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UNIVERSITY SERIES

BIOLOGICAL SCIENCES
VOLUME XI

Current Biological Research in the Alaskan Arctic

IRA L. WIGGINS, *Editor*

G. W. COMITA, W. T. EDMONDSON
JOHN LUTHER MOHR, DONALD E. WOHLSCHLAG
WILLIAM CAMPBELL STEERE, WILLIAM V. MAYER

STANFORD UNIVERSITY PRESS
STANFORD, CALIFORNIA
LONDON: GEOFFREY CUMBERLEGE
OXFORD UNIVERSITY PRESS
1953

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STANFORD UNIVERSITY PRESS
STANFORD, CALIFORNIA

Current Biological Research in the Alaskan Arctic

A symposium based on investigations conducted at the Arctic Research Laboratory, Point Barrow, Alaska, under contracts with the Office of Naval Research, and presented at the Twenty-second Annual Winter Meetings of the Western Society of Naturalists, Portland University, Portland, Oregon, December twenty-ninth and thirtieth, 1952

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PUBLISHED IN GREAT BRITAIN, INDIA, AND
PAKISTAN BY GEOFFREY CUMBERLEGE,
OXFORD UNIVERSITY PRESS,
LONDON, BOMBAY, AND KARACHI

THE BAKER AND TAYLOR COMPANY
HILLSIDE, NEW JERSEY

HENRY M. SNYDER & COMPANY, INC.
440 FOURTH AVENUE, NEW YORK 16

W. S. HALL & COMPANY
457 MADISON AVENUE, NEW YORK 22

PRINTED AND BOUND IN THE UNITED STATES
OF AMERICA BY STANFORD UNIVERSITY PRESS

Library of Congress Catalog Card Number: 53-9964

FOREWORD

This symposium was presented during the twenty-second annual winter meetings of the Western Society of Naturalists, held on the campus of the University of Portland, Portland, Oregon, December 29 and 30, 1952. The papers are based on work done at the Arctic Research Laboratory, Point Barrow, Alaska, under contracts between the respective investigators' home institutions and the Office of Naval Research. The research contracts provided financial support covering travel to and from Point Barrow; salary for assistants and, under certain conditions, for the principal investigators; purchase of necessary equipment and supplies; laboratory and field facilities at the Arctic Research Laboratory and on the arctic slope of Alaska; and logistic support during their stay in northern Alaska.

Financial support for the publication of the symposium in the Stanford University Series came from three sources. Stanford University, through its Publications Committee, contributed $500 toward the costs of publication. The Office of Naval Research provided $500 and the remaining $100 of the actual cost of publication was contributed by an anonymous donor who is interested in the research work being done in the Alaskan arctic. The home institutions of the respective investigators absorbed the costs of typing the manuscripts in those cases in which the funds in the contracts were insufficient, at the end of the season, to cover this service.

Besides the papers in this volume, Dr. Frank A. Pitelka presented a paper entitled "Lemmings and Their Predators at Point Barrow, Alaska, in 1951–1952." Since it was in the nature of a progress report on an unfinished research program, publication is deferred until completion of the study.

The chairman of the symposium wishes to thank each of the contributing institutions, agencies, and individuals for the support that made possible the publication, under one cover, of papers resulting from certain segments of the work done at the Arctic Research Laboratory during the period of his incumbency as its Scientific Director.

IRA L. WIGGINS

POINT BARROW, ALASKA
March 15, 1953

CONTENTS

Current Biological Research in the Alaskan Arctic

THE ORGANIZATION AND FACILITIES OF THE ARCTIC RESEARCH LABORATORY[1]

IRA L. WIGGINS

The Johns Hopkins University and Stanford University

Although biological research on problems involving the Alaskan arctic is going on at other centers also, it is only with that conducted at the Arctic Research Laboratory, Point Barrow, Alaska, that the present symposium deals.

The Arctic Research Laboratory is located about 120 yards from the Arctic Ocean, at 71° 20′ N., 156° 40′ W., in the U.S. Naval Petroleum Reserve No. 4. Only research workers cleared by the U.S. Navy's Security Office and certified to the officer in charge of construction in Fairbanks, are permitted to enter the reserve. They are given clearance only if they (*a*) represent an agency holding a contract with the Office of Naval Research, or (*b*) are members of a governmental agency doing research under a co-operative agreement with the Navy, or (*c*) secure financial support elsewhere sufficient to defray their expenses to Fairbanks and return and to cover the cost of special equipment and supplies needed in their investigations. Workers in each of these categories receive logistic support from the Office of Naval Research throughout their stay at the Arctic Research Laboratory. Normal logistic support consists of air transportation from Fairbanks to Point Barrow and return, lodging, meals, laundry and dry cleaning services, medical consultation if needed, cold-weather clothing, laboratory space and equipment (with some restrictions as to amount and scope of this type of support), as much surface transportation as equipment and conditions permit, and use of certain special gear if it can be supplied by the Arctic Research Laboratory. Some bush flying may be furnished in special cases.

The Arctic Research Laboratory is under the sponsorship of, and supported financially by, the Office of Naval Research. It is operated by The Johns Hopkins University under contract Nonr-248 (25) between that institution and the Office of Naval Research. All permanent operational staff members are employees of The Johns Hopkins University.

The camp at Point Barrow, where the laboratory is located, is operated by, and chiefly for, the Arctic Contractors, a civilian organization exploring for oil in the Alaskan arctic under Contract NOy-71333 with the United

[1] Contribution No. 1953-4 from the Arctic Research Laboratory, operated for the Office of Naval Research by The Johns Hopkins University under Contract Nonr-248-(25).

States Navy. Other agencies stationed at Point Barrow operate through co-operative arrangements with the Arctic Contractors, and then only to the extent that their activities do not interfere with the prime objective—that of exploring and drilling for oil. Services and supplies secured from the Arctic Contractors are paid for at cost, plus a set overhead rate established under the terms of Contract NOy-71333. Co-operation from the Arctic Contractors has been excellent throughout the existence of the Arctic Research Laboratory and the laboratory could not otherwise operate effectively at the present annual cost.

The physical plant of the laboratory at Point Barrow consists of 3 quonset huts integrated in the form of the letter H and houses 17 laboratories, 3 photographic darkrooms, stock rooms, library and assembly hall, staff offices, shop, garage for four vehicles, and a dormitory for 32 men. Each laboratory is supplied with electricity, hot and cold water, compressed air, and gas. A smaller quonset provides an "animal house"; wanigans give additional storage space; a 36-foot motor launch equipped with a light dredge and a fathometer provides facilities for limited oceanographic and other marine work. Several skiffs and outboard motors supplement the launch and are of use on near-by lakes and lagoons. Track-laying light vehicles (weasels) are rented from the Arctic Contractors and are available for teams needing to get out on the tundra to carry on their studies. Camping equipment is available for those who operate far afield. Stocks of common chemicals and reagents are kept on hand, but special needs require correspondence with the Scientific Director prior to arrival in camp—or the purchase of the items on the individual contract of the investigator. Instruments, glassware, and equipment commonly used in biological and physiological laboratories are available in the stock room, and some other specialized pieces of apparatus are kept on hand.

Six apartments, 2 in each of 3 quonset huts, are provided for married couples employed as staff personnel or engaged in research at the laboratory. A field laboratory at Umiat, about 175 miles from Point Barrow, provides living quarters for 8 men and a working laboratory approximately 20 feet square. No stock room is maintained at this satellite station, so all equipment and supplies needed to carry on field operations must be obtained through the main establishment at Point Barrow.

The area around Point Barrow, and extending inland about 100 miles, is a flat, water-soaked plain on which thousands of ponds, lakes, lagoons, and widely meandering streams present a landscape of monotonously low relief—about one-half of the surface being covered with water during the summer season. In the winter everything is frozen until the breakup of the ice on the rivers and ponds begins in June. Breakup of sea ice is 2 to 4 weeks later than that on the fresh-water ponds and streams. For a period of from 2 to 6 weeks during the breakup and for a similar period during the fall freeze-up, surface travel is virtually at a standstill.

During the summer the soil thaws to a depth of 1 to 3, or sometimes 4 feet. Below these levels, except beneath deep streams and lakes, the substrata are perennially below freezing temperatures. Thus, all biological activity on and in the soil is confined to the thin blanket of the "active layer," that portion of the soil that thaws in summer. Winter temperatures drop to, or a little below, 50° Fahrenheit below zero. Air temperatures in the summer rarely go above 55° Fahrenheit above zero.

The tundra is carpeted with a dense growth of low perennial vegetation, composed mostly of prostrate shrubs, herbs, grasses, sedges, mosses, and lichens. The ponds, lakes, and wet surface of the soil support a large number of algae. Thousands of birds nest on the tundra, myriads of insects and mites inhabit the peaty "active layer," and populations of such mammals as lemmings, foxes, weasels, and shrews occur in varying numbers near Point Barrow. Farther inland, particularly in the rolling foothills of the Brooks Range, such additional mammals as the barren-ground grizzlies, caribou, arctic squirrels, voles, wolves, marmots, and wolverines occur.

Dredging done in the Arctic Ocean by Professor George E. MacGinitie has shown the invertebrate life on its floor to be rich in number of species and individuals. Crustaceans, mollusks, sponges, worms, echinoderms, tunicates, bryozoans, and foraminifera, among others, are very numerous.

If there were sufficient time, it would be desirable to sketch the work done in each of the fields not represented by the speakers who are to follow during this symposium. In the brief space remaining to me, perhaps a few of them can be mentioned and further discussion carried on informally later.

During the early days of the laboratory a number of physiological projects were initiated; a survey of the blood types among the Eskimos was made; work was done on the epidemiology among the native populations; and on the incidence of, and changes in, the susceptibility to dental caries among the Eskimos. A shift to a more general type of program followed shortly, with investigations of migration among arctic birds, the composition of the fish, insect, and recent foraminiferal fauna undertaken. MacGinitie studied the marine invertebrates and collected prodigious numbers of specimens. Surveys of the paleobotany, the mammalian fauna, and of several different groups of living plants were initiated. Life history studies of certain organisms and ecological investigations were undertaken. Work in anthropology, crystallography of recent and older ice, magnetic storms, the aurora, and a number of projects of particular interest to military agencies has been prosecuted diligently.

I should like to discuss the details involved in a number of the projects just mentioned, but with this brief and woefully incomplete sketch of the general conditions and activities at and in the vicinity of Point Barrow as a background for the speakers about to address you, I wish only to make one more point before yielding the floor to them. It is with considerable pleasure and great satisfaction that I express my thorough appreciation of the excellent spirit of co-operation that has existed at Point Barrow among the investigators, between the Arctic Research Laboratory and the Arctic Contractors, the Navy, and other agencies at the Barrow camp, and which, since the end of the summer season of 1952, has culminated in the preparation of this symposium. May I say "Thank you!" to each contributor.

SOME ASPECTS OF THE LIMNOLOGY OF AN ARCTIC LAKE[2]

G. W. Comita and W. T. Edmondson
University of Washington

The purpose of this study is to contribute to our very limited knowledge of the limnology of the shallow arctic lakes of northern Alaska. It has been confined to 8 lakes and many smaller marshes and pools located in a 100-mile radius from Point Barrow in the region extending southward toward the foothills of the Brooks Range, a region with a large number of bodies of water ranging from small pools formed by melting of ice wedges to large, extensive lakes. So numerous are these waters that it is estimated that locally the lakes or drained lake basins comprise from about 25 percent to as much as 90 percent of the surface of the land, although in most places the lakes probably comprise between 50 and 75 percent of the surface (Black and Barksdale, 1949). Since many are elongated in a northwest-southeast direction, the name "Oriented Lakes of Northern Alaska" has been applied to them. The area of oriented lakes is more than 25,000 square miles, but in spite of this areal extent the lakes of any magnitude are remarkably similar in shape and depth, and perhaps in many other respects. This paper constitutes a preliminary report on the progress of part of our investigations.

The existence of the Arctic Research Laboratory near Point Barrow has made it possible to study a coastal fresh-water lake in considerable detail, and with the laboratory as a base, a survey of some of the outlying lakes was made. The survey of the outlying lakes was made during the summer of 1951. During that summer an attempt was made to investigate a limited number of lakes so that a comparison could be made between these lakes and a strictly coastal lake which was studied the following summer, and, further, comparison could be made with waters of lower latitudes. On these outlying lakes the usual important routine measurements of temperature, transparency, *p*H, and others were made. During the summer of 1952, all work was concentrated on Imikpuk (Fresh water Lake) near the coast. Here measurements were made of photosynthesis, oxygen, bicarbonate, *p*H, chlorophyll, and a study made of the phosphorus and nitrogen cycles, as well as of the seasonal changes in the zooplankton. Adequate plankton tows for faunistic purposes were made in all waters investigated.

In this paper some of the aspects of the study of photosynthesis in Imikpuk and part of the data on one of the zooplankters are presented. In regard to the general description of the area, the surface features of the Coastal

[2] Contribution No. 1953-5 from the Arctic Research Laboratory, presented in partial fulfillment of Contract N8 ONR-52013 with the Office of Naval Research.

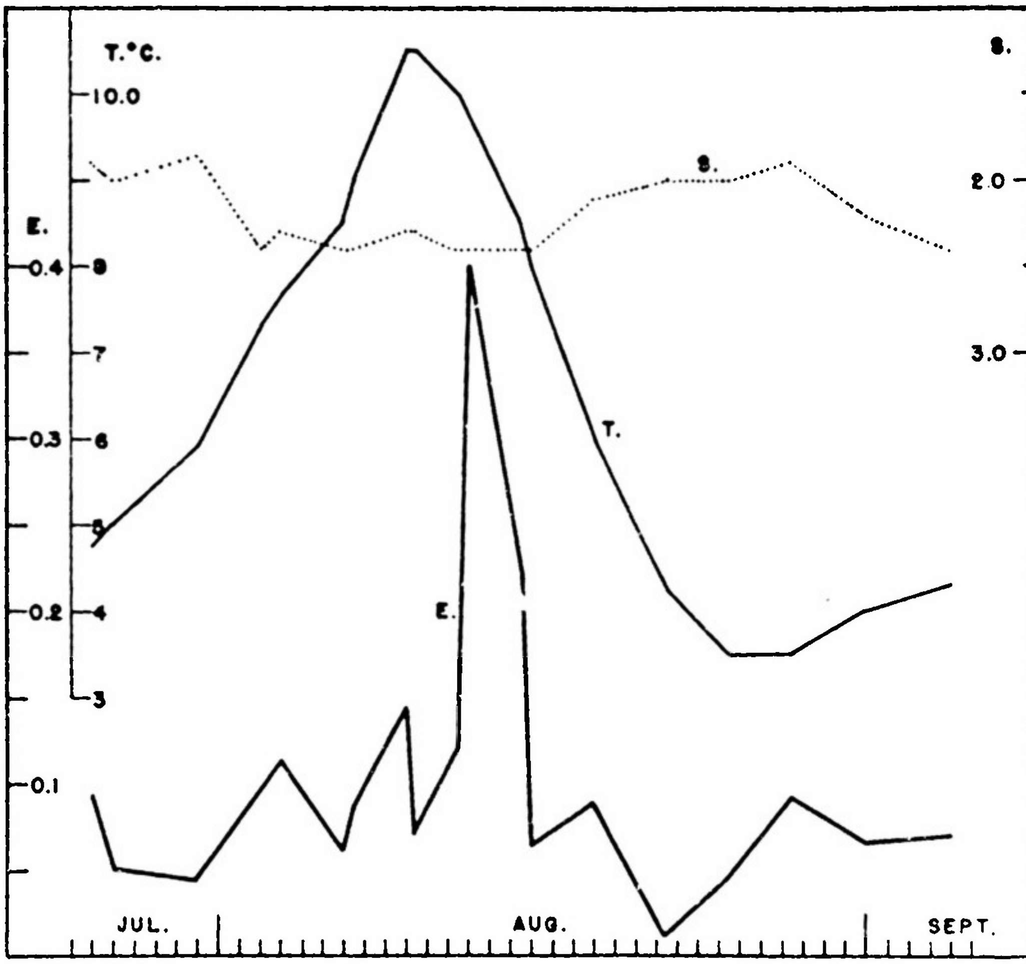

FIG. 1.—Graph of population efficiency, *E*, as percent, temperature, *T*, as °C., and Secchi disc transparency, *S*, as meters.

ture is 0.49, which is significantly different from zero at the 5 percent level. The analysis of the variations in efficiency has not yet been made, but inspection of the data shows that the chlorophyll content of the population is responsible for little of the variation, and the transparency of the water may have been more important in controlling photosynthesis. To show this relationship the Secchi disc readings were also included in the figure.

For Imikpuk, 0.085 percent of the available solar energy was actually used in photosynthesis during the period in which the lake was studied. As a comparison, the following efficiencies for other lakes are presented:

0.026%	Chase Lake, Washington (Anderson, 1953)
0.056%	Linsley Pond, Connecticut (Riley, 1940)
0.085%	Imikpuk, Arctic Alaska (Present paper)
0.1 %	Cedar Bog Lake, Minnesota (Lindeman, 1942)
0.4 %	Lake Mendota, Wisconsin (Lindeman, 1942)

In the cases of the Alaskan and Connecticut lakes, the data pertain to studies carried through less than a year, while the remaining percentages are drawn from studies extending over at least one year. The data on Cedar Bog Lake and Lake Mendota are approximations based on measurements of the standing crop over a period of time, hence are indirect estimates not based on measurements of photosynthesis. The others are based on direct measurements of photosynthesis. For the purposes of this comparison, however, it must be remembered that the Alaskan lake is exposed to very little light between the first of November and the first of March, after which it is covered with thick ice until late in July.

A better comparison would be made using equivalent time periods. An approximation was made to the efficiency of phytoplankton production in Cedar Bog Lake during the summer, using Lindeman's data and sources. Mr. Anderson furnished a calculation of the summer efficiency of Chase Lake (18 July to 26 August 1951). This comparison follows:

0.17 %	Cedar Bog Lake
0.045%	Chase Lake
0.085%	Imikpuk

Lindeman's small bog lake produced a large crop of rooted plants, the equivalents of which were not present in the arctic lake. Anderson's study was made on a small dystrophic bog lake with a well-developed mat of sphagnum moss and a moderate rooted flora. In both these lakes, the water was rather less transparent than in Imikpuk. A more extended discussion of this matter is in preparation for future publication.

The basic production of the lake was assessed by the measurements of photosynthesis. The utilization of the material produced by animals is more difficult to determine. As part of the analysis, detailed studies are being made of population changes of the zooplankton. The dominant members of the zooplankton were a rotifer, a *Daphnia*, and a calanoid copepod. The life history of the copepod will be briefly discussed.

The dominant copepod, *Limnocalanus johanseni*, Marsh, 1920, is of great interest ecologically in that it is a coastal form and is a member of a genus having in addition to a marine form, *L. grimaldi*, a form found coastally as well as at considerable distances inland in North America, *L. macrurus*. Records of the fresh-water forms indicate that they are apparently always found in lowlands that may have been covered by the sea. Interesting data on the processes of speciation might be brought to light by a study of members of this genus that are presently inhabiting lakes formed after recession of the seas. Geological evidence indicates that such a situation occurs on the Arctic Coastal Plain, and hence a study of the distribution of *L. johanseni* over the lakes of northern Alaska would be of considerable interest.

In 1952 while the lake was covered with about 5.5 feet (1.7 meters) of ice, collection of the zooplankton was started, but quantitative sampling was not possible until 10 July, by which time the ice had melted sufficiently to allow sampling around its fringes in small open areas of water. By then, the third nauplius stage had already reached its peak in numbers and was changing to nauplius stage IV. The approximate time spent in each nauplius and copepodid stage was estimated from the sequence of stages as each appeared in the population, passed through a maximum of numbers, and disappeared. The time between peaks of curves smoothed to the population counts of each stage was taken as the time spent in the stage. Nauplius stages I and II continued to be present over a known period of 18 days, suggesting that hatching is a process that takes place slowly with the first slight rises in water temperature. Data are available that indicate that the lake does not freeze to the bottom in winter (official files of U.S. Geological Survey), and that the eggs can survive in a layer of free water approximately 1 meter thick in the deeper parts of the lake at the time of thickest ice formation. These same data indicate that this 1-meter layer of water just above the bottom of the lake at the time of lowest winter air temperatures does not get colder than +1°C. The mud beneath the water does not get colder than +2°C., thus acting as a reservoir of heat. In Imikpuk, therefore, eggs of copepods can winter-over under conditions not much more severe than those found in any mid-latitude lake where freezing occurs in the top layers of water and the remainder of the lake water is maintained at a temperature at or near +4°C. We have no information on the possible survival in the more shallow frozen mud.

As indicated in Table I, the adult copepod emerged from stage V copepodid about forty-seven days after the eggs hatched. It did not attain sexual maturity until after it had lived for about a month, as indicated by the time of appearance of eggs in the oviduct of the female. At this time the lake began to freeze over, and later gravid females were taken under ice in water at about +1°C. Eggs must remain in water of this temperature until the following July. Since the last collections taken under the ice were made on 1 December 1952, it is somewhat uncertain in what form the animal spends the first six months of the following year. The occurrence of only middle nauplius stages at the time of melting in July suggests very strongly that the adult population dies off during the winter. On the basis of the rate of mortality in the quantitative samples taken before freezing, it is estimated that the adult population may have died off after about 120 days. Since it is very unlikely that the early nauplius stages persist very long, the time of hatching of the eggs must have been mid-July. It was also mid-July that solar and sky radiation had reached sufficient intensity for a long enough period of time to melt the heavy ice cover and start warming the water. The total time the

TABLE I

SEQUENCE OF STAGES OF *Limnocalanus johanseni*

Stage	Date of Maximum Occurrence	Duration of Instar (Days)
N-I	?	6, estimated (N-I to N-III)
N-II	?	
N-III	?	
N-IV	July 16	2
N-V	July 18	3.5
N-VI	July 21–22	5
C-I	July 26–27	3.5
C-II	July 30	3
C-III	August 2	3
C-IV	August 5	5
C-V	August 10	16
		Approximately 47 for all immature stages
C-VI (Adults)	August 26	120 (4 months), approximately
		167, approximate span of activity

lake was free of ice was 65 days. This allowed the adult copepod about 23 days in an ice-free lake for growth and maturation, which some of the copepods just attained before ice formation.

ACKNOWLEDGMENTS

We are greatly indebted to Dr. I. L. Wiggins, Scientific Director of the Arctic Research Laboratory, for co-operatively placing the facilities of the laboratory at our disposal and for providing necessary logistic support. To all the laboratory and Arctic Contractor personnel who contributed to our efforts while working the lakes, appreciation is hereby expressed. Deep appreciation is also expressed to Robert A. Main, whose efforts during the summer of 1951 made the survey of all the lakes possible, and to Jean J. Comita for doing many of the laboratory analyses and contributing to the arduous collection of samples in the field. Thanks are due also to George C. Anderson, who kindly made available his unpublished data on Chase Lake.

We take this opportunity to express our appreciation to John J. Koranda for taking seven plankton hauls from Imikpuk after it had frozen over. These collections made it possible for us to assess certain facts in connection with the biology of the copepods.

We gratefully make acknowledgment to the Office of Naval Research for the support extended us in the form of the contract under which the work has been done.

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SOME OBSERVATIONS ON ARCTIC CRUSTACEANS AND THEIR ASSOCIATES: NOTES ON THE FAUNA OF NUWUK POND, POINT BARROW[3]

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On the gravel spit that is the "point" of Point Barrow there are several ponds. The largest of these and in some ways the most interesting we have called Nuwuk Pond, applying to it the Eskimo name for the whole prominence. This pond is about 750 feet in greatest dimension, its northwest margin lying about 200 feet from the Arctic Ocean. About halfway between the ocean and Nuwuk Pond is a very shallow pool which from the air shows connections, clearly recent, with the main pond, so from time to time the waters of the two must be confluent and so close to the sea as to be within splash range during very severe storms. [Since the writing of this paper Norman J. Wilimovsky *in litt.* has confirmed the fact that waves reach Nuwuk Pond during an autumnal storm.]

Salinity of the water was tested once (7 July 1952), the sample having a chlorosity of 1.3 percent or a salinity of roughly 2.45 percent, an oligohaline or meiomesohaline level depending upon where one draws the line between "low" and "low medium" salinity (Dahl, 1948). The contour of the pond bottom appears to be that of a somewhat elongated obtriangulate basin shallowest seaward and reaching a depth of not less than 17 feet. A sulfide mud covers the bottom in the deeper portion. The only living vegetation appeared to be an alga forming a film on the gravel in shallow water, although dead leaves and stems of unidentified flowering plants and thallus fragments of bryophytes occurred in small quantities.

When Nuwuk Pond was first visited by the speaker in July (2 July 1952), it was covered, except for a 10-foot border area, by a thick sheet of ice. At this time and subsequently on several occasions, water birds were seen apparently in feeding activities. Windrows of gammaridean amphipods on the northwest shore indicated that the pond was or had been inhabited.

Collecting with 1/16-inch mesh nets in weasel-roiled waters yielded three crustaceans (*Gammarus setosus* Dementieva, *Onisimus* sp., both gammaridean amphipods, and *Mysis relicta* Lovén) and an enchytraeid oligochaete still unidentified. These occurred in the ratio of roughly 100 *Gammarus* to 5 *Onisimus* to 1 or 2 *Mysis* by this method of collecting (in a wire screen

[3] Contribution No. 1953-6 from the Arctic Research Laboratory, presented in partial fulfillment of Contract Nonr-777(00) with the Office of Naval Research.

trap, the proportion of *Mysis* ran somewhat higher). No attention was given the oligochaetes which were intermediate in numbers between the *Gammarus* and *Onisimus*.

The combination of these organisms in a pond of low salinity raises a number of ecological considerations. *Gammarus locusta* (Linnaeus) has until recently been treated as an exceptionally adaptable species, probably circumterrestrial in a wide range of littoral and sublittoral situations. The studies of Sexton, Spooner, and Segerstråle have thrown light on a sympatric group all morphologically similar to *G. locusta* but having different ecological requirements, the relationships to salinity having been elucidated especially. In this *G. locusta* complex the species *G. setosus*, which is found in Nuwuk Pond, is a low arctic member. While the literature yields no specific data on the salinity tolerance of *G. setosus* [Dahl's (1944) reference to *G. locusta* f. *setosus* in the Baltic being referable to the closely allied *G. z. zaddachi* according to Segerstråle (1947)]. Stephensen's Greenland records strongly suggest a very euryhaline amphipod confined to shallow water. The present observations are of a thriving population in a pond of low salinity.

In contrast to the family Gammaridae in which several euryhaline lines appear to lead to fresh-water life (in the low arctic cf. especially the widespread *Gammaracanthus loricatus* Sabine and its limnetic form *G. l. lacustris*), the amphipod family Lysianassidae to which *Onisimus* belongs, is not known to have any trend toward brackish water and to fresh-water representatives with one possible exception [Madsen (1936, 1940) notes that the lysianassid *Pseudalibrotus littoralis* may occur at the months of rivers of the low arctic]. Although the genus has two widespread littoral, low arctic species, its survival in a lacustrine, oligohaline situation appears noteworthy. Experimental study of the salinity tolerance of this strain would appear to be desirable.

The third crustacean of Nuwuk Pond is *Mysis relicta* Lovén. *M. oculata* is a common circumpolar mysid of salt water and brackish water. It appears that wherever stocks of *M. oculata* are confined to weakly brackish or fresh water, breeding individuals develop which particularly in the character of the second antennae and of the telson resemble juvenile *M. oculata*, but are in current practice assigned to the separate species *M. relicta*. The *M. relicta* of Nuwuk Pond are removed from the *M. oculata*—which Dr. Banner (*in litt.*) reports to be "quite common in Arctic Alaska" and which we too have from Point Barrow marine collecting—by a few yards of gravel spit and presumably a relatively short space of time in view of the association with *Onisimus*. However, they would appear to be quite as good *M. relicta* morphologically as those of the Baltic or the North American Great Lakes basin which date their isolation from separate marine stocks to glacial times.

From study of extensive Spitzbergen materials, Olofsson (1918) reported that where certain fjords of Bel Sound present large-scale salinity gradients, intermediates between the marine and fresh-water forms exist. Accordingly he treated the fresh-water (or oligohaline) mysid as a *forma* of *M. oculata.* Although some others have tended toward this point of view, Holmquist (1949) on a careful statistical study of *oculata*-examples from northern Norway, Spitzbergen, and Greenland and *relicta*-examples from Swedish relict lakes and the Baltic Sea states that one can distinguish even small individuals (up to 4 mm. body length) of the two kinds, and she remarks categorically that no direct intermediates have been found although a tendency in some geographical races of *M. oculata* to approach a *relicta*-condition may appear. Obviously a considerable degree of adaptability is present and presumably a certain plasticity of development. Dr. Banner (*in litt.*), who has worked up the mysids of the MacGinities' Point Barrow collections, suggests that the materials for experimental examination of these variables are at hand about Point Barrow.

The remaining macroscopic invertebrate of Nuwuk Pond is an enchytraeid worm which is present in large numbers. Enchytraeids in low arctic areas in Eurasia, Spitzbergen, and America include notoriously eurytopic species so that our species is unlikely to add any evidence as to the source of the Nuwuk Pond fauna. Because of the relative coarseness of the nets used in the collecting (a $^1/_{16}$-inch mesh), none of the smaller crustaceans which have thrown light on the origins of the fauna of relict lakes in other areas was studied.

It is of some interest to consider the Nuwuk Pond crustacean species, all of which would appear to have come from the ocean in not too remote time, in light of Remane's (1934) analysis of brackish-water fauna in Europe. As one may see from Remane's diagram, in a more typical situation in water of about 2.5 percent salinity there should be a broad preponderance of fresh-water species with a few characteristically brackish-water and still fewer proper marine species. In absence of data on the microfauna, the Nuwuk relationships appear to be quite reversed. This might be explained by the remoteness of fresh-water bodies, but a shallow pond about 200 yards east had abundant fairy shrimp and smaller entomostracans.

The breeding of the animals reported here has not been studied; however, it should be noted that in the earliest collections made (July 2), females of *Gammarus setosus* with well-developed young were present. It would appear from this that breeding took place while the pond was still covered with ice and that this species may be active or subactive throughout the winter. This would doubtless be possible in the deeper center portion of the basin. The considerable windrows of dead individuals seen at the beginning of July, mostly rather large gammarids, may include the normal winter's dead as well as individuals caught in the grounded portion of the ice. As to the over-wintering devices of the enchytraeid worms, Stephenson (1926) was of the opinion that even the hardiest of the Spitzbergen species survived the winter in the egg stage. Madsen (1940) reports that in East Greenland the enchytraeid *Lumbricillus lineatus*, which appears to occupy a niche corresponding to that of the Nuwuk oligochaete, survives in the adult stage throughout the winter. Because there appear to be many mature worms in the Nuwuk Pond collections, it is thought that these too may over-winter as adults.

A further observation (Mohr, 1952) reflects both on the over-wintering and the origin of *Gammarus*. On the pleopods and less often on the gill plates of *G. setosus* there is a sessile ciliate of the order Chonotrichida and family Stylochonidae. Chonotrichs have not so far been found to develop resistant stages. They are found only on crustacean hosts known or inferred to be active throughout the year. The stylochonids, moreover, are an essentially marine group, only one species, a *Heliochona*, on one of the *G. locusta* complex, having been reported (Rentsch, 1860) from a brackish-water habitat (Wismar Bay in the western Baltic).

ACKNOWLEDGMENTS

Charles Horvath was a co-worker in the planning and field work at Point Barrow. Robert Rex called attention to the presence of *Gammarus* in Nuwuk Pond; Edward Taylor and Roy Robinson took part in the mapping of the pond. Dr. A. H. Banner and J. L. Barnard aided in the identification of the crustaceans. The friendly help of each is gratefully acknowledged. The contractural support provided by the Office of Naval Research through the Arctic Research Laboratory made the work possible and is appreciated greatly.

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SOME CHARACTERISTICS OF THE FISH POPULATIONS IN AN ARCTIC ALASKAN LAKE[4]

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The purpose of this study was to determine the magnitude and some of the characteristics of fish populations in an Alaskan arctic lake and to relate these determinations to the possible future development of fresh-water fishery resources of the area.

Fresh-water fishery resources of the Alaskan arctic have been utilized only locally and sporadically by the Eskimos. With the general development of Alaskan resources in the future, it is quite probable that fishery resources will become more extensively utilized commercially as well as for sport. The developmental sequence of utilization and management of northern Alaskan fresh-water fisheries will quite possibly be similar to the sequence of events in the Yukon and Northwest Territories as summarized by Dymond (1947).

Collectively, the fresh-water ponds, lakes, and streams of the northern arctic slope of Alaska comprise as much as 50 percent of the land surface. Arctic lakes and ponds, if not completely isolated from the sea and if deep enough to prevent freezing to the bottom, may be expected to contain resident fish populations (Wynne-Edwards, 1953). Resident populations of fish might also be expected in the larger and deeper streams which never freeze completely. In addition to the resident populations, seasonal concentrations of migrating species might also be expected in most of the waters flowing to the sea.

Practical considerations alone should be justification enough for the study of fishes of this region prior to any extensive future depredations. The isolated populations of arctic lakes are also ideal for theoretical studies inasmuch as fish have slow growth and recruitment rates and complications from past exploitation are largely absent. With these motives in mind, an intensive study of some of the characteristics of the fish populations in Ikroavik Lake was undertaken during the summer of 1952.

DESCRIPTION OF IKROAVIK LAKE

Ikroavik Lake, whose roughly oval surface configuration has a long axis at approximately 348–168 degrees true azimuth, is one of the thousands of oriented lakes and ponds in the Point Barrow region described by Black

[4] Contribution No. 1953-7 from the Arctic Research Laboratory, presented in partial fulfillment of Contract Nonr-225(08) with the Office of Naval Research.

and Barksdale (1949). It is about 2½ miles long and nearly a mile wide. Its approximate geographical center is at Lat. 71° 13.5′ N., and Long. 156° 38′ W., 6 miles south of the Arctic Research Laboratory at Point Barrow. The maximum depth over most of the area of the lake is only 7 to 7½ feet.

One inlet drains the spring and early summer runoff from several ponds immediately to the northwest of the lake; the other inlet is a small stream about two miles long flowing into the west side. The single outlet is a shallow meandering stream which flows into Elson Lagoon to the southeast; it freezes solidly in the winter. Although at times there could be movement of fish to and from the sea, the lake is believed to remain essentially isolated. The north shore line is made up of gravel which grades into sand at the northeastern beach. The west shore is quite largely an abrupt tundra wall up to 5 feet high, formed by ice movement during the spring. Swampy shore line characterizes most of the remainder of the lake. During the spring of 1952 Dr. Ira L. Wiggins made two borings in the ice; he found that the ice was 1.84 meters thick with 45 centimeters of underlying water at one place; at another, the ice thickness was 1.87 meters with 52 centimeters of water.

The severity of the aquatic environment is marked not only by the small amount of water beneath the winter ice cover, but also by the extended period of ice action in the spring and by the very short ice-free summer season. The sequence of thermal relationships during the 1952 season is illustrated by the surface temperatures plotted in Figure 1. By the middle of June the

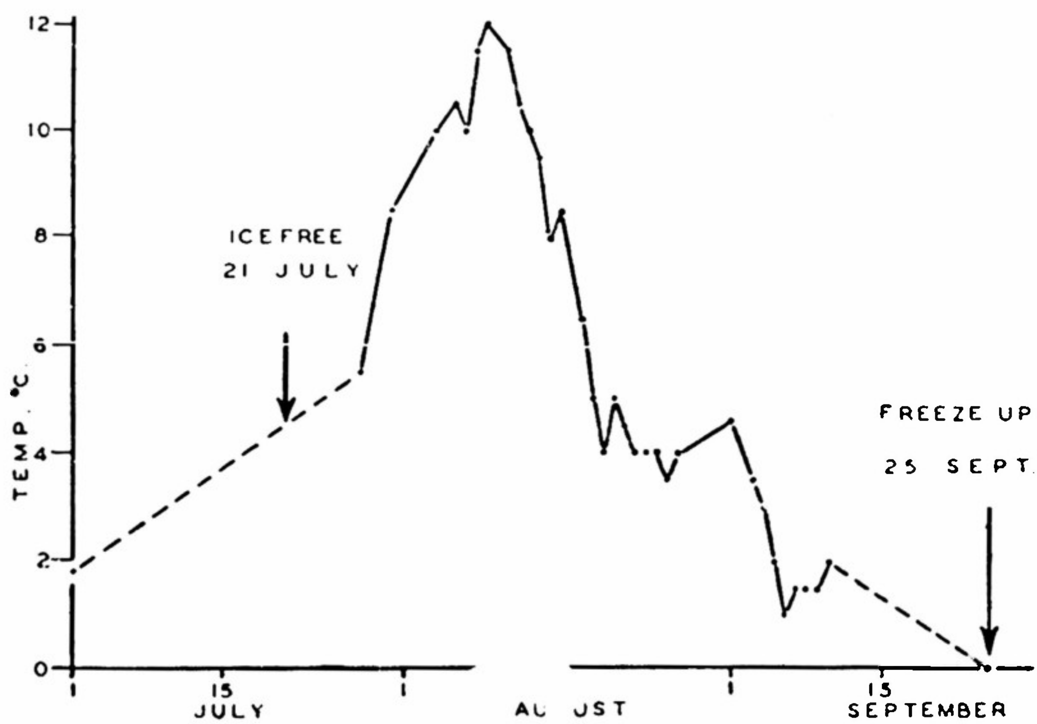

FIG. 1.—Surface water temperatures of Ikroavik Lake during summer, 1952.

ice had started to melt slightly around the edges. Early in July the ice mass had become free enough from the shores to shift with the wind and plow up extensive areas of shore-line tundra, gravels, and sands.

THE FISHES OF IKROA-VIK LAKE

At the time of the melting of the ice along the shores, large numbers of the small, nine-spined stickleback *Pungitius pungitius*, were in evidence. When the ice, which was piled up on the shores, melted or receded, large numbers of dead sticklebacks were found where they had been entrapped. That not a single specimen of any other kind of fish was found dead at this time indicated that any permanent fish population must have been isolated under the ice. Continual seining and trapping around the edges of the open water leads in early July failed to yield a single fish until July 15 when one seine haul netted twelve large and very fat *Prosopium cylindraceum*. By the end of July several large collections including many *Leucichthys sardinella* and a few *P. cylindraceum* had been made. Routine observations were continued until September 10, 1952.

The larger *Prosopium* which were autopsied indicated that gonadal maturity and spawning occurred in early August. One school of fry was observed, but only a single 2.5 centimeter specimen was obtained. Norman J. Wilimovsky (personal communication) obtained specimens of the same size on June 29, 1951, but it should be noted that the lake had become ice-free by late June in 1951. Careful observations during 1952 revealed neither spawning activities nor deposited eggs. With but one exception, 14 *Prosopium* examined during September had spawned; the exception was a large marked female which had been recaptured twice and which had begun to show the wear of excessive handling.

Examination of adult *Leucichthys* suggested that gonadal maturity was just being attained at the time of the September collections. Only 16 of 127 mature fish had definitely spawned by September 10. Among fingerling *Leucichthys* specimens taken from late July to late August, specimens from about 4 to 6 centimeters long were just beginning to form their first scales. These small fish had most likely hatched under the ice during the previous winter.

In August two ripe male specimens of chum or dog salmon (*Oncorhynchus keta*) were taken. Since the previous occurrence of salmon in the lake had been unknown to the Eskimos, it was assumed that these two specimens were "strays."

Norman J. Wilimovsky, who is currently studying the history of the Eskimo fisheries, has noted that Ikroa-vik Lake has been virtually unexploited since 1944, the last known fishing being an unsuccessful week for Eskimos in 1950. Prior to 1944, Eskimo travelers sometimes stopped briefly at the lake and fished for several days in the spring or in the autumn; there is no evidence to indicate that the lake ever supported a continuous fishery.

THE WHITEFISH POPULATIONS

Methods

The Schnabel (1938) mark-and-recapture method was used for the estimation of the *Prosopium cylindraceum* and *Leucichthys sardinella* populations. The "average" estimated population, P, from a series of estimates made while marking is in progress, is

$$P = \frac{S(A \times B)}{S(C)}$$

where A is the total number of fish observed during each period of samplings, B is the total number of fish marked and at large at the time of sampling, and C is the number of recaptures in any one sampling period. "S" denotes "sum of."

From July 15 through August, fish were seined with a 200-foot ¾-inch mesh seine which was 15 feet deep in the middle and tapered to 6 feet deep at the ends. During August additional fish were captured by the use of a 100-foot, 1-inch mesh gill net which was 6 feet deep. After concluding marking operations in August, the final sampling in September was by means of the 1-inch gill net and two "experimental" gill nets. Each experimental gill net was 250 feet long and 6 feet deep, and was comprised of 50 feet each of meshes of ¾, 1, 1¼, 1½, and 2 inches.

Marking was accomplished by fin-clipping fish whose fork lengths were over 180 millimeters. Marks, successively changed at weekly intervals, were adipose, left ventral, right ventral, left pectoral, and right pectoral fin clips. Both whitefish species 180 millimeters long or longer appeared to be fully vulnerable to the ¾-inch mesh of the seine, which was the gear used for the capture of most of the live fish; all population estimation data deal with fishes above this minimum length.

When fish were captured, they were immediately placed in floating live cars, from which they were withdrawn for measuring, weighing, sampling of scales, and marking. Standard, fork, and total lengths were recorded to the nearest millimeter. Weights were recorded to the nearest gram for fish weighing less than 500 grams, to the nearest 2 grams for fish weighing between 500 and 1,000 grams, and to the nearest 25 grams for fish over 1,000 grams. The scale samples were preserved for age and growth determinations.

Seining was feasible only on the gravel and sand beaches of the northern part of the lake, and in order to assure more random distribution of marked fish they were transported in large tubs to the middle of the lake where they were released. Injured fish (especially those from the gill net) were removed for measuring and weighing and were observed for sex, maturity, and infection by parasites.

Four or five 1-inch poultry-mesh traps, similar to those described by Wohlschlag (1952), were set in the outlet so that immigrating or emigrating fish could be caught. Several gill net sets across the outlet were made also.

Results

Except for the abundant, but very small, sticklebacks which were not sampled and the two chum salmon, the two whitefish species comprised *the* fish populations of the lake.

The *Leucichthys sardinella* data for the July 31 to September capture-recapture operations broken down into six periods are summarized in Table I. The "best" estimate from these data would be 5,736 with 0.95 confidence

TABLE I

CAPTURE-RECAPTURE DATA FOR THE ESTIMATION OF THE POPULATION OF *Leucichthys sardinella* IN IKROA-VIK LAKE

Period	Number Handled (*A*)	Number Marked and Returned	Number of Marks at Large (*B*)	Number of Recaptures (*C*)	$\frac{S(A \times B)}{S(C)} = P$
1	38	38	0	0	.....
2	68	58	38	2	1,292
3	126	106	96	1	4,893
4	17	14	202	1	4,529
5	84	74	216	2	6,043
6	372	0	288	19	5,736*

* 0.95 confidence limits from 3,659 to 8,475 by Poisson approximation method of Chapman (1948).

limits ranging from 3,659 to 8,475, as calculated by the Poisson approximation method of Chapman (1948). The average weight of 721 *L. sardinella* over 180 millimeters fork length was 181.59 grams; the weight of the estimated population would be accordingly 1,059 kilograms (2,334 pounds).

In Table II are the mark-and-recapture data for the *Prosopium cylindraceum* whose fork lengths were greater than 180 millimeters. Because of the very few fish handled, the data are grouped into 4 two-week periods between July 15 and September 10. The estimate of 189 has binomial confidence limits from 102 to 441 when calculated from the table of Fisher and Yates (1949). The average weight of 55 *P. cylindraceum* having [illegible] lengths over 180 millimeters was 433.98 grams; accordingly the wei[illegible] estimated population would be 82 kilograms (181 pounds).

TABLE II

CAPTURE-RECAPTURE DATA FOR THE ESTIMATION OF THE POPULATION OF *Prosopium cylindraceum* IN IKROA-VIK LAKE

Period	Number Handled (A)	Number Marked and Returned	Number of Marks at Large (B)	Number of Recaptures (C)	$\frac{S(A \times B)}{S(C)} = P$
1	18	15	0	0	.....
2	13	12	15	1	195
3	5	5	27	0	330
4	31	3	32	6	189*

* 0.95 confidence limits from 102 to 441 from Table VII of Fisher and Yates (1949).

The traps and the gill net sets at the outlet yielded neither emigrants nor immigrants.

DISCUSSION OF ESTIMATES

Basically, the successful application of the Schnabel (1938) mark-and-recapture technique depends upon two assumptions: first, a population being estimated must be a "closed" or constant population without removals due to emigration or mortality and without additions due to immigration or to growth of individuals into the size range being sampled; second, either or both the marked and the unmarked fish must be randomly sampled. A complete discussion of these assumptions has been given by Ricker (1948).

Several lines of evidence indicate that the whitefish populations in Ikroa-vik Lake were, for all practical purposes, constant during the summer. Even though the two salmon did bypass the traps, there was no indication that the whitefishes moved into or out of the lake past the traps and nets set at the outlet. During the summer a series of scale samples was taken from *Leucichthys sardinella*, which occurred in the marine waters of Elson Lagoon several miles to the southeast of Point Barrow, for comparison with the scales of the Ikroa-vik Lake *L. sardinella*. Each of these populations had quite distinctive growth patterns reflected in the arrangement of annuli and circuli of the scales. Furthermore, as is well known to the local Eskimos, the lake forms of *L. sardinella* are much fatter and plumper than the marine or river forms. The natives of the Ungava Bay region of eastern Canada also have noted similar differences between lake and river *Prosopium* (Dunbar and Hildebrand, 1952). Only a few of the Ikroa-vik Lake fish had the "skinny" appearance of the fish from the lagoon. Of the dozen or so skinny lake *Leucichthys*, which were examined internally, heavy infestation by trematode (probably Dibothriocephalid) parasites was observed. Rawson (1947) has noted that heavily parasitized [illegible] contrast in a similar manner with the healthier and plumper forms of the same species in two Canadian lakes. Except for the few parasitized fish, these morphological differences provide fairly conclusive evidence that the lake population of the *Leucichthys* at least existed in an isolated state. Since the scales of the *Prosopium* had much the same growth pattern as the lake *Leucichthys*, it was assumed that the *Prosopium* were also isolated.

There is little evidence that the two whitefish species in the lake grow at great enough rates to make recruitment of individuals initially shorter than 180 millimeters of any consequence. Preliminary examination of the age and growth characteristics indicated by scale structure has shown that these species are very slow-growing. Several *Prosopium*, which had been marked with numbered discs and which were recaptured after two weeks to two months, showed little or no growth. If the populations of whitefish had been increasing due either to growth of smaller individuals or to immigration the population estimates from period to period would have gradually increased. The data do not indicate such a tendency.

Had the whitefish populations suffered a high rate of mortality or had numbers of them emigrated from the lake, the population estimates from period to period would have shown a tendency to decrease consistently; again, the data do not substantiate such a tendency. In population estimations of this kind, mortality (and/or emigration) must be of considerable magnitude if population estimates are to be affected appreciably (Wohlschlag and Woodhull, 1953). Undoubtedly there was some small degree of mortality during the summer among these two populations. Aside from possible mortality among fishes which had been handled during marking, other observed causes of mortality were parasitism and the predatory activities of birds. No piscivorous fish were observed in the lake except the two chum salmon, and they were in the last stages of migration when they engage in no feeding.

No direct information was available to indicate whether or not the release of marked individuals at the center of the lake resulted in their random distribution either as individuals or as individuals within randomly moving schools. If the fish released at the center of the lake had a tendency to home to the north end of the lake where they were first captured, the number of recaptured fish, marked at a given weekly period, should have appeared in the seine hauls fairly regularly. Actually there was no well-defined regularity to the occurrence of recaptures. At the close of the season when a two-day series of experimental gill net sampling was carried out near the west inlet, it was noted that the fraction of recaptures was of the same magnitude as the fraction among those taken at the north end of the lake. Taking into account these circumstances, it was assumed that over all the sampling periods, the sampling of the marked fish was reasonably random.

The natural distribution of the whitefishes can be inferred from the frequencies of the various numbers of fish taken in the different seine hauls. The large number of water hauls and the infrequent large catches indicated that both species occurred in schools. Gill net catches, although somewhat more uniform than seine catches, owing to the greater length of time of a gill net set, likewise provided evidence of schooling. The sporadic occurrence of schools at the north end of the lake implied that the schools must have been relatively few and wide-ranging, so that over the season the entire population of each species could have been exposed to the gear on a more or less random basis.

The *Prosopium* estimate of 189 fish seems very low. If this estimate were biased downward, the most likely explanation would be that a disproportionately large number of recaptures were made. Some evidence for this explanation might be based upon the recaptured fish from a group of 10 *Prosopium* which were marked with numbered discs on July 15; two of these were recaptured and removed on July 31 (these recaptures were not counted during the first period when no fish were considered to be marked and at large); of the 8 remaining tagged fish, one was taken during the final period in September. One other *Prosopium* marked in the first period was recaptured in both the second and last periods. However, there is no way of deciding (1) whether the marked fish were more vulnerable than the unmarked population due either to the nonrandom distribution of the marked fish or to their propensity to be captured by the seine or gill nets, or (2) whether the population was actually so small that frequent recaptures should really be expected.

During the seining operations prior to September, the ratio of *Prosopium* to *Leucichthys* was 0.108; during the gill-netting operations in September the ratio was 0.083. *If* the *Leucichthys* estimate of 5,736 were accepted, and *if* the two species were equally vulnerable to the gear, the *Prosopium* estimates would be respectively 619 and 476. However, the field observations would tend to suggest that the *Prosopium* were much more vulnerable than *Leucichthys* to both types of gear, which means that these latter *Prosopium* estimates would be biased upward. In any event, the population of *Prosopium* is very small, and the estimate of 189 is as good as any.

FRESH-WATER FISHERY POSSIBILITIES IN THE ALASKAN ARCTIC

While Ikroavik Lake is the northernmost lake in Alaska known to contain a permanent fish population, its fishes occur under what must be considered to be near minimal conditions of existence. Taking into account the short summer season, small populations, slow growth rates, and the time necessary for growth to maturity, it must be suspected that the biological production rate of fishes is very low in many, if not all, lakes and streams of the Arctic Alaskan Slope. In lakes farther to the south of Point Barrow, additional species of whitefishes, grayling, and the more predatory pike, chars, lake trout, and a few other species are present. The predatory species like lake trout would be expected to exist in less total bulk than the plankton-feeding whitefishes. Rawson (1947) estimated tentatively that lake trout could be removed from Lake Athabaska on a continuing basis if taken in about one-fourth the bulk of the whitefish species. It should be noted that the predatory species could also provide an excellent sport fishery.

The foregoing observations along with a few notes on the present small-scale Eskimo fresh-water fishery may be utilized as a basis for some interesting speculations about the future of fishery development in this region. Modern Eskimos fish almost exclusively with gill nets set in places where the fish tend to be concentrated, as in rivers or in narrows between lakes; here the populations are unusually vulnerable, and, upon a basis of catch-per-unit-effort, the populations may erroneously be assumed to be large. For example, in Ikroa-vik Lake where the fish were well distributed, 600 feet of gill netting captured about one-tenth of the estimated populations within a week. Some Eskimos apparently have recognized the possibility of over-fishing and have noted that lakes can be fished to the point where returns become unprofitable after a few years (Wilimovsky, in press). Because transportation of both gear and catch over the tundra and the multitude of lakes and streams is difficult, there would be a great temptation for commercial fishermen to fish in one location until small returns made moving imperative. Past experience in the lake fisheries of northern Canada has shown that stringent regulations are necessary in many cases to prevent the use of too much gear for too long at one time at any one place.

In northern Alaska this tendency could be circumvented if improved transportation facilities could be devised in order that a fishery could move readily after only the larger fish from small populations had been removed.

Efficient utilization of the different species will quite possibly create problems if fisheries develop in the future. The smaller species can be taken efficiently only by gear with small meshes, while the larger species would be removed largely before the attainment of sexual maturity. Proper exploitation of the larger species by gear with larger meshes would leave the smaller species largely unexploited. Satisfactory methods of simultaneous and efficient utilization of both large and small species should be devised and their effects thoroughly understood before any haphazard regulations are imposed.

SUMMARY

The unexploited fish populations of Ikroa-vik Lake were studied during the ice-free summer season of 1952. In this moderately large, and very

shallow lake, the northernmost Alaskan lake known to contain a permanent fish fauna, there was at most about 1½ feet of water under the 6-foot ice cover during the late spring. The lake contains permanent populations of the very small nine-spined stickleback (*Pungitius pungitius*) and two whitefishes (*Leucichthys sardinella* and *Prosopium cylindraceum*). At least two ripe adult salmon (*Oncorhynchus keta*) had wandered into the lake during the summer.

Spawning of the *Leucichthys sardinella* occurs in late summer or autumn and quite possibly under the ice. Yearlings whose first scales were forming were found just after the melting of the ice in late July; they had apparently hatched under the ice during the previous winter. The *Prosopium cylindraceum* spawn and hatch shortly after the ice melts in the early summer.

Population estimates by the mark-and-recapture method were made for the two whitefishes whose fork lengths were over 180 millimeters. The estimates were: *L. sardinella*, 5,736 with 0.95 confidence limits from 3,659 to 8,475; and *P. cylindraceum*, only 189 with 0.95 confidence limits from 102 to 441. Average weight of each *L. sardinella* was about 185 grams; the estimated population weight was 1,059 kilograms (2,334 pounds). The average weight of each *P. cylindraceum* was about 434 grams; the estimate population weight was 82 kilograms (181 pounds).

The possibilities and anticipated problems of future fresh-water fishery development on the Alaskan Arctic Slope are discussed.

ACKNOWLEDGMENTS

It is a pleasure to express thanks to Dr. Ira L. Wiggins, Director of the Arctic Research Laboratory at Point Barrow, and to his staff, whose help in supplying information about the region and maintaining logistics of the field operations was indispensable. Many other field investigators generously co-operated to make transportation facilities available.

Special thanks are due Daniel M. Cohen, Project Assistant, who helped with all the laborious and tedious field work and who organized much of the field data. Norman J. Wilimovsky has been especially helpful in identifying fish species and in supplying information about the Eskimo fishery.

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ON THE GEOGRAPHICAL DISTRIBUTION OF ARCTIC BRYOPHYTES[5]

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Extensive field studies on arctic American bryophytes during the past few years have provided materials and data contributing to several fields of botany, and one could speak at length on the contributions of arctic bryology to plant sociology, autoecology, phytogeography, and systematic botany, among others. Because of the restrictions on time and space inherent in any symposium, however, the present paper will be limited to the field of plant geography, with special reference to a single important floristic element.

Mosses and liverworts furnish excellent material for studies on the geographical distribution of plants, a fact requiring emphatic restatement because it has been obscured by too common a belief among botanists that the long-lived, wind-borne spores of bryophytes give them a nearly universal distribution. Just as in higher plants, some weedy and ubiquitous species—*Funaria hygrometrica* and *Marchantia polymorpha* are excellent examples—have followed man and the effects of his civilization to all parts of the world. When one looks beyond the weedy species, however, he finds that bryophytes demonstrate as characteristic patterns of distribution as the higher plants, although not necessarily the same ones.

In a region where the number of species of bryophytes approaches or equals that of higher plants, arctic mosses and liverworts acquire correspondingly greater importance as materials for the investigation of phytogeographic problems. Nevertheless, even the simple and basic problem of whether or not a strictly arctic bryophyte flora or floristic element really exists has been debated up to the present day. The opinion still prevails that the whole bryophyte flora of the arctic regions is only an attenuated and depauperate temperate flora, composed of those few species that have been able to endure the rigors of the northernmost climates; and that any "species" seemingly restricted to the arctic are only reduced or adaptive forms too closely related to their counterparts in temperate climates for full specific status. Implicit in this negativistic idea, of course, is the belief that arctic mosses and hepatics are materially reduced in size because of their unfavorable environment (Meylan, 1940). The basis for this idea is not hard to find, since enough of the arctic species actually are reduced temperate species to con-

[5] Contribution No. 1953-8 from the Arctic Research Laboratory, presented in partial fulfillment of Contract N6onr-25134 with the Office of Naval Research.

firm a superficial impression. However, careful field studies in arctic America, at least, soon reveal a rich bryological flora that consists of several distinct floristic elements of considerable phytogeographical significance, in addition to the group of widely distributed, sometimes weedy species. This discussion will center on one of the most interesting of these floristic elements, which consists of a group of species endemic to the arctic regions, and which makes up about 10 percent of the total number of species of bryophytes there.

These species stand out from the weedy group because they are not at all reduced physiological states or ecological varities of species which flourish farther south. Furthermore, these truly arctic species are not even closely related systematically or phylogenetically to those of temperate regions immediately to the south, and most certainly have not evolved directly from them. Quite the opposite, they may be equal in size to, or even larger than, the species of the same genera occurring in more temperate climates. For example, the arctic species, *Aulacomnium acuminatum*, *Scapania simmonsii*, *Diplophyllum plicatum*, *Radula prolifera*, and *Trichostomum cuspidatissimum* are among the largest in their genera.

Our relative lack of knowledge, in the past, concerning even the larger features of the geographical distribution of arctic bryophytes arose not from a lack of interest in or appreciation of the problems involved, but simply from the few available data upon which to base generalizations. Most of the early exploring and searching expeditions found themselves far too occupied with the pressing problems of travel and of survival to collect plants in any quantity, especially the lower ones. Some collections, furthermore, after being made had to be abandoned or were lost when ships were caught in the ice. Consequently, until the past two decades, only a few extensive and representative collections had been made in the north polar regions, of which the most important came from Spitzbergen (Berggren, 1875), from Siberia (Lindberg and Arnell, 1889, 1890; Arnell, 1913, 1917), and from arctic Canada (Brown, 1823; Bryhn, 1907; Williams, 1921; Steere, 1948). Substantial reports based on these few large collections of bryophytes from widely separated areas, especially Siberia and northernmost Canada, have tended to give an impression that two or more centers of speciation or areas of endemism exist in arctic regions (Herzog, 1926). The recent concept that a relatively large, truly arctic, circumpolar element exists (Steere, 1948; Persson, 1949) was made possible through the availability of much new material from arctic and subarctic America, and the resultant discovery that many of the species previously considered to be endemic to local areas really have a much wider geographic range. The apparent richness of Ellesmere Island and of Siberia in endemic species, which in my opinion belong to the circumpolar arctic floristic element just discussed, brings northern Alaska and northwestern Canada into sharp focus as an area of critical geographical significance, where these "bicentric" species might be expected to find a common meeting place.

The outstanding support given to my work by the Arctic Research Laboratory during the summers of 1951 and 1952, especially in providing excellent facilities for travel, enabled me to visit many widely separated areas on the north slope of the Brooks Range. Through this intensive field work, following field seasons in the region of Great Bear Lake and Coppermine in arctic Canada (1948), and in central Alaska (1949), a region that was almost completely unknown bryologically has now provided us with abundant evidence to support the thesis that a group of strictly arctic bryophytes extends more or less continuously around the north polar basin. In fact, this region proved to be so unexpectedly rich in endemic arctic species, some of them new to science, that it may very well have been a primary center for the dissemination of bryophytes during interglacial and post-Pleistocene times, as Hultén (1937) has indicated for higher plants.

As examples of the kind of data used in establishing a floristic element and its distribution, the geographical ranges of a few representative species of arctic mosses and hepatics, out of many studied, will be discussed and illustrated.

1. *Aulacomnium acuminatum* (Lindb. & Arn.) Paris (Map 1). This handsome species, the largest in its genus, was originally described from the valley of the Jenisei River in Siberia (Lindberg & Arnell, 1890), and later reported from the valley of the Lena (Arnell, 1913). First rediscovered on Ellesmere Island (Bryhn, 1907), it is now known to have a rather wide distribution in arctic Canada: on Baffin Island (Steere, 1948), Cornwallis Island (Steere, 1951), and Prince Patrick Island (Steere, 1953*b*); in the Yukon Territory (Persson, 1946), and at Great Bear Lake and Coppermine, Northwest Territories (Steere, *ined.*). Reported from several localities in central Alaska (Persson, 1946), this moss has been found to be very common on the north slope of the Brooks Range (Steere, *ined.*).

2. *Funaria polaris* Bryhn (Map 2). For nearly a half century this species was known only from the single original collection made on the southern end of Ellesmere Island (Bryhn, 1907) until it was recently reported from Southampton Island (Steere, 1949) and from Greenland (Holmen, 1952). It can be recorded here as occuring in several widely separated localities in arctic Alaska, from the headwaters of the Utukok River in the west to Schrader Lake in the east (Steere, *ined.*). Furthermore, on the basis of its known distribution, this moss will certainly be found to occur in Siberia.

3. *Radula prolifera* Arnell (Map 3). Originally described from the mouth of the Lena River, Siberia (Arnell, 1913), and soon thereafter reported from Taimyr Island (Arnell, 1917), this hepatic was reported from North America relatively recently (Steere, 1941; Castle, 1950), from a

fragmentary specimen collected by Dutilly at Coppermine, where my own field work in 1948 later showed it to be abundant. Persson (1947) has reported this species from Alaska, and my studies on the arctic slope clearly demonstrate that this is a common and abundant species in the foothill and montane provinces of the Brooks Range (Steere, *ined.*).

4. *Scapania simmonsii* Brylm (Map 4). This handsome hepatic was described originally from two adjacent localities at the southern end of Ellesmere Island (Brylm, 1907), and then first rediscovered in Siberia, at Cape Tscheljuskin on the Taimyr Peninsula (Brotherus, 1910), and at Kunachsur and Bulkur near the mouth of the Lena River (Arnell, 1913). Still later, it was reported from Spitzbergen and from arctic Finland (Buch, 1934). Very recently, the discovery of this species at a second locality in North America, in Ungava, northernmost Quebec, has been announced (Arnell, 1950). From personal experience, I can report that this conspicuous and easily recognized species occurs in abundance at Great Bear Lake and at Coppermine in arctic Canada, and at nearly every locality visited in the various physiographic provinces on the north slope of the Brooks Range in Alaska.

5. *Lepicolea fryei* Persson (Map 5). This phytogeographically interesting hepatic is known in the literature only from the single original specimen, from St. Lawrence Island, Alaska (Persson, 1946). However, I have collected it, with perianths and sporophytes, in a half dozen widely separated localities in arctic Alaska, from near the headwaters of the Utukok River in the west to Schrader Lake, near Mount Chamberlin, in the east. Furthermore, some very small and fragmentary specimens segregated from a collection of *Sphagnum* made at Chesterfield Inlet, on the west coast of Hudson Bay in 1936 by Dutilly, were very recently identified with this species, thus giving it a much more extensive range, quite parallel with that of the other arctic species discussed here. In view of this rapid expansion of the known geographic range of a species described as recently as 1946, it seems perfectly safe to predict a still wider occurrence, when bryologists have had a chance to make field studies in other arctic areas, especially Siberia.

6. *Blindia polaris* (Berggren) Hagen (Map 6). Originally described from several collections from Spitzbergen (Berggren, 1875), this moss is now known to occur in arctic Norway, Sweden, and Finland (Jensen, 1939). In arctic America, it was early discovered on Ellesmere Island (Brylm, 1907), recently reported from Cornwallis Island (Steere, 1951), and is now known to be widely distributed in northernmost Alaska (Steere, *ined.*). The geographic range of this species will surely be greatly extended, with further field work.

7. *Cinclidium latifolium* Lindb. (Map 7). This, one of the most beautiful and the best-characterized species of a fine genus, was originally proposed

viously discussed, yet, like them, occurring with greatest frequency within the Arctic Circle. In a way, the generalized distribution of this species (originally described from Greenland) sums up the much more restricted and localized ranges of the much rarer species just listed, and indicates one of the types of evidence used in predicting their discovery in other regions.

To different degrees, then, the geographical distributions of the species discussed here give evidence that no matter where its type locality, each one belongs to the same group of arctic species that are restricted to an area around the polar ocean and occurring with greatest frequency within the Arctic Circle. Just as with flowering plants (Hultén, 1937), arctic Alaska seems to be the region richest in these species, which become progressively less common or disappear altogether in northernmost Scandinavia on the west and in Greenland to the east. Because of the remarkable parallelism shown in the known ranges of the species as outlined above, it becomes possible to predict the remainder of their distribution by extension or extrapolation; that is, if an arc matches part of a circle, it must belong to that circle. Thus some species are known from Siberia only; others are known from Greenland and the eastern arctic islands of Canada; whereas still others are known only from arctic Alaska and near-by areas. Yet we can predict that careful exploration by bryologists will fill out most or all of the circle. Other truly arctic species, most of them now discovered in Alaska, that exhibit this characteristic geographic distribution are: (Hepaticae) *Barbilophozia binsteadii, Mesoptychia sahlbergii, Marsupella arctica, Plagiochila arctica, Scapania hyperborea, S. kaurini, S. spitzbergensis,* (Musci) *Andreaea obovata, Bryobrittonia pellucida,* (cf. Steere, 1953*a*), *Ceratodon heterophyllus, Cinclidium arcticum, C. subrotundum, Claopodium subpiliferum, Cynodontium alpestre, Distichium hageni, Drepanocladus badius, D. latifolius, D. lycopodioides, Fissidens arcticus, Hygrohypnum polare, Lyellia aspera, Mnium blyttii, M. hymenophyllum, Polytrichum hyperboreum, Psilopilum cavifolium, P. laevigatum, Trichostomum cuspidatissimum,* many species in the complex genus *Bryum,* as well as at least one new genus and several new and as yet undescribed species.

Now that the existence of a substantial group of arctic bryophytes has been established with certainty, the next question of basic phytogeographical importance concerns itself with the origin and the age of this floristic element. In my opinion, these species demonstrating so restricted a distribution in circumpolar areas are very ancient ones, apparently widely distributed in warmer pre-Pleistocene or interglacial climates, which have found refuge in the far north, where their survival has been permitted by the generally scant precipitation and the resultant lack of large-scale or continental glaciation. This opinion can be supported by several types of evidence, as follows: (1) Most of the truly arctic species of mosses and hepatics seem to have no close relatives at all, and in their lack of variability and their evolutionary isolation, as illustrated by an unusually large proportion of small or monotypic endemic genera (*Bryobrittonia*, *Mesoptychia*, *Haplodon*, *Cinclidium*, etc.), they clearly reflect a very ancient origin. (2) These species show no close relationship to those of temperate regions immediately south of their present range, and certainly have not evolved directly from them, as we would expect modern species to have done. This geographic isolation seems as significant of great age as the genetic isolation. (3) The closest relatives of these species, where they exist, occur in very distant parts of the world, usually in the southern hemisphere, which are characterized by ancient and primitive floras, a further indication of antiquity. An excellent example is *Radula prolifera* (see Map 3), a member of the small and distinctive section *Amentulosae* of the subgenus *Acroradula*, which, fortunately for our purpose here, has just been revised critically (Castle, 1950). The only other known species in this section are *R. uvifera* Tayl., of New Zealand, *R. amentulosa* Mitt., of Japan and Fiji, *R. formosa* (Meissn.) Nees, of "Java, Celebes, Sumatra, Ceylon, Amboina, Samoa, Tahiti, New Caledonia, and the Fiji Islands," *R. scariosa* Mitt., of Fiji, and *R. novae-guinae* Steph., of New Guinea (Map 11). Another example is *Lepicolea fryei* Persson (see Map 5), a member of a somewhat heterogeneous and perhaps polyphyletic genus as defined at the moment. In his *Species Hepaticarum*, Stephani (1909, 1922) listed 13 species of *Lepicolea*, of which all are not necessarily valid. However, regardless of their specific status, the geographic distribution of these species may be considered independently, thereby shedding a good deal of light on the point at issue here (Map 12). Stephani lists *Lepicolea teres* Steph., and *L. quadrilaciniata* Sull., from Fuegia; *L. scolopendra* (Hook.) Dum., of New Zealand, Tasmania, Oceania, and Formosa; *L. ochroleuca* (Spreng.) Spruce of South Africa, Brazil, Chile, Patagonia, Fuegia, and Mexico; *L. pruinosa* (Tayl.) Spruce of Colombia, Ecuador, and Bolivia; *L. boliviensis* Steph. and *L. herzogiana* Steph., of Bolivia; *L. loriana* Steph., of New Guinea, *L. longifissa* Steph., of New Zealand, *L. abnormis* Steph., of Chile, *L. fissa* Nees and *L. flaccida* Steph., of Java; and *L. georgica* Steph., of the antarctic island of South Georgia (Map 12). Other species of *Lepicolea*, described more recently, are *L. ramentifissa* Herzog from Bolivia, and *L. simplicior* Herzog from Java. In a recent discussion of the distribution patterns of Hepaticae in South America, Fulford (1951) characterized *Lepicolea* as follows, "The genus is of southern origin and belongs to a primitive family," a conclusion which seems to me to be inescapable, in spite of the single anomalous arctic species, *L. fryei*. Further evidence is given by the fact that the closest relatives of *Funaria polaris* Bryhn seem to be *F. aequidens* Lindb., of the Caucasus, *F. kashmirensis* of Kashmir, and *F. erectiuscula* Mitt., of Chile (Brotherus, 1924). A still undescribed species of *Porella* from the headwaters of the Utukok River, in the De Long Mountains toward the western end of the Brooks Range, is most closely related to a species from the Chinese province of Shen-Si, in the latitude of San Francisco, and these two species differ so fundamentally from the remainder of the genus that they are almost certain to be recognized as a separate genus when the reproductive structures are eventually found. A new species of the genus *Lejeunea*, or of some related genus of very tropical affinities, repeats this same pattern.

An interesting ecological sidelight on the age of these species is given by the fact that several of the species of arctic hepatics occurring in open tundra belong to genera of markedly tropical distribution and that are normally restricted in their habitat to the trunks of trees (*Radula*, *Porella*, two species of *Frullania*, *Lejeunea*). Although speculations are as unsafe as they are fascinating, we can perhaps think in terms of a bark-inhabiting series of hepatics that persisted after the trees disappeared, through a gradual adjustment to climatic changes. Furthermore, the tundra tussocks present ecological conditions surprisingly parallel to those of tree bark, since in a region of low precipitation and of high insolation during the growing season they are essentially xeric, obtaining water only occasionally from rains or fogs. Furthermore, like bark, they are very poor in minerals and in nitrogen sources.

It would not require too great a stretch of the imagination to postulate that we are dealing with the last remnants of a widely distributed Tertiary or interglacial flora that originated in some far distant area, probably in the southern hemisphere, and that has now been restricted to the arctic regions by the destructive activities of continental glaciations at lower latitudes, as well as by the success in competition of more rapidly speciating genera and of younger and more aggressive species there. The identification of *Cinclidium latifolium*, one of the species now most narrowly restricted in its distribution to the high arctic regions, in fossil condition in Denmark, in Pleistocene deposits (Hesselbo, 1910), offers us excellent corollary evidence of the wider distribution of the truly arctic species during Pleistocene times. The concept of the persistence of bryophytes during and through the Pleistocene epoch, in unglaciated refugia, has now been rather widely accepted (Gams, 1932; Steere, 1937; Müller, 1951; Löve, 1953). Furthermore, most of the species of bryophytes discovered in Pliocene deposits are still living species.

It should be emphasized that our knowledge of arctic bryophytes is still too incomplete to draw any final and detailed conclusions on their geographical ranges and geological history, since too many of the patterns of distribution recognized so far—and reported here—may reflect the accident of distribution of collectors rather than that of bryophytes. Nonetheless, it is possible to make several generalizations, in summary: (1) There is a truly arctic floristic element of mosses and hepatics. (2) This element is apparently circumpolar in its presest distribution rather than being restricted to two or more isolated centers of speciation. (3) The most typically arctic species at present are survivors of a widespread Tertiary (or warm interglacial) flora, as indicated by (*a*) the morphological and genetical distinctness of the species from any other living ones, (*b*) their taxonomic relationship to species of Oceania, tropical Asia, and America instead of to species of the north temperate regions (or even northern tropical regions), and (*c*) their very wide present-day geographical distribution in north polar regions, something very difficult to explain on any theory of foot-by-foot progression of vegetation during the relatively brief post-Pleistocene times.

ACKNOWLEDGMENTS

In closing, I wish to acknowledge with deep appreciation the support given so generously to my work by the Arctic Research Laboratory, under the terms of a contract between the Office of Naval Research and Stanford University. To my old friend and colleague, Dr. Ira L. Wiggins, professor of biology at Stanford University and Scientific Director of the Arctic Research Laboratory, I owe a very special debt of gratitude for much professional and personal help.

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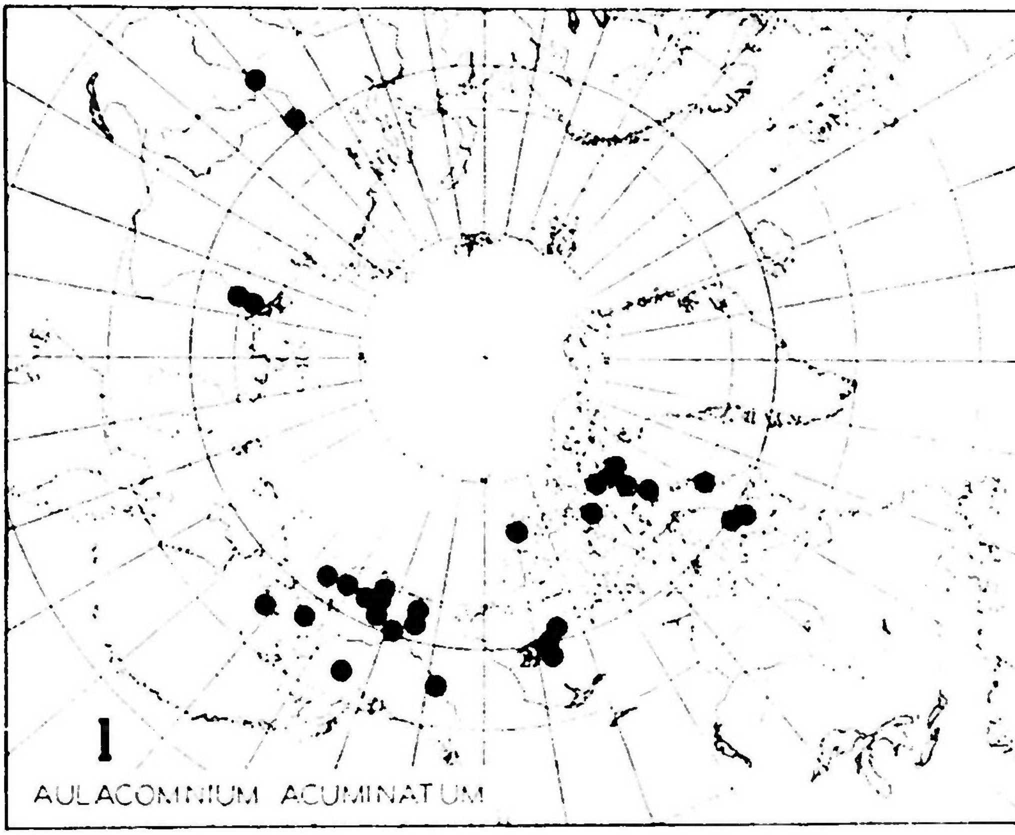
LIST OF MAPS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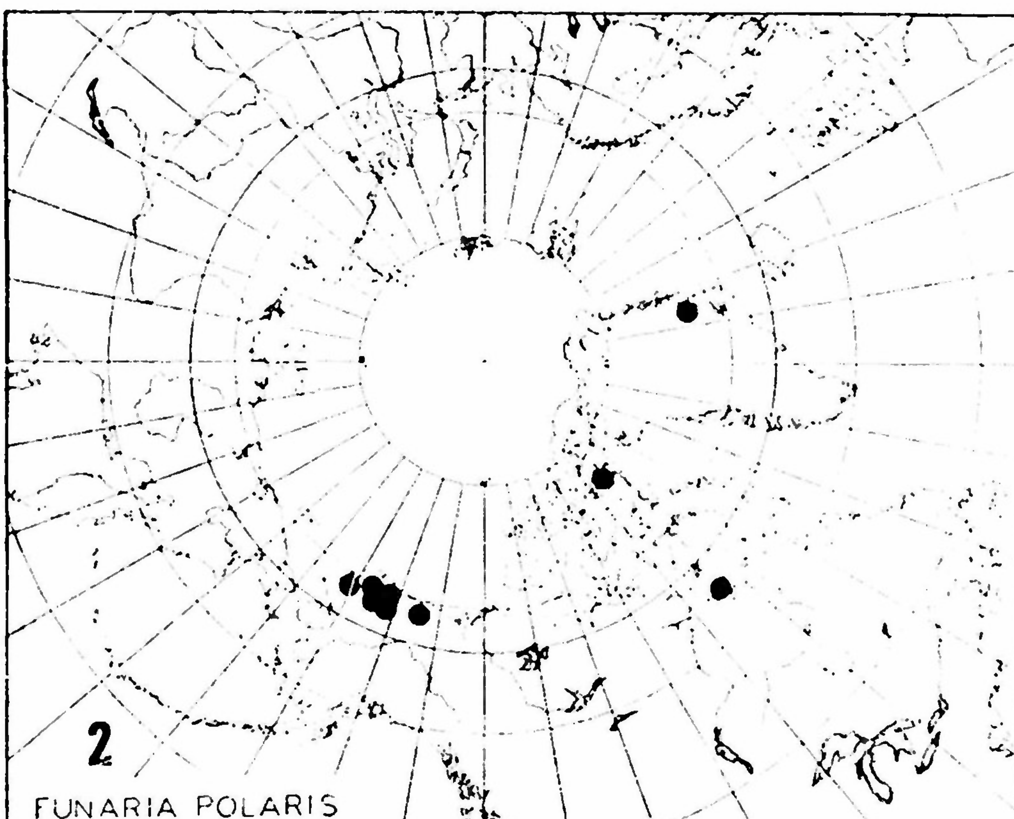
AULACOMNIUM ACUMINATUM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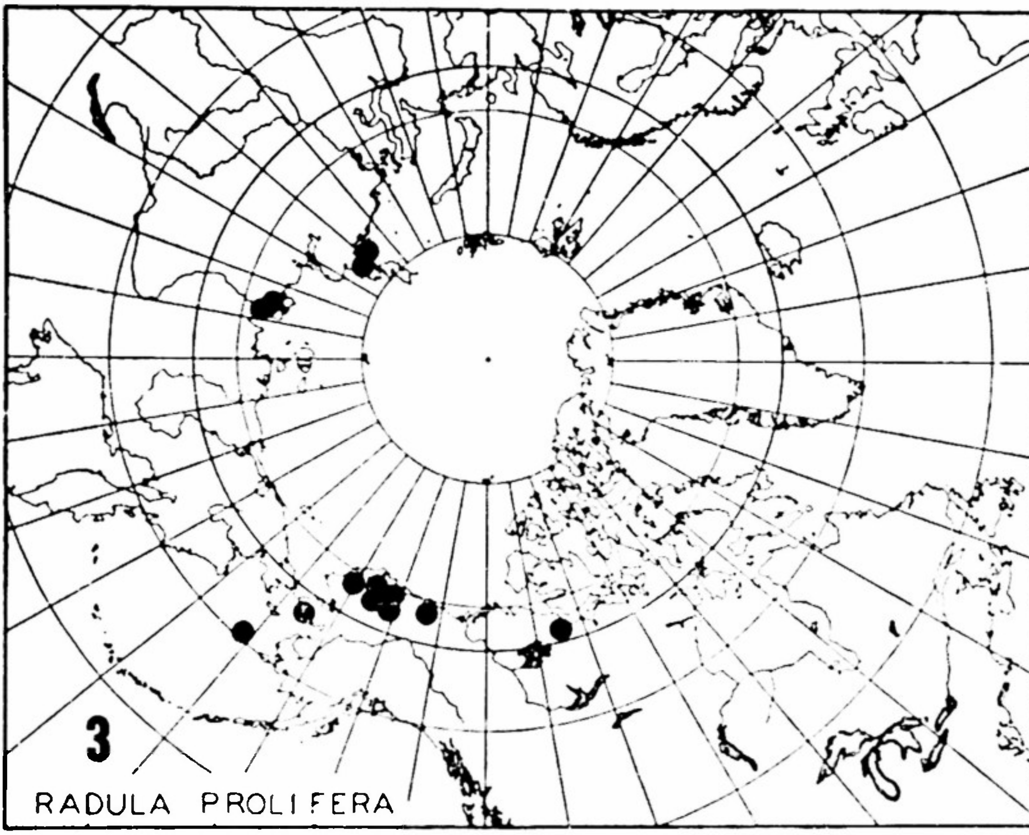
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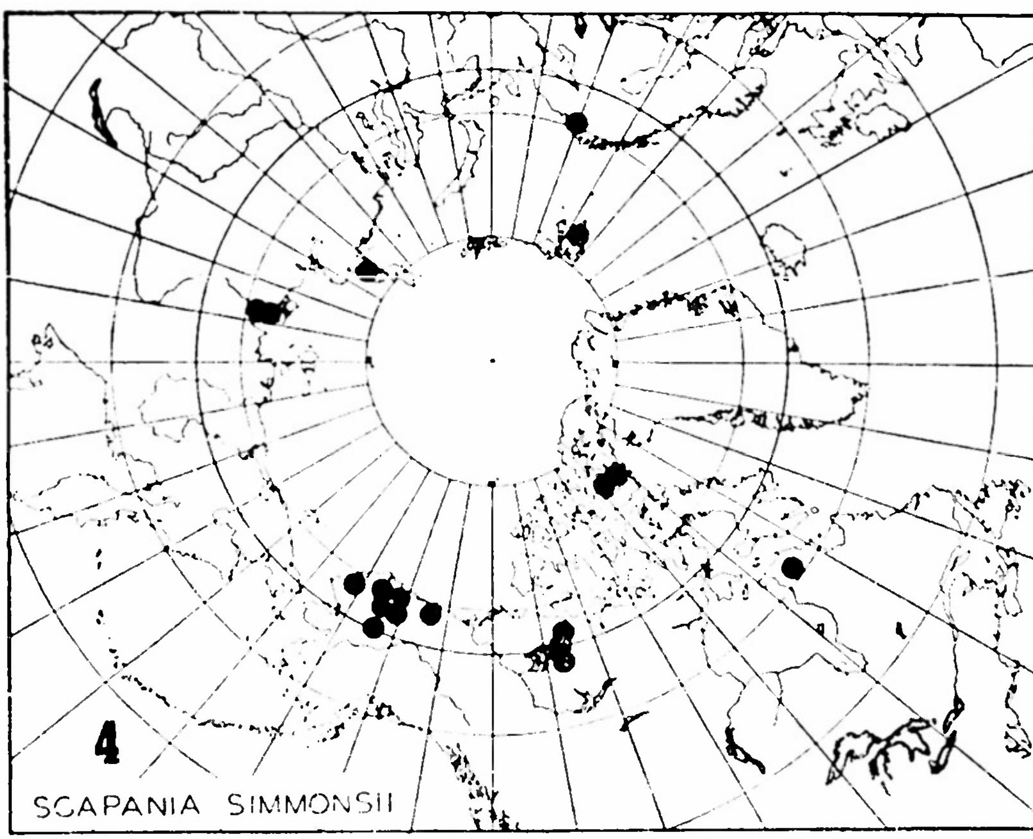
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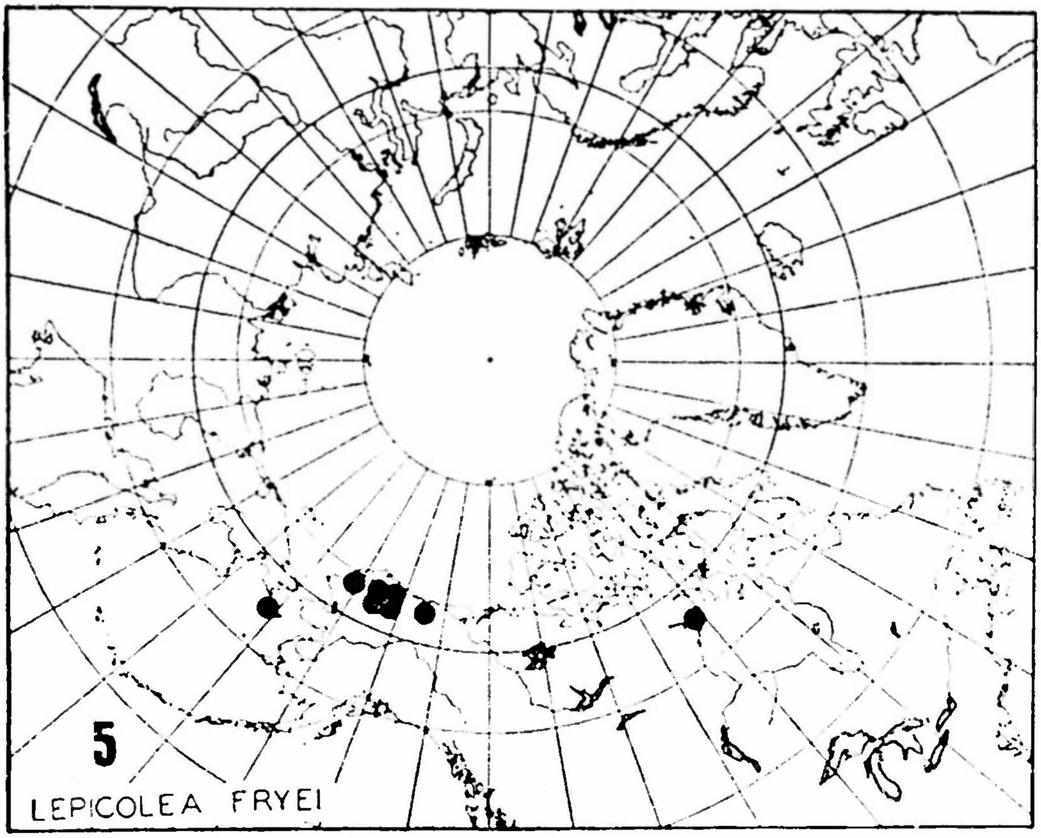
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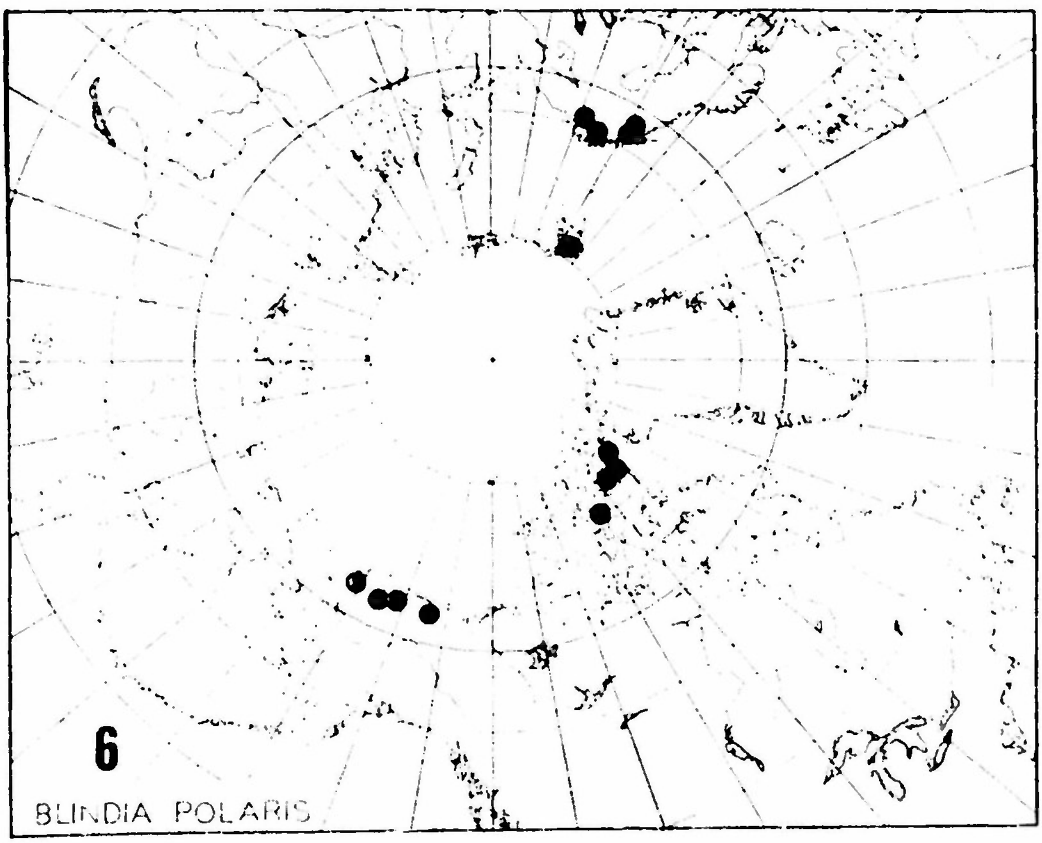
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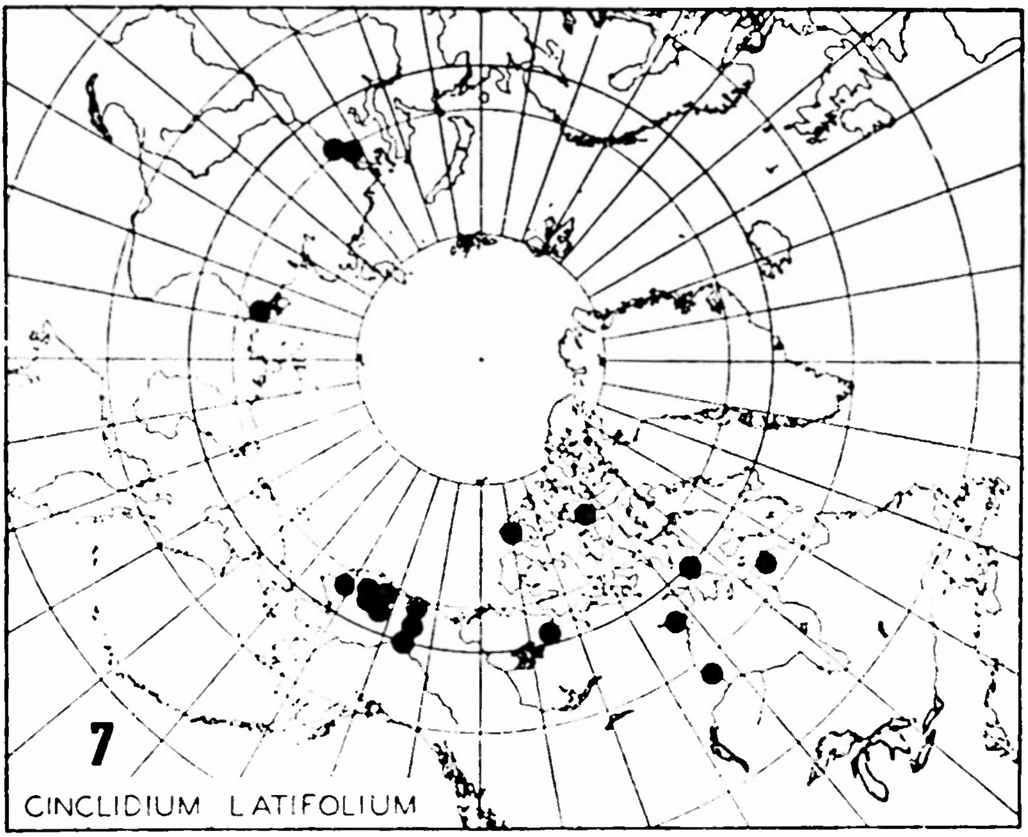
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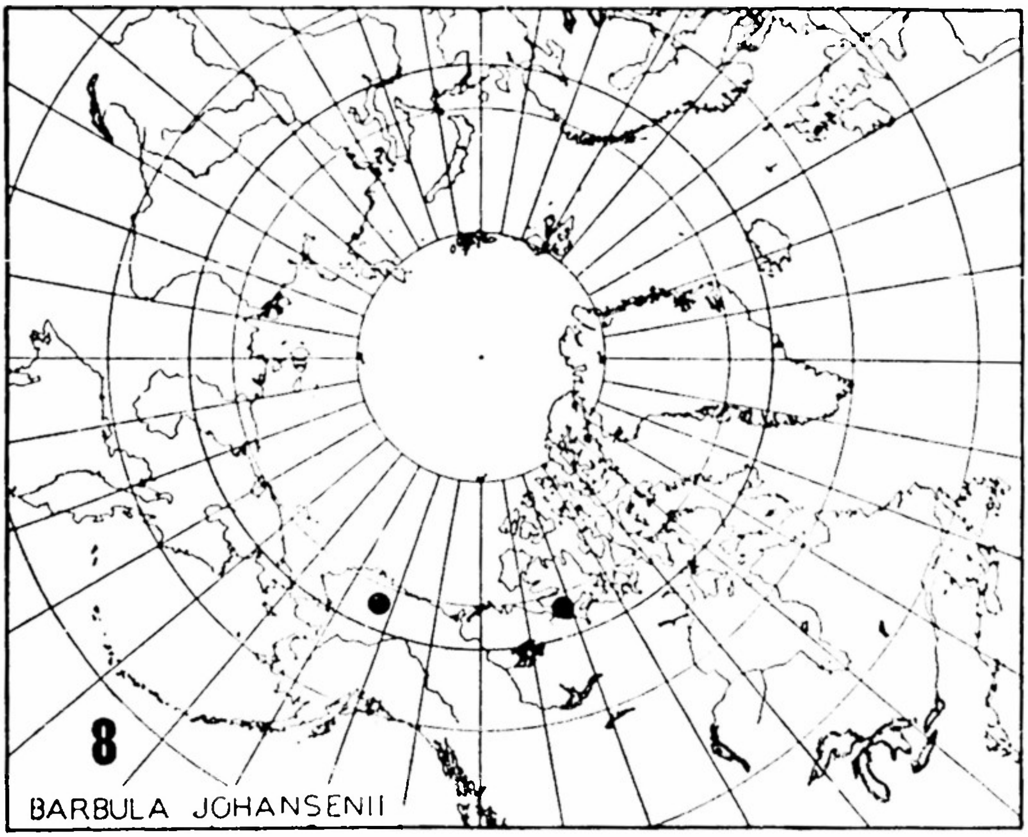
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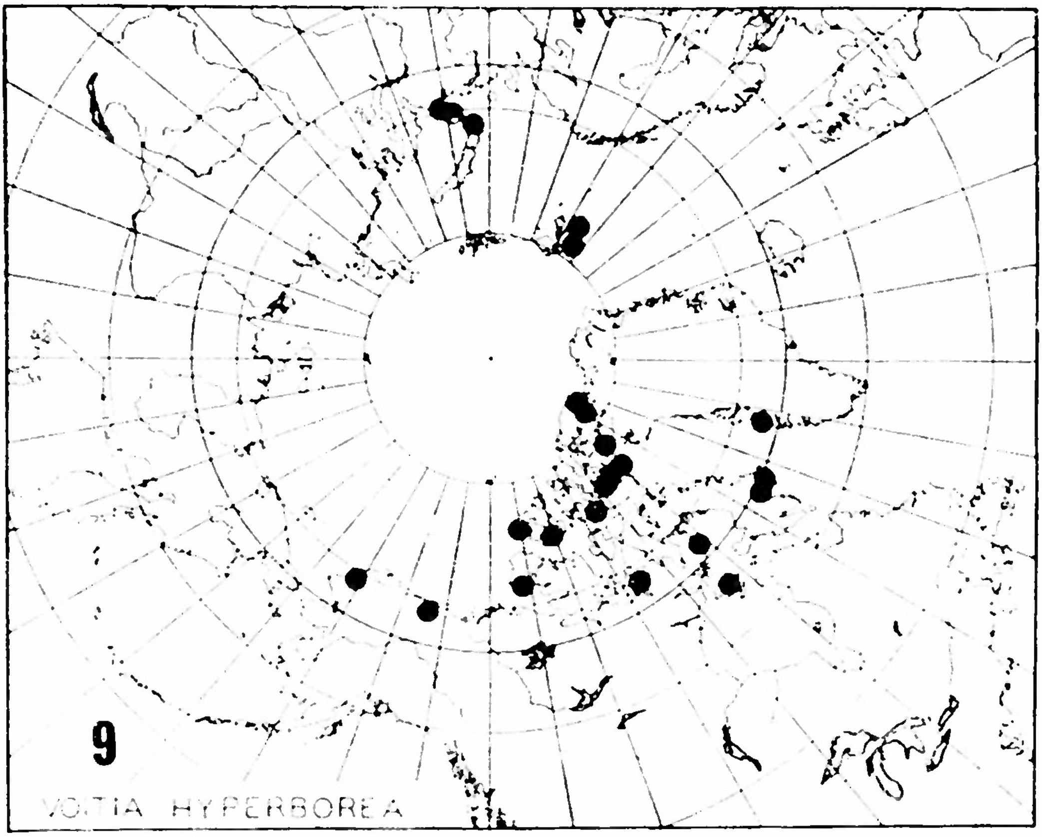
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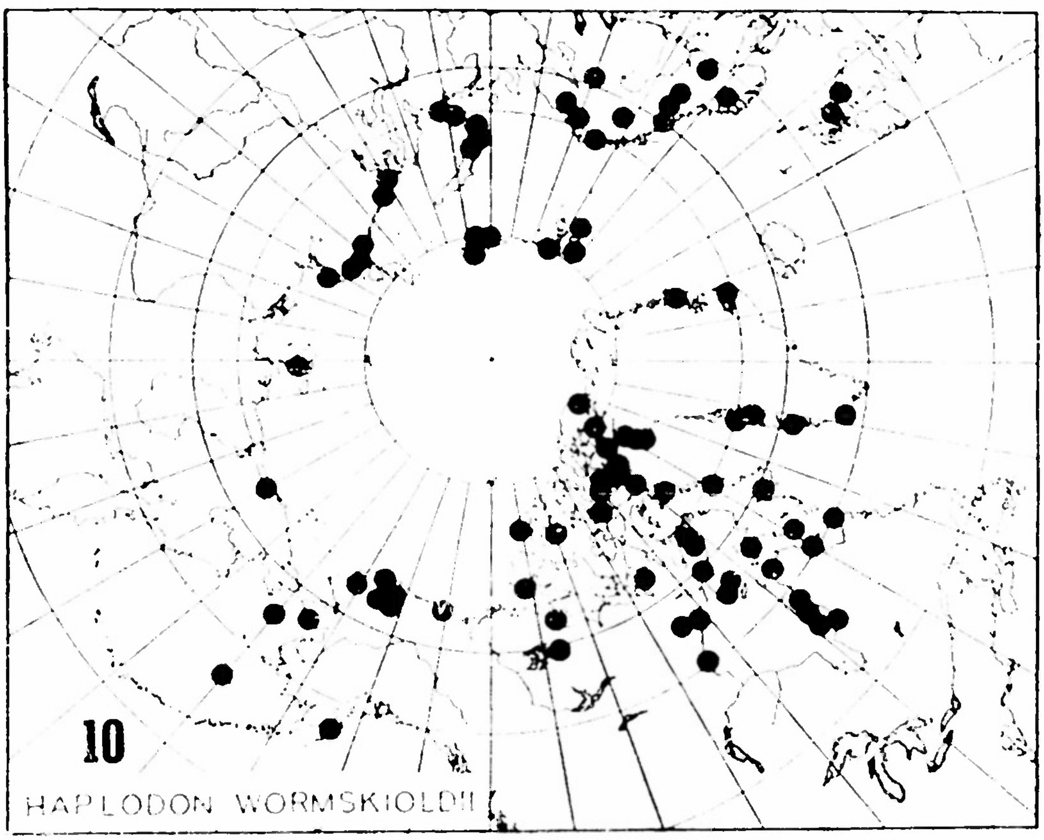
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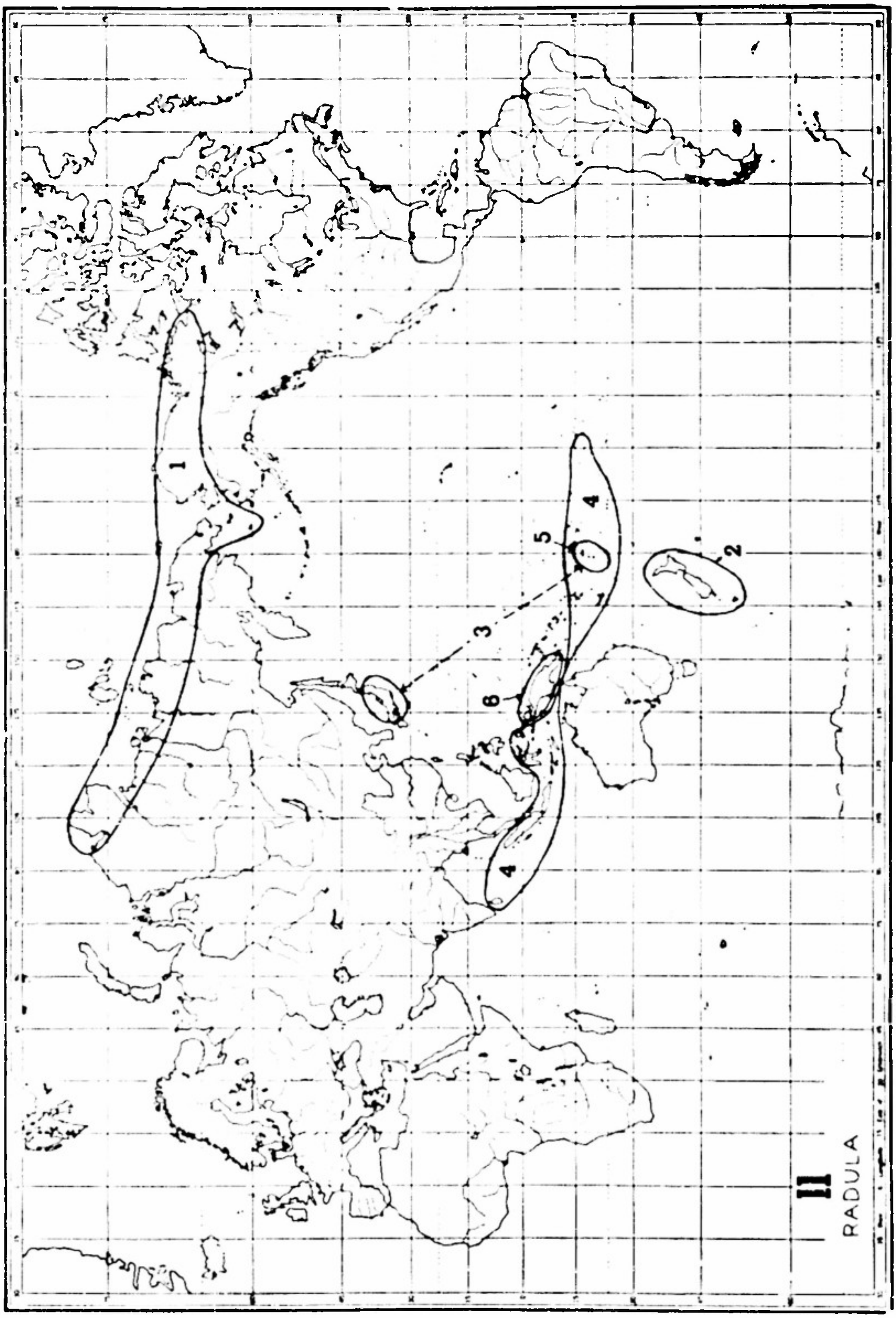
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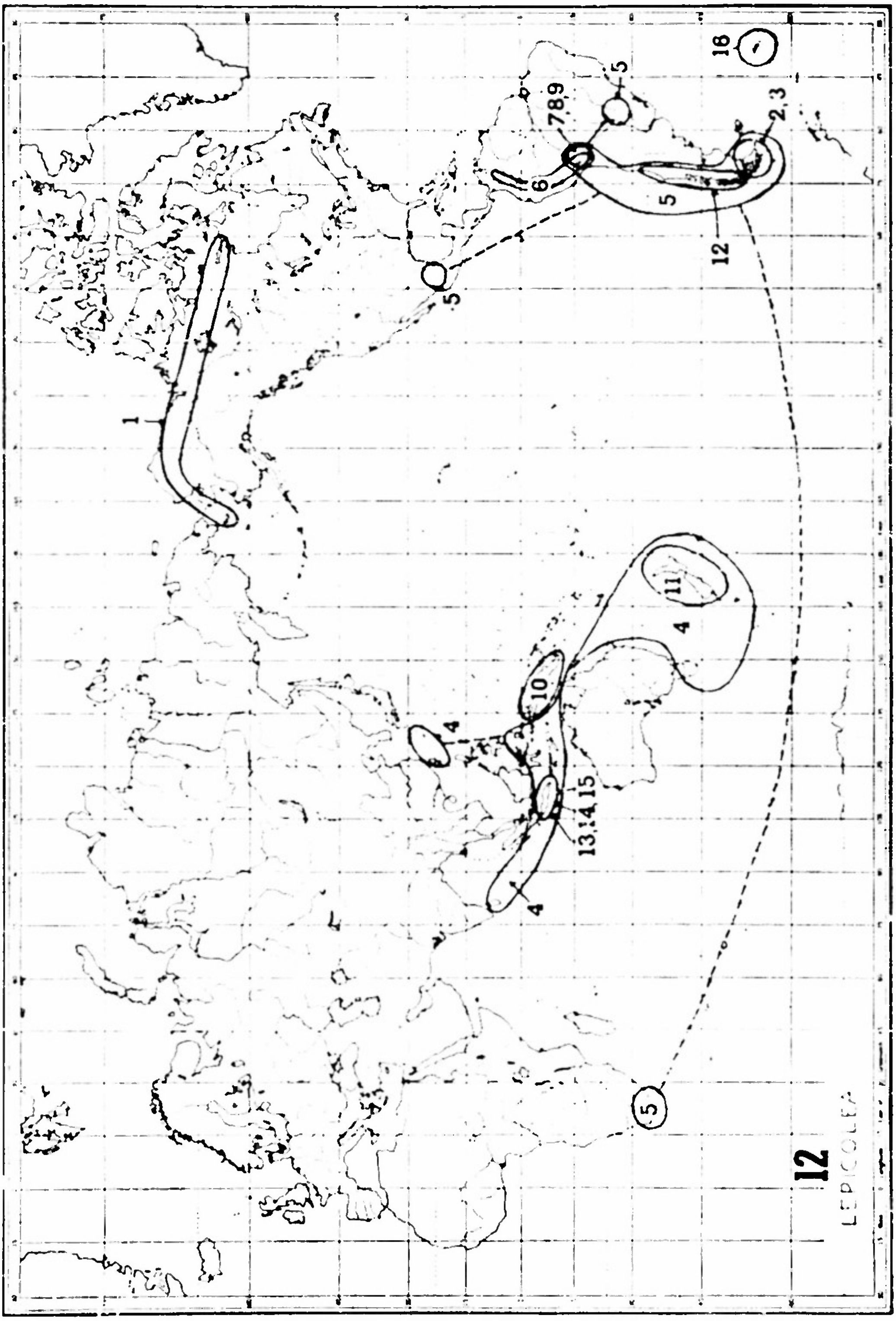
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SOME ASPECTS OF THE ECOLOGY OF THE BARROW GROUND SQUIRREL, *CITELLUS PARRYI BARROWENSIS**

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Exploratory field work was conducted by the author from the Arctic Research Laboratory base at Point Barrow, Alaska, from 12 July to 28 August 1951. Ground squirrel colonies were studied at three different localities in U.S. Naval Petroleum Reserve No. 4: (*a*) in the vicinity of the Meade River, 46 miles south of Point Barrow (July 17–25), (*b*) an abandoned oil camp at East Oumalik, approximately 110 miles south of Point Barrow (July 31–August 7), and (*c*) Teshekpuk Lake, approximately 115 miles east of Point Barrow (August 18–24). The following summer the author and two graduate students from the University of Southern California, Edward T. Roche and Roy G. Robinson, Jr., concentrated their observations on one particular ground squirrel colony located on the south bank of the Meade River. Either one or two observers were present continuously from 7 May to 6 October 1952. Mr. Robinson observed from May to August, the author from June to August, and Mr. Roche from July to October.

The field studies were supplemented by laboratory observation of a group of 10 captive squirrels which was brought to the University of Southern California by the author in the fall of 1951 and which increased in number to 25 as a result of breeding experiments carried on the following spring. An almost complete life history of the Barrow ground squirrel has been obtained, and work scheduled for the summer of 1953 will provide the additional material necessary to bring the study to completion.

METHODS

The sandy riverbank dunes selected for observation were restricted by the Meade River to the north, the flat tundra to the south, and by a flattening and narrowing of the dunes east and west so they were separated from the other near-by dunes similarly suited for habitation by ground squirrels. Within this area, approximately a mile in length and a half mile in width, 21 trapping stations were set up, each being marked by a red flag on a 3-foot numbered stake. Trapping operations continued from May through September, although no previously untrapped squirrels were caught after August. Each animal was weighed and measured when captured and pertinent in-

* Contribution No. 1953-9 from the Arctic Research Laboratory, presented in partial fulfillment of Contract Nonr-377(00) with the Office of Naval Research.

formation as to genital condition, presence of parasites, etc., was carefully noted. The animal was then toe-clipped and released. An attempt was made to reduce disturbance of the colony to a minimum, and there was no indication that the animals became trap-shy, for the same individuals were captured again and again, one being taken 15 times in 4 days.

In addition to the data obtained through the capture and recapture of marked animals, the investigators' visual observations on habitats and behavior were recorded, food plants collected and identified, burrows excavated and mapped, nests studied, and wide use was made of recording instruments to obtain measurements of temperature, barometric pressure, humidity, and light intensity. Manual recordings were made of wind directions and velocities, and other information of possible significance in the total life history of the arctic ground squirrel was obtained.

DISTRIBUTION AND HABITAT

The race *Citellus parryi barrowensis* represents the most northerly extension of the genus *Citellus* in continental North America, and its adaptation to the rigors of the arctic environment is of particular interest.

One of the first problems of adaptation for a fossorial animal is that of finding a suitable habitat in the frozen tundra region. The ground of the arctic slope is permanently frozen to a depth of many hundred feet, and only during the brief summer does it thaw superficially to a depth of a few inches to a few feet. To a genus such as *Citellus*, which in California may burrow to depths of 5 feet or more, this high permafrost table greatly restricts the area of possible burrow sites. Also, though areas of suitable habitat for fossorial animals are quite widely distributed over the arctic slope, they are not continuous, appearing as somewhat isolated "islands," each being relatively small in size. These islands are areas of good drainage and a relatively low permafrost table, such as river sandbanks, lake banks, tundra ridges, hillocks, and other raised areas with a sandy or partially sandy soil. The burrows of the ground squirrels are located near the top of these drained areas; thus the animals avoid the possibility of flooding during the spring thaw. Although these isolated islands suitable for habitat are found almost to the Arctic Ocean, the flat, wet, coastal plain must be regarded as a somewhat marginal habitat for *Citellus parryi barrowensis*. Its presence in a locality can be taken as indicative of an area of relatively low permafrost table on the arctic slope.

ACTIVITY

The first squirrel to be observed above ground was seen on May 8, the day after the first investigator arrived at the Meade River study site. Although this was possibly not the very first appearance of an animal for the year, it was doubtless one of the earliest appearances, for at this time the ground was still covered with snow which varied in thickness from several inches to several feet, acording to the underlying ground contours and snow drift. The ground squirrels can tunnel from underground burrows through the snow, bringing up little of the frozen soil. Their first appearances above ground, however, are restricted to the immediate vicinity of the burrow, as was evidenced by tracks noted on the eighth. These indicated that the animal never went more than 4 feet from the burrow entrance on its first foray outside the tunnel. At the time of emergence the squirrels are quite sensitive to climatic changes, and a bad day of cold, snow, or wind will cause them to remain beneath the surface. Tunnels uncovered under the snow indicate that the animals are sometimes active beneath the snow cover. As the season progresses the animals are more frequently seen above the snow, and they wander farther and farther from the home burrow. By the thirteenth of May one individual was observed to travel 165 yards from the point of its emergence. Little active foraging can be observed at this time, although the squirrels have been seen to scratch at the snow and even to take a mouthful of it, as if to secure water. Stocks of seeds and other vegetable materials were noted to remain in the hibernation nest from the previous year, and the animals probably survive through the first days of emergence on these stored stocks.

At this time of year the contrast of a dark figure moving against the snowy background attracts the attention of the ground squirrels and makes them harder to approach and to observe than at any other time. Until about the twenty-second of May the squirrels maintain a complete silence when active in the field, the only sound heard by an investigator before this date came from a captive animal. By this time, however, they are seen to chase each other and to run from one burrow to another. They become more vocal during these activities. Fighting was noted May 23, the vanquished animal leaving both blood and fur at the scene of the encounter. That fighting is common is attested to by the skins of captive animals which are frequently noted to be perforated with holes, sometimes as many as a dozen.

Although final analysis of the environmental data obtained during the summer of 1952 has not yet been completed, several general statements may be made concerning the ground squirrels' response to environmental changes. Once the winter snow has begun to melt, the inclement arctic weather appears to limit the activity of the squirrels very little, and animals were observed above the surface on days when the temperature was as low as 22° F. Only unusually severe downpours of rain restricted the squirrels to their burrows. They were frequently observed foraging during rains and were often captured with their pelage soaked by rain and drip from the vegetation. Other unfavorable weather conditions such as severe winds also failed to keep them in their burrows. The squirrels seem to be impelled by the necessity of making the most of every day of their brief summer season, and, as noted, only extremely unfavorable weather keeps them from their normal activities above ground.

Light intensity is believed to exert considerable effect upon the activity of the ground squirrels. Despite the fact that from the second week of May to the first week of August the sun is above the horizon 24 hours a day, the intensity of its light diminishes during what would normally be the night hours at lower latitudes. The ground squirrels' response to this varying intensity is seen in their diurnal rhythmicity, their longest activity period noted beginning at 0410 and ceasing at 2130. During the spring and fall the animals appear above ground somewhat later than this and retire beneath the surface earlier, the maximum time above ground being spent in July and August.

The adult squirrels begin to enter hibernation early in September, and none was trapped after the middle of September. The month prior to entering hibernation is spent chiefly in enlarging burrows, gathering grasses, lichens, and other available materials for making nests, and storing as much food as possible in the nest. By August 22 one had stored 1,967 grams of food.

Owing to the permafrost the ground squirrels' burrow systems are shallow as compared with those made by *Citellus beecheyi* in California. On high, level ground the burrow systems do not exceed a depth of 3 feet below the surface and are usually less than this. The deepest burrow system observed reached a depth of 8 feet; however, it was located on the top of a lakeside bank, where thawing was possible not only from the top but from the sides as well. The entire system was near the edge of the bank and did not extend beyond the lateral thaw line. Other burrows were observed which extended downward to permafrost with their nesting chambers located only a few inches above the permafrost table. Many of the burrow systems are extensive, reaching tunnel lengths of 68 feet and being excavated on several levels. These colonial burrows are used year after year and upon destruction of part of a system, the squirrels extend the remaining part or parts. Other burrows of a simpler pattern are scattered throughout the habitat. These serve as temporary protected nesting places. When destroyed they are not rebuilt.

The temperature within the burrows remains far more constant than that of the surrounding environment. Records taken in the summer of 1952 showed that the burrow temperature began increasing slowly in the spring until it reached a maximum of 44° F., on August 12, then slowly decreased. From May 28 to October 3 the variation in burrow temperature was only 22° F., while the outside variation during the same period was 60° F.

GROWTH AND DEVELOPMENT OF THE YOUNG

In the field the first positive mating was observed on May 24. Laboratory observation at the University, during which one male sired a litter from each of four females, indicated that the males were polygamous. In the field mating occurred only during the month of May, the breeding season being less than three weeks in duration. This is an important limitation, for the young must be produced early enough to enable them to reach the stage of development necessary for entering hibernation in October and surviving during the long winter. Under these conditions more than one litter a year would be an impossibility. In June, after gestation of approximately 25 days, litters of from 5 to 10 were born. Any young which could not be taken care of because of either insufficient mammary development or for other reasons were soon eaten by the mother. The largest litter raised to maturity was nine, one additional newborn having been eaten.

The young are born naked and blind, their eyes opening approximately 20 days after birth. The integument darkens with pigment at about the fourth day, beginning in the head region and extending over the entire dorsum by about the sixth day. Hair appears at approximately the eighth day, and its growth is rapid, the spotted dorsum typical of the adult becoming apparent within the second week.

The brooding female ground squirrel will care for her own young only, so an observer may be sure that any young caught at a burrow site before the young begin to leave their home areas belong to that litter. A demonstration of this fact occurred when a young squirrel from one litter was introduced into another litter of animals of almost the same size, weight, and age, and was found dead and partially eaten the following morning. It had been singled out by the female as an intruder.

The young squirrels grow so rapidly that in less than two months they have approximated adult weight. For example, one laboratory litter of 9 averaged 10.8 grams at birth, 141.2 grams on the twenty-fourth day, 463.3 grams on the thirty-eighth day, and 785 grams by the fifty-third day. By September, just prior to entering hibernation, the squirrels may have attained a weight of 1,187 grams.

The young do not emerge from the natal burrow until July, about one month after birth, at which time they begin to forage on plants near the burrow entrance. They stay very close to the home burrow during their first week above ground, but within another week they are found at increasing distances from the burrow, and by August they are found as far as two miles away.

After about 12 days above ground the young squirrels abandon their natal burrow, either taking shelter in an abandoned burrow nearby or digging a new one of their own. As the young of the year increase the population of an area approximately three to five times, it is obvious that the limited number of burrow sites and availability of food must force some of the squirrels to move to new areas or to utilize poorer sites and less food. These latter alternatives may be major factors in limiting population size, for the ground squirrel shows no cyclical build-up in numbers as does the lemming, and predation is negligible. In July 1952, for example, the excavation of two young squirrels' shallow burrow in the low, wet tundra area roughly 100 yards from their natal burrow revealed a nest of paper, moss, and lichens. Doubtless the animals could not have survived the rigors of the arctic winter had they hibernated in such a nest. Other young who attempt to winter in burrows of inadequate depth or ones which lack drainage or good location, together with young who have failed to store sufficient food to provide for the period of emergence in the spring, unquestionably face a similar fate and do not survive to form part of the breeding population the following spring.

In the field the young of the year were observed to remain active for a period of several weeks after the last adults had ceased to be trapped. This prolongation of their time above ground is understandable in view of their necessity to prepare burrows, store food, and to gain sufficient weight to enter hibernation. The entire reproductive and developmental cycle of the ground squirrel seems to be attuned to this end—the mating soon after spring emergence, the short gestation period, the rapid growth, and early assumption of independence by the young.

By October all surface activity has virtually ceased. The last squirrel was thought to have been seen above ground on October 2. However, before the last observer left the area on October 6, two additional animals had been noted. In the literature (Howell, 1938) there is some indication that the squirrels may periodically come to the surface during the time they are supposed to be in hibernation, and they have been recorded above ground on rare instances even in December.

FOOD

A complete list of the food plants eaten by the arctic ground squirrel would include nearly all the plants of the arctic slope. The squirrels eat not only leaves, but seeds, flowers, stems, and roots of various plants. *Douglassia* roots, *Polygonum* seeds, *Arctostaphylos* leaves, and *Oxytropis* flowers are indicative of the variety of plant foods utilized by the squirrels. In addition to their normal herbivorous diet, the squirrels will readily eat any meat they find, consuming even the discarded carcasses of other ground squirrels and lemmings which had been prepared as study skins. One bold individual ate the fat from the nose and ears of a caribou hide stretched out to dry, and several study skins were damaged in quests for scraps of meat. Camp food similarly proved attractive to these omnivorous creatures, and they would enter the investigators' tent to steal bread, prunes, beans, and any other items they happened across.

CONCLUSIONS

Life is possible for the Barrow ground squirrel on the arctic slope only because it utilizes the small, isolated habitats on the tundra which allow the pursuit of fossorial habits. Within these habitats the animals dig relatively shallow burrows and build large nests which give a maximum amount of insulation from the frozen earth. Early resumption of activity in the spring, even before the snow has begun to disappear, allows early mating. The short gestation period, coupled with rapid growth of the young, permits the newborn animals to prepare for the winter in a span of less than four months. The animals avoid the rigors of winter by entering hibernation no later than October, having utilized the summer months without taking advantage of the full 24 hours of daylight available for activity during most of the summer season. An almost omnivorous diet allows them to take full advantage of the plants and available animal food, and storage of food makes it possible for them to assume early spring activity. The Barrow ground squirrel has utilized all of these mechanisms to invade and successfully remain on the arctic slope.

NOMENCLATORIAL NOTE

This brief mention of the taxonomic status of *Citellus parryi* is included to clarify some of the difficulties which have arisen concerning the variety of names applied to this form. This confusion of names has led to uncertainty in the minds of certain workers (Wilber and Musacchia, 1950) as to its correct nomenclatorial status.

J. A. Allen, in writing of the arctic ground squirrel (1877), stated that the species was first noted by Forster in 1772. In the original description the trivial name *parryii* was applied by Richardson (1825) in honor of the English arctic explorer, Captain W. E. Parry (rather than the well-known American explorer, Admiral R. E. Peary, as is commonly believed). B. R. Ross (1861) employed the name *Arctomys Kennicottii*. Preble (1908) designated the race as *Citellus parryi kennicotti*, treating the *Spermophilus barrowensis* of Merriam (1900) as a synonym. This racial designation was followed by Anderson (1924), Hall (1929), and Dufresne (1946), although Howell (1938), considering a larger series of animals than that available to Preble, revived Merriam's name and designated the race *Citellus parryii barrowensis*. In so revising the group Howell disposed of the name *kennicottii* in synonomy. A recent decision dropping the final *i* in male patronymics leaves the racial name *Citellus parryi barrowensis*. Recently, however, Quay

(1951) indicated that Ognev found that the formerly overlooked name *Citellus undulatus* Pallas (1778) should be considered the correct species epithet for the group. Previously, Hershkovitz (1949) proposed a revival of the genus *Spermophilus* of Cuvier to replace *Citellus.* However, until a competent revision of the group includes these latter two names, it is the intent of this author to continue to use the currently employed *Citellus parryi barrowensis.*

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