-N-1, plus various related ones indicated here, can be profitably combined as successive or concurrent phases of the overall study program. Thus, the subject breakdowns indicated here are arbitrary, and based primarily on convenience of presentation. If forest succession, or food depletion by the moose themselves, reduces the moose population we must determine the consequences to the wolf population, for it is a key animal in the maintenance of a balanced ecosystem by virtue of its controlling position at the top of the pyramid.

Determine population trends in the moose themselves, their possibly changing food relations to forest, bog and swamp succession, their changing distribution, reproductive success, the age composition of moose kills. Continue, for several decades, a program of close observation of the fate of the wolf population, to document the rise and decline of the various packs under changing leaderships and other social factors; home ranges, reproductive success, behavior, efficiency in capturing moose as affected by vigor of leadership and physical condition of all contestants. Determine, in advance of construction, the degree of interference with wolf reproduction success and with normal behavior patterns, likely to result from the public campground proposed at Feldtmann Lake.

A study of forest succession, as determined and influenced by the moose and other species, is sufficiently significant, time consuming and complicated, that it could be carried on as a separate though related and thoroughly coordinated range and habitat survey. Some has already been done on this, using extensive range study plots that are periodically revisited. This important work should be continued for many years, and should be further refined. (See Botany Section.)

PROBLEM: The beaver, though not at the top of the ecological pyramid, occupies a dominant position by reason of its extensive engineering works, which modify, and even create, various ecosystems. Additionally, the social organization and engineering devices of the beaver enable this animal to minimize various direct mortality factors. Resembling human society in these respects, they tend to overmultiply and exhaust their natural resources, thereby furnishing an instructive parallel for students of human ecology.

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RESEARCH NEEDED: Determine (more completely than has been done so far) whether the arrival of the wolf has prevented, or mitigated, the drastic boom and bust fluctuations in beaver populations that occurred in earlier decades. Determine the rate at which beaver dams create new aquatic habitat to replace old ponds that are lost through successional swamp, bog and forest stages. Determine extent to which moose impair beaver habitat through their own use and suppression of the aspen and birch food supplies. Determine minimum food requirements of beaver colonies vs. their consumption of resources during favorable times when, as with human society, there is much waste. Determine extent to which beaver benefit moose habitat by cutting mature aspen, birch and mountain ash, thereby stimulating sprout growth used by the moose. Explore the apparently commensal relationship between beaver and muskrats whereby the latter appear to be tolerated in occupied beaver lodges. Determine whether, in this marginal muskrat habitat, these animals can survive without food and shelter provided by the beaver.

PROBLEM: The snowshoe hare, though exercising less influence than the moose on vegetation, nevertheless can profoundly affect its long-term development, particularly during the animals' recurring cycles of abundance. The cyclic hare population fluctuations on Isle Royale have unusual interest in relation to synchronization (or the lack of it) with hare fluctuations on the mainland. There is significant information to be worked out on the effects of overpopulation stress on hares.

RESEARCH NEEDED: Determine distribution; cyclical population changes and effect on park vegetation, effect on hare reproduction, and relation to various types of mortality. Determine interrelationships between hares and foxes, whether foxes suffer population declines as a result of hare declines, or whether the foxes can prevent or mitigate drastic buildups in hare populations and resulting severe declines. Determine whether cyclic hare fluctuations on Isle Royale coincide with those on the mainland to indicate that overall regional ecological factors are responsible, or whether the Isle Royale fluctuations are primarily a response to habitat and predation factors of local origin, unsynchronized with those of the mainland.

PROBLEM: The red squirrel represents a separate race, restricted to Isle Royale. More information is needed on its ecological role and requirements, particularly if the marten, its prime natural enemy elsewhere, should be reintroduced. Questions as to what new ecological balances and control factors take over in the absence of the usual major enemy, can be studied here to great advantage, and can have long-range management significance.

RESEARCH NEEDED: Determine population numbers, distribution, reproductive success, and mortality factors under present conditions. Then, if the marten is introduced, conduct parallel "after" studies on the squirrel populations, habits, and ecological relationships. Very complete parallel studies on the population dynamics of the introduced marten, would be exceedingly important.

PROBLEM: Owing to difficulties of survival, even during transportation on floating ice, to which small terrestrial mammals are subject when travelling to the island from the mainland, only one species of mouse, the deer mouse (Peromyscus maniculatus) has become established there. This circumstance should allow its populations to expand and fill ecological niches additional to and different from its ancestral one--just as, in more extreme instances, the Hawaiian drepanids and the Galapagos finches have done. It is important to basic science to determine the extent, if any, that this has begun to occur.

RESEARCH NEEDED: Determine how much change has taken place in the ecology, behavior and morphology of this species in comparison to mainland populations. Determine how much the habitat relationships of this mouse have broadened and diversified to fill niches elsewhere occupied by other kinds of small rodents. Determine whether the red vole (Clerthrionomys) exists on the island, and (if it does) its ecological relationship to the deer mouse.

PROBLEM: The sharptailed grouse is a bird of somewhat limited flight powers. It deserves investigation to determine whether there have been any changes in this bird's living habits or ecology comparable to those of the mouse.

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RESEARCH NEEDED: Determine whether there have been any changes in this bird's habits and ecology due to isolation. Determine its survival requirements.

PROBLEM: The continent-wide dispersal of agricultural pesticide residues such as DDT threatens the survival of the bald eagle throughout North America except in Alaska and southern Florida. The Isle Royale eagles have participated in this population mortality, which reduces the fertility of eggs laid and the survival of those chicks which manage to hatch. Since this is a national problem, effective protective measures to be taken by park management would appear to be nonexistent, but it is essential to at least obtain the facts, and the current status of the park's sparse bald eagle population.

RESEARCH NEEDED: Determine rate of reproductive success of the island's bald eagle population, and other factors essential for species survival.

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PROBLEM: The hydatid tapeworm, normally passed between wolf and moose, is contractable by man. The circumstances of contagion and the requirements for survival of the organism in the extra-host environment need to be determined, not only for completing the ecological story but for developing safety precautions to be applied by management for protection of visitors.

RESEARCH NEEDED: Determine full-life cycle of the hydatid tapeworm and the ecological roles of the wolf and moose hosts. Determine the most feasible management measures (such as warning against drinking from streams or treatment of drinking water?) for the protection of visitors.

PROBLEM: Caribou disappeared after 1927, about the time moose numbers were rising sharply. Until the reasons for the disappearance are determined, the question of whether they should be reintroduced cannot be answered.

RESEARCH NEEDED: Determine (1) the probable cause for the disappearance of caribou from Isle Royale, (2) whether it was related to their apparently simultaneous disappearance from the Sibley Peninsula on the Canadian mainland, and (3) whether human activities played any significant role.

Formulate conclusions as to the ecological feasibility and desirability of reintroducing them, provided their disappearance was a result of human activities (such as the extensive setting of fires).

PROBLEM: Herring gulls are part of the ecological complex but may have been encouraged to concentrate unnaturally around local commercial fish establishments. Since this gull is to some degree a predator on other nesting birds, its ecological impact under these conditions should be determined.

RESEARCH NEEDED: Determine the ecological impact on other forms exerted by the herring gull in the vicinity of commercial fishing establishments. Determine the extent of herring gull population declines (if any) at fishing establishments as they become abandoned.

PROBLEM: The lynx (and bobcat?) formerly was abundant but has been thought to have wholly disappeared from the island as a result of trapping. Whether the disappearance was complete is now uncertain, for in the last two years several sightings have been made in the park of a lynx or bobcat. Whether the unquestionably great decline of the lynx was due to trapping likewise is uncertain, for a parallel decline appears to have occurred at the same time on the Sibley Peninsula of the Canadian mainland. Thus, the only sure thing about the lynx is that virtually nothing is known about the causes of its decline, and very little about its present status, and the trend of its population.

RESEARCH NEEDED: A program of observations should be undertaken to resolve these uncertainties.

PROBLEM: The relationship of moose to park visitors, particularly if the island's interior trail system continues to be developed and its use promoted, might eventually give rise to safety problems for which management has a responsibility.

RESEARCH NEEDED: Determine the conditions with respect to presence of young calves, the breeding season, etc., under which moose aggressiveness might be hazardous to park visitors. Develop and test procedures, precautions, regulations, and any other techniques and measures that might effectively reduce the possibility of visitors being harmed by an occasional aggressive moose.

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PROBLEM: The abundance of moist habitats results in a large amphibian population that has been largely ignored by natural scientists. The abundance of amphibians is also of interest to park visitors. The island's isolation, coupled with the limited home range of amphibians and reptiles, leads to some excellent opportunities to study the ecology and morphology of these species as compared with mainland populations.

RESEARCH NEEDED: Taxonomic, morphologic and ecological studies and surveys of amphibians and reptiles.

E. AQUATIC BIOLOGY

Investigations of the park aquatic environments, including their floral and faunal occupants, are required in order to provide the data and understanding needed to: (1) assure a continuing crop of those fishes permitted to be harvested for recreational and commercial purposes; (2) protect and assure the perpetuation of resident endemic species both unique and commonplace and the habitats which they require; and, (3) permit better interpretive presentation to the park visitor of the natural aquatic environments and the interrelationships of living forms found therein.

PROBLEM: Fishing. Recreational fishing is permitted for a limited number of fishes in the lakes and streams of Isle Royale and in adjoining Lake Superior waters. Limited commercial fishing may be conducted within the boundaries of Isle Royale in the open waters and the bays and harbors of Lake Superior.

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To what degree and in what areas can such harvest be conducted in inland and Lake Superior waters without endangering the basic stocks of fishes and the aquatic habitat and with minimum disturbance to other flora and fauna and the enjoyment of the park by nonfishing visitors?

RESEARCH NEEDED: Analyses of the taxonomic status, distribution, population structures, food relationships and requirements, age and growth characteristics, reproductive capacity and success, spawning requirements, and behavior, movement, limits of tolerance to physical and chemical factors of the aquatic environment, interrelationships with other vertebrate and invertebrate aquatic organisms, influence of parasitism, response to predation, etc., for each fish species found within the park boundaries.

Establishment of the degree of fishing effort and success for each harvestable fish species in each aquatic habitat within the park and the impact of this effort and success upon the fish and other animal populations resident in park waters.

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Development, insofar as is possible, of an inventory and the geographical distribution of native fish fauna at the time white man first visited the park. Determination of the habitat requirements for those species which may have been severely depleted. This information is necessary if we wish to reestablish the species in appropriate park waters.

Careful and continuing study of the relationship between the sea lamprey and fish populations in Lake Superior: identification of suitable lamprey habitats; detection of any change in distribution of lamprey in park waters, especially invasion of inland lakes; and development of means for control and eradication of adult and larval lampreys should they ever occur in park lakes and streams.

PROBLEM: Aquatic habitats. Although certain gross information is available on the aquatic resources of the park and rather broad extrapolations have been made from these data, it must be recognized that, for all intents and purposes, precise and documented data on the nature and distribution of these habitats are remarkably sparse. It is essential that we know where and what these bodies of water are and what goes on in them, if management and preservation of the habitats and their residents is to be successful and if their interpretation to the visitor is to be authoritative and complete.

RESEARCH NEEDED: Development of accurate and detailed hydrographic maps for each lake, swamp and bog revealing: location and character of shoreline and banks; depth contours; morphometry; distribution and kinds of bottom materials; character and amount of inflowing and outflowing water where appropriate; pertinent watershed and its character with regard to plant cover, soil materials, nutrient qualities, and state of erosion; location of beaver dams or other structures influencing water levels, etc., and, distribution, density, and kinds of emergent, floating or submerged aquatic vegetation.

Development of detailed tables and maps of streams and rivers showing: configuration; channel widths and depths; nature, volume and rate of flow at different times of the year; bottom materials, character of banks and their

vegetation cover; shading from bank; riffles, rapids and permanent pools; aquatic vegetation, character of inflowing water, high water and flood levels; nature, extent and nutrient quality of watershed; and, artificial or nature produced structures and features.

Analysis of water temperature at different levels, the degree of thermal stratification, presence of a thermocline, degree of turbidity, color state, light penetration, and wind or convection induced internal water movement at different times of the year in lakes and, where appropriate, in swamps and bogs. Ascertain temperature, velocity, turbidity, light penetration and color throughout the year in streams and rivers.

Establish dissolved and free gas (oxygen and/or carbon dioxide) concentrations and chemical qualities (alkalinity, hydrogen-ion concentration, dissolved nutrients, minerals and electrolytes) at different levels of lake depths (and where appropriate, swamps and bogs), for different times of the year, for different water temperatures and for different conditions of ice and snow cover. Dissolved gas and chemical properties throughout the year must be sought for streams and rivers as well.

Undertake qualitative and quantitative analyses of phytoplankton, zooplankton and periphyton populations, their interactions and their relationship to light levels, temperature, depth distribution and water quality throughout the year; seasonal qualitative and quantitative examinations of other benthic and littoral flora and fauna, their interrelationships, and their role in the food chain and welfare of fish and other vertebrate and invertebrate populations in park waters.

PROBLEM: External influences on aquatic habitats. The activities of man and other animals and certain catastrophic events are believed to have an impact upon the aquatic habitats but no real data are available to identify the mechanisms of these influences or to indicate whether the impact is desirable or undesirable.

RESEARCH NEEDED: Ascertain the influence of moose trampling and browsing on aquatic plant communities and upon the

welfare and integrity of the aquatic environments in other respects. This might well involve the use of exclosures in order to determine the effect of negative moose pressure upon shallow-water aquatic plants, sedge mat formation, etc.

Determine impact of beaver activities upon the aquatic ecosystem and its inhabitants through dam building operations and food gathering.

Studies of the physical impact of visitors upon the aquatic inhabitants; and of the effects of trails, portages, campsites and other physical and human disturbances upon the distribution and welfare of lake and stream shore vegetation and associated wildlife.

Establish the effects of fire upon aquatic environments and inhabitants through increased erosion and siltation, introduction of ash and other minerals to the water, and increase in the soil and water temperature.

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THE BIBLIOGRAPHY

The following is a bibliography of 195 titles covering natural sciences subjects for Isle Royale, Michigan, and vicinity and other pertinent areas or topics. The list is thought to be reasonably complete at this time (March 1966).

As new bibliographic material becomes available, it should, of course, become a part of this listing. For this reason, the bibliography should be updated periodically--perhaps every 5 years, and pen-and-ink changes should be made as the material becomes available.

Annotations have been included in the present listing commensurate with our present knowledge and available time. Some may be too lengthy, some too brief. As time permits, and as information is obtained, additional annotations should be inserted for at least the most important items.

The six columns at the right of the list denote subject field, as follows:

A: Aquat:	Aquatic Biology
V: Veget:	Vegetation-Botany
C: Clim:	Climatology-Meteorology
G: Geol:	Geology
Z: Zool:	Zoology-Fauna
M: Mgmt:	Management

Checkmarks in the appropriate column denote the field or fields covered in the item.

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decline of the lake trout fishery expanded the importance and value of the lake whitefish. Greater exploitation of the lake whitefish is being carried on to supplement incomes provided by the lower-priced lake herring and chubs.

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| Sound management and rational exploitation of the whitefish, <u>Coregonus clupeaformis</u> , should be based on a thorough knowledge of this commercially important species in Lake Superior. Production declined from over 4.5 million pounds in 1885 to 113,000 pounds in 1913. Since 1913 production has fluctuated widely; the take exceeded 1 million pounds in 1948-50 and 1954-55, but dropped to 284,000 pounds in 1960. Over past 50 years production of whitefish in Wisconsin waters of Lake Superior has contributed about 35 percent of total U. S. output in the lake. Whitefish has become of increased importance to the economy of commercial fishermen since the progressive decline of the lake trout fishery in 1955 and the complete closure of the lake trout fishery in 1962. This paper makes a contribution to knowledge of the life history of this species. | | | | | | |
| Dryer, William R. and Joseph Beil. 1964. LIFE HISTORY OF LAKE HERRING IN LAKE SUPERIOR. USF&WS Fishery Bulletin 63(3):493-530. | | | | | | ✓ |
| The lake herring, <u>Coregonus artedii</u> , is an important commercial species. It assumed first position in the total Great Lakes fisheries production in the early 1900's and has held this rank ever since. Average annual production in the Great Lakes, 1929-1961, stands at 19 million pounds. Since 1908, it has been the principal species in commercial production in U. S. waters of Lake Superior. The cash value, however, has been relatively low because of the strongly seasonal production (90 percent during November-December spawning runs), the capture and handling | | | | | | |

procedures, and the technological problems. Now the lake herring is used mostly for mink food. The seasonal distribution of the herring has been subject of considerable speculation. What happens to the fish during the summer is now well known. Prior to 1960, the only summer fishery for lake herring on Lake Superior existed along the north shore and at Isle Royale where floated nets yielded small catches. Distribution of the lake herring may be influenced by temperature, abundance of plankton and spawning conditions. During early summer, the fish are most common near the surface where plankton is most abundant. As the surface water temperature increases in midsummer, they move to deeper levels despite the high concentrations of plankton near the surface. By mid-September, they are distributed from the surface to about 20 fathoms. During the November-December spawning period, the lake herrings are captured at all depths down to 90 fathoms.

Dryer, William R., Leo F. Erkkila and Clifford L. Tetzloff. 1965. FOOD OF LAKE TROUT IN LAKE SUPERIOR. Trans.Am.Fish.Soc. 94(2)(April): 169-176.

Lake trout food habits in Lake Superior as determined from the examination of the stomach contents of 1,492 lake trout and 83 siscowet lake trout. Close to 100% of the volume of foods eaten by legal trout (over 17 inches) consisted of fish. Between 1950 and 1953, ciscoes (Coregonus ssp.) made up 52.2 to 87.5% of the foods eaten by volume. The introduced nonnative American smelt made up 65.6% of the volume in 1963; This represented an increase in occurrence from 1.7% represented in stomachs in 1950. Cottids, insects and crustaceans were also present. Items in the stomachs varied from season to season and with the depth from which the fishes were taken. Some of the specimens were collected in waters adjacent to Isle Royale.

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Elliott, J. C. 1953. COMPOSITION OF UPLAND SECOND GROWTH HARDWOOD STANDS IN THE TENSION ZONE OF MICHIGAN AS AFFECTED BY SOILS AND MAN. Ecological Monographs 23:271-288.		✓		✓		
Eschmeyer, Paul H. 1956. THE EARLY LIFE HISTORY OF THE LAKE TROUT IN LAKE SUPERIOR. Mich. Dept. Conservation, Instit. Fish. Research, Misc. Publ. No. 10 (October). 31 pp. Some of the investigations on phases of the life history study were conducted at two Marine Stations located within the park in 1952 and 1953.	✓					
Eschmeyer, Paul H. 1957. NOTE ON THE SUBPOPULATIONS OF LAKE TROUT IN THE GREAT LAKES. In: Contributions to the Study of Subpopulations of Fishes. USF&WS Spec. Sci. Report Fish. No. 208, p. 129. Expresses the urgent need for research on various problems relating to the identification of the various subpopulations of lake trout because of the varied management problems each present.	✓					
Eschmeyer, Paul H. 1964. THE LAKE TROUT (<u>SALVELINUS NAMAYCUSH</u>). USF&WS Fishery Leaflet 555. 7 pp. This account describes the lake trout essentially in the Great Lakes. The matter of the kinds of lake trout are discussed. Effects of the sea lamprey upon the valued lake trout fishery is described. Prior to the advent of the sea lamprey, the lake trout was the most valued fish on Lake Superior.	✓					
Eschmeyer, Paul H. and Reeve M. Bailey. 1955. THE PYGMY WHITEFISH, <u>COREGONUS COULTERI</u> , IN LAKE SUPERIOR. Trans. Amer. Fish. Soc. 84(1954): 161-199.	✓					

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The pygmy whitefish was discovered to be present in the deeper water of Siskiwit Bay. This paper deals with the life history of the species. This whitefish has the greatest discontinuous distribution of any North American fresh water species.						
Eschmeyer, Paul H. and Arthur M. Phillips, Jr. 1965. FAT CONTENT OF THE FLESH OF SISCOWETS AND LAKE TROUT FROM LAKE SUPERIOR. Trans.Am.Fish.Soc. 95(1)(January):62-74. Fat content as a possible means of recognizing various subpopulations. Flesh samples from hybrids, lake trout, siscowets, and hatchery reared lake trout tended to support the view that the wide difference in fat content between siscowets and lake trout is genetically determined. Some specimens examined were collected from three stations located on Isle Royale. Subpopulations of lake trout consist of "lean" lake trout, <u>Salvelinus namaycush namaycush</u> , and the siscowet or "fat" lake trout, <u>S. n. siscowet</u> . Although the "lean" is similar to lake trout found elsewhere throughout its range, the "fat" has somewhat different appearance and characteristics and is believed to be confined to the upper Great Lakes; especially Lake Superior. Most siscowets are caught at depths of 50 to more than 100 fathoms in contrast to lake trout which usually are caught in shallower waters.	✓					
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Only two forms, the "lean trout," <u>Salvelinus namaycush namaycush</u> , and the siscowet, <u>S. n. siscowet</u> , have been given subspecific status. This study was made of 3,705 fish collected on a reef located 4 to 5 miles off the southerly shore of Isle Royale, abreast of Rock Harbor. Mean lengths of humpier trout from commercial gill nets were smaller than those of lean lake trout. At minimum legal size of 1 1/2 pounds, 98% of the males and 56% of the females were mature. Humpers live on isolated offshore reefs surrounded by water deeper than 50 fathoms (such as those near Isle Royale and Caribou Island). Their spawning season begins in mid-September. This is the first report dealing with the life history of humpier lake trout, also known among commercial fishermen as "humpies," "bankers," or "paperbellies."						
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