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To the Graduate Council:

I am submitting herewith a thesis written by Edward Ernst Cooper Clebsch entitled "The Summer Season Climatic and Vegetational Gradient Between Point Barrow and Meade River, Alaska." I recommend that it be accepted for twelve quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Botany.

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Dean of the Graduate School

# THE SUMMER SEASON CLIMATIC AND VEGETATIONAL GRADIENT BETWEEN POINT BARROW AND MEADE RIVER, ALASKA

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

by

Edward Ernst Cooper Clebsch

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# INTRODUCTION

The purpose of the present investigation was to examine the summer season climatic gradient between Point Barrow and Meade River, Alaska, and to determine to what degree the gradient is reflected in the vegetation of the area. The area under consideration includes the northernmost portion of the Arctic Coastal Plain of Alaska and extends from 70° 25' to 71° 25' north latitude and from 156° 30' to 157° 30' west longitude. All points in the area lie within thirty miles of the Arctic Ocean, and Point Barrow itself extends some four miles out into the ocean as a narrow gravel spit.

The portion of the Arctic Coastal Plain Province under consideration is relatively flat, with a maximum local relief of approximately fifty feet developed along major rivers and along sections of the coast-line. It is covered in large part by unconsolidated sediments of the Gubik Formation (Pleistocene) which lie unconformably on sediments of the Colville Group (Cretaceous). The latter sediments are locally exposed in the Meade River area. Both active and stabilized sand dunes are locally well developed along inland portions of the major watercourses. On the river terraces and on the upland between rivers there are well developed systems of polygonal ground, and many of the low center polygons are filled with water or ice the entire year. Near the coast in the region of Barrow Village there are several well-preserved uplifted beach ridges which resemble the present-day spit leading to Point Barrow. Shallow northwest-southeast oriented lakes are very abundant on the landscape and vary from less than one to many acres of surface area.

The climate of the region is deep within the boundaries of the tundra climate type of the standard classifications, the average temperature of the warmest month being below fifty degrees Fahrenheit but above thirty-two degrees Fahrenheit. Most of the days are either cloudy or partly cloudy, with very few days during the "summer" months (June, July, August, September) being entirely clear. The only U. S. Weather Bureau station in the area is at Barrow Village, within a mile of the coast, and its records for the past thirty years show a very high fog frequency and a high degree of cloudiness. Recorded precipitation is low, the annual average for twenty-seven years being 4.2 inches. Over half of that amount falls as rain during the four summer months.

The area lies well north of the forest-tundra ecotone and is thus covered with arctic tundra vegetation. It is primarily a grassland in aspect but contains a highly variable admixture of low shrubs and cryptogams.

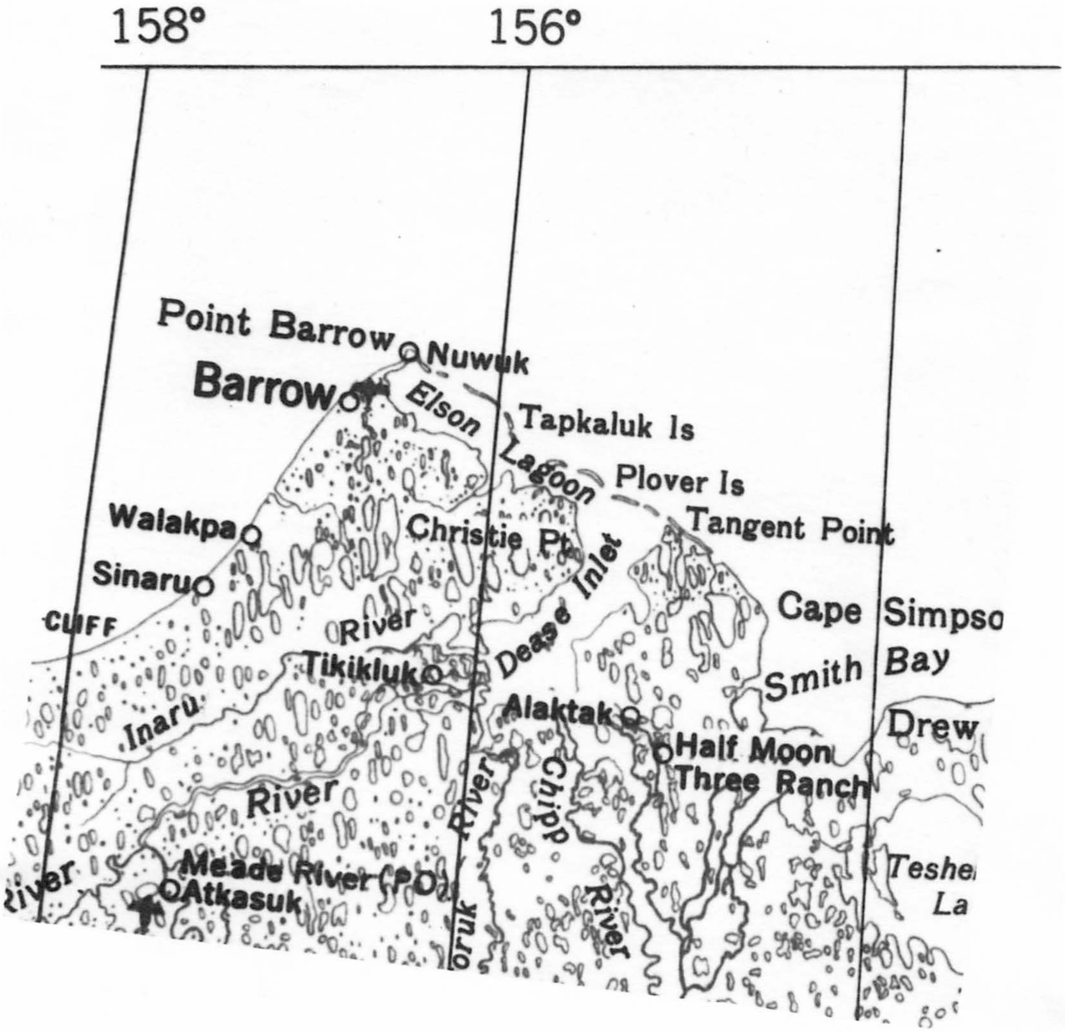


Figure 1. Map of the northern tip of Alaska showing location of stations used in this study.

## LITERATURE SURVEY

The nature of botanical research in Arctic Alaska has until recently been descriptive and qualitative rather than analytical and quantitative. Before the development and improvement of tracked vehicles during World War II and the extended use of them in oil and gas investigations in northern Alaska following the war, overland travel was decidedly restricted during the growing season. Most of the plant collections were made either at or near the coast or, in later years, in the vicinity of places easily accessible by light aircraft. Botanical investigation flourished with the increased interest in the area on the part of the military authorities of the United States. Tundra plant communities have been described from various regions and many localities in Arctic Alaska by Spetzman (1951), Churchill (1955) and Hanson (1950, 1951, 1953). The comprehensive taxonomic and phytogeographic work of Hultén (1941-1950) has been of great value to investigators in the area. Plant names in this thesis are those of Hultén.

The only known available publication which deals with the microclimatic relations of Alaskan Arctic tundra plants is that of Bliss (1956). The effects of certain climatic elements on the development of plants of Greenland has been dealt with in exhaustive detail by Sørensen (1941). M. E. Britton and R. E. Shanks (personal communications) have gathered much information about the microclimates of the

Barrow region in order to better understand the energy relations underlying the operation of the ecosystem in the area. Mather and Thornthwaite (1956) have begun investigation of the microclimates in the Barrow region. Conover (1953) has investigated the climatology of the Arctic Slope of Alaska, but his report has not yet been released from military classification. It is likely that additional literature dealing with the climatology of the Arctic may be found in the classified files. The most comprehensive monograph on climatic conditions in the north higher latitudes available at present is that of Petterssen, Jacobs, and Haynes (1956). Hare (1956) has briefly reviewed the climates of the American Arctic and Subarctic.

Evapotranspiration is the process by which water moves from the soil to the atmosphere. It is important ecologically because it is the link in the hydrologic cycle through which vegetation exerts its influence. Its fundamental economic importance is attested to by the literature dealing with water problems (Blaney and Muckel 1955, Gilbert and von Bavel 1954, Harrold and Dreibelbis 1951, Sanderson 1948b, 1950, Thornthwaite 1951, Thornthwaite and Mather 1955a, 1955b). Evapotranspiration involves physiological as well as physical processes, and thus is of interest to plant physiologists and ecologists as well as climatologists. It involves the amount of energy received from the sun and the forces which hold water in the soil. The first varies principally with the time of day, season of the year, and latitude; the second with the wetness of the soil, the soil temperature, and the concentration of the soil solution. The complexity of the process is reflected in the labyrinthine literature which deals with various phases of it (Lull 1953). Since Thornthwaite (1948) presented a climatic classification system based upon the single parameter of potential evapotranspiration, interest in the process has grown tremendously.

A closer union between the topoclimatological approach of Thornthwaite (1953) and the "site" concept of foresters has been suggested (Thornthwaite and Hare 1955), and had already been approached by Harrold and Dreibelbis (1951). However, publications describing the use of evapotranspiration measurements as an indication of climatic differences over short distances have not been encountered in the literature.

Sanderson (1948a, 1948b, 1950) has done much to increase the knowledge of the role of evapotranspiration in the climatology of Canada and particularly in the climatology of Arctic Canada. Her data indicate that over eighty-eight per cent of the thermal efficiency is concentrated during the summer period in northern Canada, and that the percentage figure decreases as one proceeds southward in eastern Canada. The average annual potential evapotranspiration follows a similar trend since it is essentially an expression of thermal efficiency. In extreme northwestern Canada the average annual potential evapotranspiration is between 5.61 and 11.22 inches. In the western part of the country the picture is complicated by the presence of extensive mountain ranges.

## METHODS

Five points in the defined area were selected as station sites. The northernmost of these was established on the eastern (lagoon) side of the spit which forms Point Barrow, near the abandoned Eskimo village site of Nuwuk. A second station was established on the foreslope of the most northerly of the series of beach ridges previously mentioned. This station was approximately six miles southwest of the Nuwuk station, two thousand yards west-southwest of the Arctic Research Laboratory, and two thousand five hundred yards from Elson Lagoon. The third station was established in the vicinity of the South Barrow Test Well Number Three (hereinafter referred to as South Barrow Three), eleven miles south of the Beach Ridge station and fifteen and one-half miles south-southwest of the Nuwuk station. The fourth study area was on the Inaru River, twenty-three miles south-southwest of South Barrow Three and seventeen and one-half miles west of the Arctic Ocean. The southernmost station was established near the village of Meade River, thirty miles south-southwest of the Inaru River site and twenty-eight miles from the nearest point on the Arctic Ocean. The airline distance between the two extreme stations is sixty-seven miles. Thus the stations were at irregular intervals along a northeast-southwest line, and each of the stations in the southward progression was progressively farther removed from the maritime influence of the Arctic Ocean (Figure 1).

The Inaru River station was visited only once and was thus not used as an installation for climatological data or phenological records. Isolation of the spot prevented more than one visit because of the limited availability of air transportation and the danger of mechanical breakdown of "weasels" too far from base for recovery and repair during the field season. Overland travel during the summer was either on foot or in tracked vehicles, and rough polygonal ground made such travel very difficult. Station readings were therefore made at somewhat irregular intervals.

Temperature measurements were made with Taylor Sixe's maximum-minimum recording thermometers which had been calibrated against American Society of Testing Materials instruments. The thermometers were mounted about four inches from the soil surface in shelters constructed from two convex sheets of aluminum separated by about one-half inch. The shelters were oriented in a north-south direction at each station and the thermometers inserted with bulb ends to the north. The dimensions of the shields and the orientation of shelters and bulbs were such that the instruments were infrequently exposed to direct solar radiation, and then only at low northerly sun angles.

Precipitation measurements were made in the following manner. An open number ten can, six inches in diameter and seven inches deep, was sunk into the soil to the depth at which the lip of the can was even with the soil surface. A thin layer of fuel oil was left in the bottom of the cans after each reading to reduce water loss by evaporation to a minimum. Field readings were made in a graduated cylinder and later converted to depth equivalents.

Evaporation measurements were also made in number ten cans which had been sunk into the soil. Periodic readings were made by weighing the cans to the nearest tenth of an ounce and converting the weight measurements to depth equivalents.

For the measurement of evapotranspiration the same kinds of containers were used, with this modification: the end of the can which had not been removed was perforated with about a dozen small holes to allow for drainage of water. Readings and conversions were as with the evaporimeters. In order to make the evapotranspirometers as uniform as possible all of the cans were filled with material from the same locality. Vegetation covering the area was a uniform and almost pure stand of *Dupontia fischeri* R. Br. Sod plugs were cut to conform to the inside diameter of the cans and were trimmed from the bottom so that the top of the sod reached the tops of the cans evenly. By using uniform materials in the evapotranspirometers and by using three evapotranspirometers per station it was hoped that differences in soils and vegetation among the stations might be eliminated as factors governing the rate of water loss by evapotranspiration.

It is recognized that transfer of water in vapor form into the precipitation gages, evaporimeters, and evapotranspirometers, and subsequent condensation of that water vapor on soil particles and on the sides of the open containers, may have added moisture to all cans embedded in the soil. Condensation on the sides of the open containers was observed, but there was no attempt to measure the amount. If it is assumed that the amount of moisture thus added to all cans was equal, then the estimates of evaporation and evapotranspiration, computed as differences from precipitation, would not be affected. Interception of fog and mist and condensation on above-ground plant parts are, among these instruments, unique to the evapotranspirometers, and would have the effect of depressing the estimate of evapotranspiration by an undetermined and presumably small amount. It might therefore be more accurate to regard these estimates as net evapotranspiration.

The "Early Alaska" variety of garden peas was selected for phenological observations. Single garden plots were established at three of the stations--Nuwuk, South Barrow Three, and Meade River. Two plots were established at the Beach Ridge site. At each of the stations used for these observations the seedbed was prepared by removing all living vegetation and then working up the soil with a mattock. Three ten-foot rows were planted one foot apart with the seeds placed at one inch intervals. Phenological scoring, where possible, was done according to the directions of Higgins (1952) at the end of the observation periods.

Data for use in vegetation analysis were gathered by listing the species present in two inch diameter circles with the centers of the circles spaced at four inch intervals along a line fifty feet or more in length. This method was devised for use in rapid reconnaissance vegetation sampling and permits the use of simple frequency tabulations as an index to the distribution and association of species. It also permits the use of relative frequency (frequency of a single species over the sum of frequencies of all species) as a quantitative basis for the determination of dominant species.

## DISCUSSION OF RESULTS

### Temperature

It was anticipated before the initiation of this study that period maximum and minimum temperatures would offer very little information concerning the thermal regime of the area, but it was felt that some attempt at measurement of temperatures with simple instruments should be made because of the likelihood that temperatures were directly or indirectly limiting to plant growth in the area, and because of its relationship to insolation, the most important physical variable influencing the evapotranspiration process.

Certain salient points should be noted from the data presented in Tables I and II. Temperatures at the U. S. Weather Bureau station at Barrow, four miles southwest of the Beach Ridge station, were recorded on standard instruments in a standard instrument shelter. All others were recorded as described in the Methods section. A second temperature and phenology station was established on the crest of the same beach ridge used for other measurements previously mentioned. This second station was in Arctic Brown soil (Tedrow and Hill 1955) and was approximately two hundred yards from the first station. The Arctic Research Laboratory thermometer was installed only a few hundred feet southeast of the Laboratory in a spot relatively well sheltered from onshore winds. Certain of the records from Meade River were made by cooperative

## TABLE I

DEVIATIONS OF PERIOD MAXIMUM AND MINIMUM TEMPERATURES (°F.) FROM U. S. WEATHER BUREAU (BARROW STATION) RECORDS JUNE AND JULY 1956

| Date | Barrow Max./Min. | Nuwuk | Arctic Res. Lab.[a] | Beach Ridge (E-T Station) | Beach Ridge (Arctic Brown Soil) | South Barrow Three | Meade River |
|---|---|---|---|---|---|---|---|
| June 29 | 36/32 | start | | | | | |
| 30 | 35/32 | | | | | | |
| July 1 | 57/32 | | | | | | start |
| 2 | 50/32 | | | | | | ?/+8.5 |
| 3 | 40/31 | | | | | | ?/+4 |
| 4 | 41/31 | | | | | | |
| 5 | 51/29 | | | | | | ?/+1 |
| 6 | 44/32 | | | | | | |
| 7 | 36/31 | -1.5/+2 | | | | | |
| 8 | 50/30 | | | | | | |
| 9 | 40/31 | | | start | | | |
| 10 | 66/39 | | | | | | |
| 11 | 41/33 | | | | | start | |
| 12 | 51/34 | | | | | | |
| 13 | 39/30 | | | | | | |
| 14 | 57/33 | 0/+0.5 | | | | | |
| 15 | 34/31 | | | | | | |
| 16 | 35/30 | | | | | | |
| 17 | 39/30 | +2/-0.5 | | +4.5/+3 | | | |
| 18 | 33/27 | | | | | | ?/-2? |
| 19 | 33/26 | | | | | | |
| 20 | 37/26 | | | | start | | |
| 21 | 43/26 | | | | | | |
| 22 | 49/29 | | | | | | |
| 23 | 43/30 | | | | | | |
| 24 | 49/29 | -6/-1 | | +3/+3 | | | |
| 25 | 60/36 | | | | | | |
| 26 | 62/50 | | | | | | |
| 27 | 60/43 | | | | | | |
| 28 | 53/39 | | | | | | |
| 29 | 41/31 | | | | | | |
| 30 | 43/34 | | | +4/+4 | +1.5/+6.5 | | |
| 31 | 36/31 | +0.5/+1.5 | | | | | |

[a]Record not begun until August 2. See following page.

TABLE II

DEVIATIONS OF PERIOD MAXIMUM AND MINIMUM TEMPERATURES (°F.) FROM U. S. WEATHER BUREAU (BARROW STATION) RECORDS AUGUST 1956

| Date | Barrow Max./Min. | Nuwuk | Arctic Res. Lab. | Beach Ridge (E-T Station) | Beach Ridge (Arctic Brown Soil) | South Barrow Three | Meade River |
|---|---|---|---|---|---|---|---|
| Aug. 1 | 40/30 | | | | | +18/+1.5 | |
| 2 | 48/33 | | +2/0 | | | | |
| 3 | 41/30 | | +1/+2 | | | | |
| 4 | 37/29 | | +8/+0.5 | | | | |
| 5 | 53/33 | | -2/0 | | | | |
| 6 | 52/31 | | -1/+1 | | | | |
| 7 | 40/28 | -7/+1 | +2.5/0 | +1/+4.5 | +5/+0.5 | | |
| 8 | 33/30 | | +4/+2 | | | -1/+1 | |
| 9 | 32/28 | | +6/+1 | | | | |
| 10 | 31/26 | | +6/+1 | | | | |
| 11 | 30/26 | | +3/0 | | | | |
| 12 | 32/29 | | +3/+0.5 | | | | |
| 13 | 33/27 | | +6/+2 | | | | |
| 14 | 32/27 | +6/-1 | +8/+1 | +6/+3 | +32[a]/-1 | | |
| 15 | 35/27 | | +14/+3 | | | +4/0 | |
| 16 | 35/31 | | +14/0 | | | | |
| 17 | 36/33 | | +3/0 | | | | |
| 18 | 39/33 | | +11/0 | | | | |
| 19 | 36/33 | | +9/+1 | | | | |
| 20 | 35/31 | | +2/+2 | | | | |
| 21 | 33/27 | +1/+1 | +4/+1 | +6/+5 | +3/+1 | | ?/0? |
| 22 | 28/23 | | +11/+1 | | | | |
| 23 | 32/22 | | +17.5/0 | | | | ?/-1 |
| 24 | 35/28 | | +13/-1 | | | | |
| 25 | 31/25 | | +6/+0.5 | | | | |
| 26 | 30/25 | | +6.5/0 | | | | |
| 27 | 30/25 | | +5/0 | | | | |
| 28 | 30/23 | +3/-1 | +6/+2 | +10/+3 | +5/-1 | | |
| 29 | 27/21 | | +5/+4 | | | +8.5/-2 | |

[a]Possibly due to a reading error.

observers and their reliability is open to considerable question.

Temperatures from all stations deviated appreciably and irregularly from those of the Weather Bureau station. On the foreslope of the Beach Ridge the extreme temperatures were higher than those of the Weather Bureau, while those on the crest of the ridge varied irregularly. Extreme temperatures at South Barrow Three were even more variable than those at the Beach Ridge station. The data presented here support the conclusion that weekly-period extreme temperatures are an inadequate basis for inferences concerning the temperature regime of the region.

## Precipitation

The two available records of daily precipitation in the area under investigation are those of the U. S. Weather Bureau at Barrow and Mather and Thornthwaite (1956), both of which are presented in the latter report. Precipitation measurements were made by the latter in 10.6 cm. diameter cans which were sunk into the soil with the lip of the can protruding about one cm. After they had made precipitation measurements in several of these instruments in a very small area and found their results to be highly variable, they concluded that the method did not give an adequate sample of the precipitation of the area and reverted to the use of a standard instrument. The Britton Manor site at which they made their measurements was approximately two miles northeast of the U. S. Weather Bureau station, within three hundred yards of the ocean and in an area of high center polygons with considerable microrelief, the individual polygons being up to three feet high. Since much of the summer precipitation in the region is in the form of very fine droplets which may be moved laterally over long distances even near the ground, it is felt that microrelief effects on turbulence may be in large part responsible for the disparate measurements of Mather and Thornthwaite. Proximity of the ocean and accompanying onshore winds may be related to the small total amount of precipitation recorded by those investigators. In addition, they made no attempt to minimize evaporation from their instruments.

The standard Weather Bureau practice concerning trace amounts of precipitation is to record a trace if any amount of precipitation is seen falling in the vicinity. The Mather and Thornthwaite records do not show trace amounts until after August 10.

Records from the stations used in the present study are compared with official U. S. Weather records and those of Mather and Thornthwaite in Tables III and IV. It is apparent from the total precipitation figures presented in Table IV that there was an increase in summer season precipitation southward and inland from Nuwuk. Apparently the highest rate of increase was very near the coast, with the rate of increase dropping off farther inland. It is significant that some

TABLE III

DEVIATIONS OF PERIOD ACCUMULATIONS OF PRECIPITATION (CM.)
FROM U. S. WEATHER BUREAU (BARROW STATION)
RECORDS JUNE AND JULY 1956

| Date | | Barrow Station | Britton Manor[a] | Nuwuk | Beach Ridge | South Barrow Three | Meade River |
|---|---|---|---|---|---|---|---|
| June | 29 | 0.20 | -0.20 | | start | | |
| | 30 | T | -T | | | | |
| July | 1 | 0.0 | 0.0 | | | | |
| | 2 | 0.0 | 0.0 | | | | start |
| | 3 | 0.08 | -0.08 | | | | +0.40 |
| | 4 | 0.53 | -0.53 | | | | |
| | 5 | T | -T | | | | -0.11 |
| | 6 | 0.66 | -0.66 | start | | | |
| | 7 | T | -T | | | | |
| | 8 | T | -T | | | | |
| | 9 | T | -T | | | | |
| | 10 | T | -T | | +0.34 | | |
| | 11 | T | -T | | | start | |
| | 12 | 0.66 | -0.28 | | | | |
| | 13 | T | -T | | | | |
| | 14 | T | -T | -0.77 | | | |
| | 15 | T | -T | | | | |
| | 16 | T | -T | | | | |
| | 17 | 0.74 | +0.70 | +0.70 | +1.20 | | |
| | 18 | T | -T | | | | +0.48 |
| | 19 | T | -T | | | | |
| | 20 | 0.0 | 0.0 | | | | |
| | 21 | 0.0 | 0.0 | | | | |
| | 22 | 0.0 | 0.0 | | | | |
| | 23 | T | -T | | | | |
| | 24 | T | -T | +0.02 | +0.01 | | |
| | 25 | T | -T | | | | |
| | 26 | 0.10 | ---- | | | | |
| | 27 | 0.48 | -0.17 | | | | |
| | 28 | T | ---- | | | | |
| | 29 | 0.15 | -0.02 | | | | |
| | 30 | 0.23 | -0.23 | | | | |
| | 31 | T | -T | -0.04 | +0.58 | | |

[a]Data of Mather and Thornthwaite (1956).

TABLE IV

DEVIATIONS OF PERIOD ACCUMULATIONS OF PRECIPITATION (CM.) FROM U. S. WEATHER BUREAU (BARROW STATION) RECORDS AUGUST 1956

| Date | Barrow Station | Britton Manor[a] | Nuwuk | Beach Ridge | South Barrow Three | Meade River |
|---|---|---|---|---|---|---|
| Aug. 1 | T | ---- | | | +1.35 | |
| 2 | T | +0.28 | | | | |
| 3 | 0.11 | -0.11 | | | | |
| 4 | T | -T | | | | |
| 5 | T | ---- | | | | |
| 6 | 1.30 | -0.24 | | | | |
| 7 | 0.23 | -0.04 | +0.29 | +0.57 | | |
| 8 | 0.02 | ---- | | | +0.51 | |
| 9 | 0.05 | +0.10 | | | | |
| 10 | 0.05 | -0.05 | | | | |
| 11 | T | -T | | | | |
| 12 | T | -T | | | | |
| 13 | T | -T | | | | |
| 14 | T | -T | +0.50 | +0.47 | | |
| 15 | 0.0 | 0.0 | | | +0.75 | |
| 16 | 0.0 | 0.0 | | | | |
| 17 | 0.0 | 0.0 | | | | |
| 18 | 0.0 | 0.0 | | | | |
| 19 | T | -T | | | | |
| 20 | 0.58 | ---- | | | | |
| 21 | 0.15 | +0.02 | 0.0 | +0.04 | | +2.80 |
| 22 | T | 0.0 | | | | |
| 23 | T | 0.0 | | | | +0.04 |
| 24 | T | 0.0 | | | | |
| 25 | T | 0.0 | | | | |
| 26 | T | 0.0 | | | | |
| 27 | T | 0.0 | | | | |
| 28 | T | 0.0 | +0.01 | +0.05 | | |
| 29 | T | 0.0 | | | +0.67 | |
| Total | 6.32 | -1.88 | +0.71 | +3.26 | +3.28 | +3.61 |
| Miles from coast | 0.3 (?) | 0 | 0 | 1.4 | 8.8 | 28 |

[a]Data of Mather and Thornthwaite (1956).

precipitation fell on a high proportion of the days during the summer months.

It has been the contention of some workers that precipitation in the Barrow area is much greater than recorded. Black (1954) states that soil pore space amounts to twenty to forty per cent of the soil volume, and could thus hold 1.6 to six inches of water before saturation. He estimated that during each of the summers of 1946, 1947, and 1950 six to nine inches of rain would have been necessary to saturate the soil to the degree that saturation was observed. He states further that on the basis of his own snow measurements in the area the annual precipitation is between two and four times as great as is recorded by the U. S. Weather Bureau station. It is possible that condensation of water vapor and fog particles on plant and soil surfaces contributes appreciably to the total moisture received by the land, but this amount would not be recorded in ordinary precipitation gages.

Conover (1953, as quoted by Tedrow and Hill, 1955) on the other hand states that precipitation during the three summer months averages less than one inch per month and states further that there is an annual water deficiency of 3.3 inches at Barrow, and that the climate should therefore be classed as semiarid. With the many permanent lakes and the abundant tundra pools in the area whose levels seem to fluctuate little or none during the summer months it is difficult to even imagine that the climate is semiarid and that lack of soil water might be restricting to plant growth.

## Phenology

The Johns Hopkins University Laboratory of Climatology has encouraged the use of "Early Alaska" variety garden peas in standardized phenological observations because development of the plants is rapid enough to produce observable daily changes. Higgins (1952) states, "In southern New Jersey four days or more are required in the cool months (for the development of one complete node) and only two to four days in the warm months." The genetics of the "Early Alaska" variety peas planted in the several garden plots was assumed to be uniform, and it is therefore inferred that variations in the peas were a function of the sum of environmental factors operative throughout their period of growth, since plant behavior is the result of the action of environmental factors upon internal physiological processes and is limited by the genetic composition of the plant. The total growth of the peas during the season should be an index of the relative development potential of the environment in which they grew.

Shanks in 1955 planted a single garden plot at the aforementioned Britton Manor site on June 30 and removed them on September 2 (Figure 2). Phenological observations which were made on the peas during the 1956 season are presented in Table V, and it is obvious from those notes and from Figures 3 through 7 that daily phenological scoring as recommended by Higgins would not have been possible.

TABLE V

PHENOLOGICAL OBSERVATIONS OF GARDEN PEAS, 1956

| | |
|---|---|
| | NUWUK STATION |
| 10 July | Peas planted approximately one inch deep in peaty substrate. |
| 31 July | A very few peas showing above the soil surface. |
| 7 August | Fifteen seedlings showing, but barely above ground. |
| 28 August | Few more seedlings above ground, but none large enough for phenological scoring. Collections made. |
| | BEACH RIDGE (Evapotranspirometer station) |
| 10 July | Peas planted approximately one inch deep in upland tundra soil. |
| 28 August | All peas examined had germinated but had not penetrated the soil surface. No collection made. |
| | BEACH RIDGE (Arctic Brown Soil) |
| 20 July | Thirty-five previously soaked and thirty-five dry seed planted. |
| 7 August | Twenty-two seedlings from soaked seeds and one from dry seeds above ground. |
| 14 August | Twenty-three seedlings from soaked seeds one-fourth to one-half inch above soil, five seedlings from dry seeds about one-fourth inch high. |
| 28 August | Collections made. |

TABLE V

PHENOLOGICAL OBSERVATIONS OF GARDEN PEAS, 1956 (continued)

| | |
|---|---|
| | SOUTH BARROW THREE |
| 11 July | Peas planted approximately one inch deep in upland tundra soil. |
| 1 August | Thirty peas above ground, average height one-half inch. |
| 8 August | Nearly all peas above ground, maximum height one inch. |
| 15 August | Twenty-four peas one inch tall, no leaves unfolded. |
| 29 August | Collection made. |
| | MEADE RIVER |
| 20 July | Peas planted approximately one inch deep in upland tundra soil. |
| 23 August | Average number of developed nodes four. Collection made. |

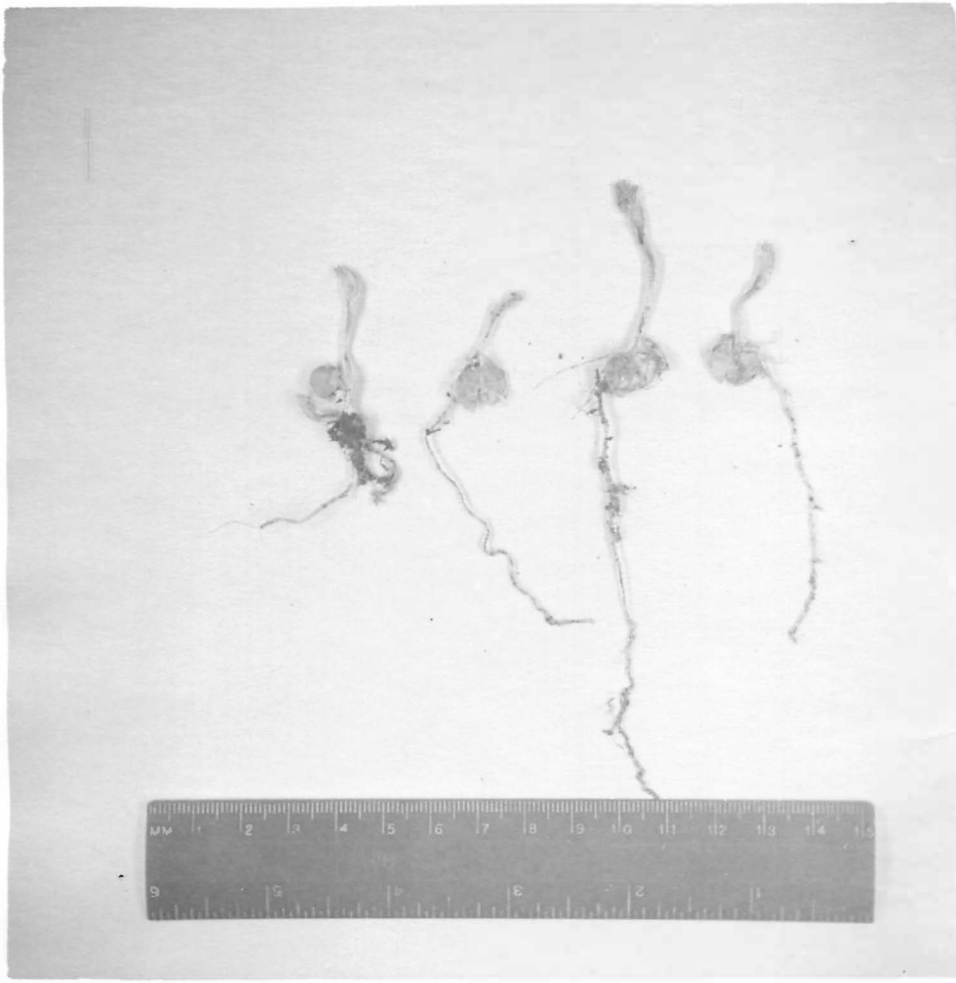

Figure 3. Peas from plot at Nuwuk station, 1956.

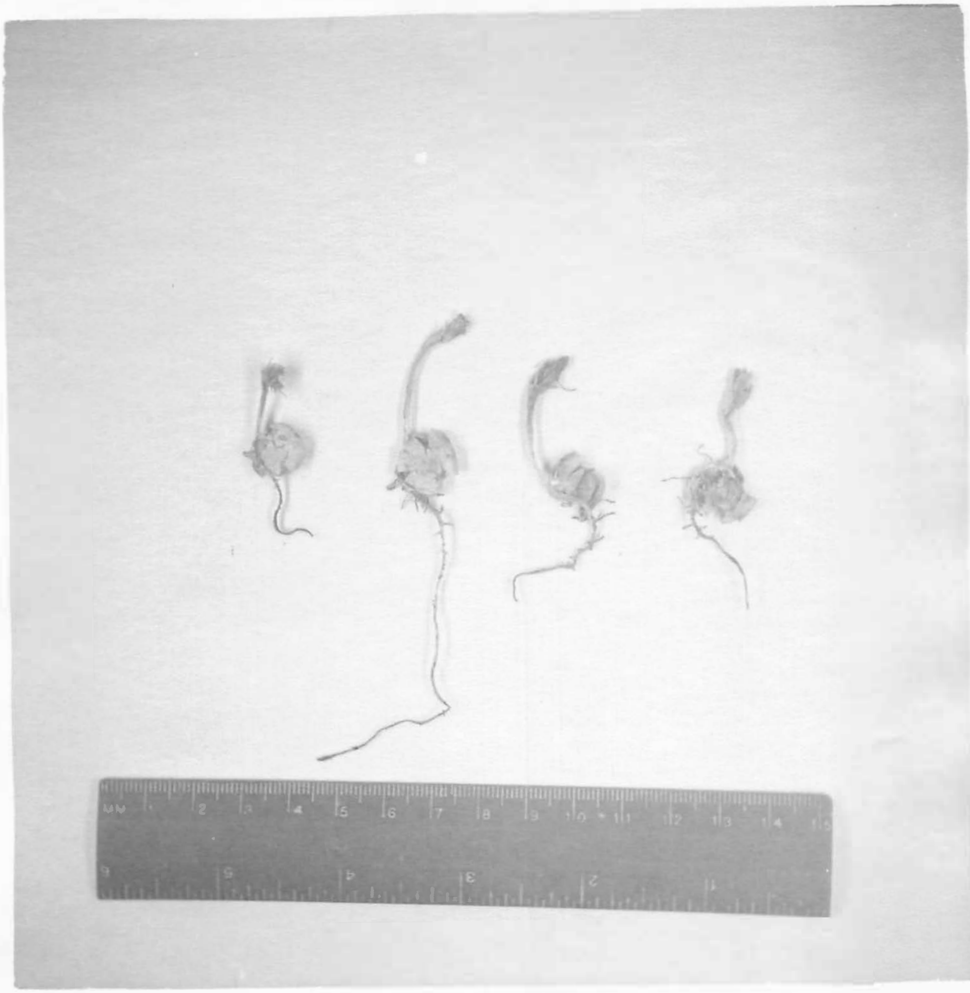

Figure 4. Peas planted as pre-soaked seeds in Arctic Brown soil near Beach Ridge station, 1956.

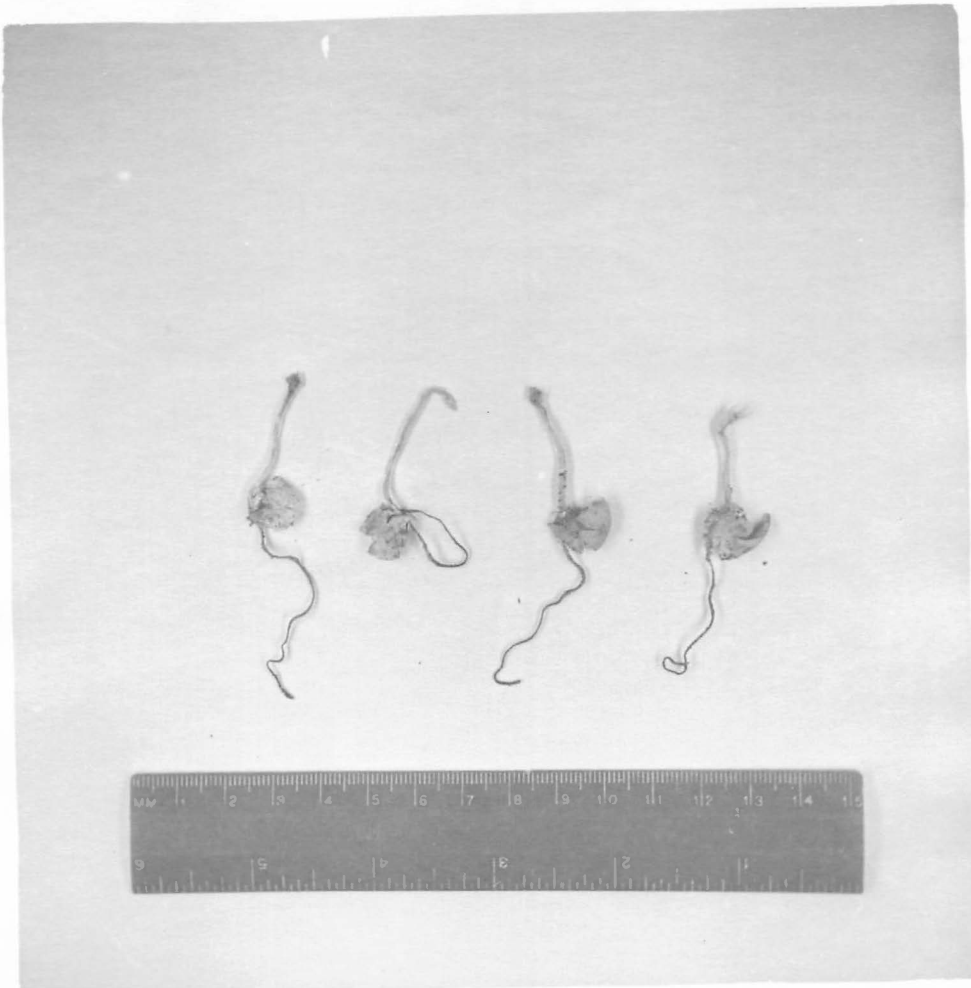

Figure 5. Peas planted as dry seed in Arctic Brown soil near Beach Ridge station, 1956.

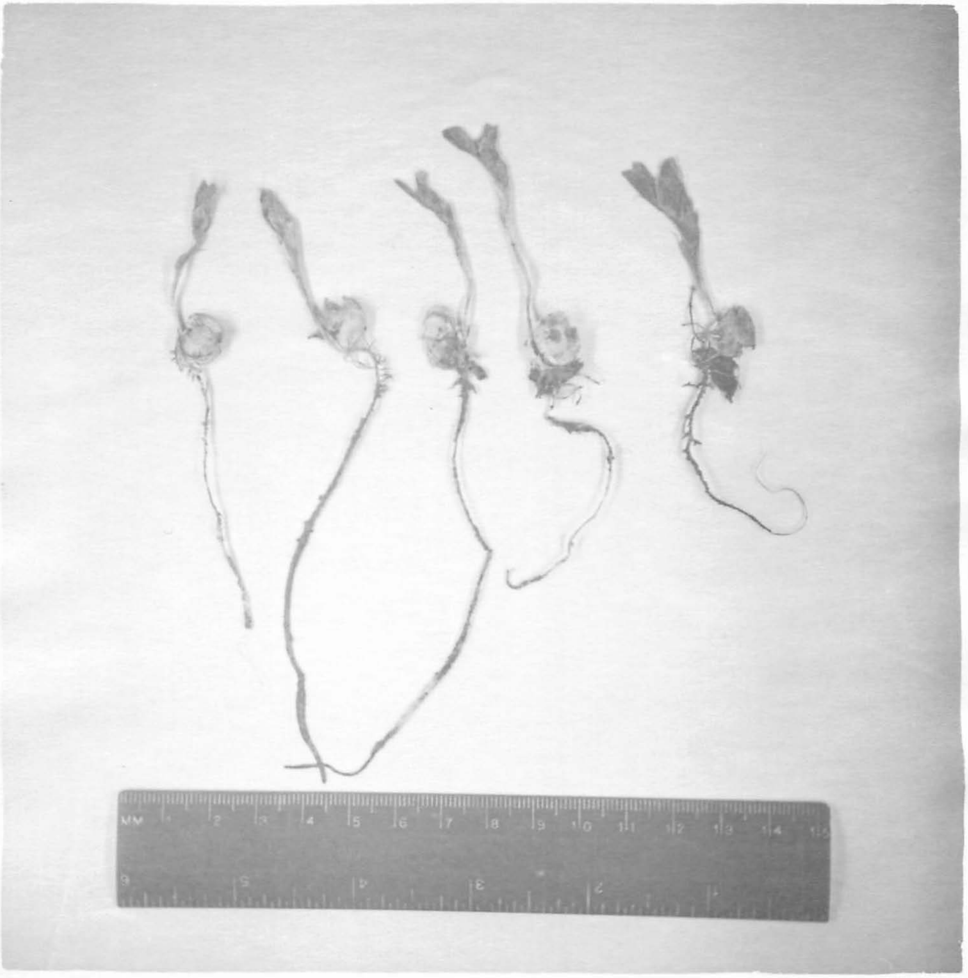

Figure 6. Peas from plot at South Barrow Three station, 1956.

Figure 7. Peas from plot at Meade River station, 1956.

The development of the peas at the Britton Manor site in 1955 indicates that the development potential during that season was greater than that during the 1956 season at all but the Meade River stations. The increase in total growth and development from station to station southward and inland from Nuwuk is a clear indication that the summer season climate ameliorates in that direction.

At the end of the observation period the vegetation in the cans used for the measurement of evapotranspiration yielded further phenological information. The average height of the vegetation was determined, the flowering stems were counted, and the plants were clipped at the soil surface and subsequently oven-dried. After oven-drying the plant materials were allowed to return to equilibrium with atmospheric moisture and were then weighed. Results are presented in Table VI. The cans at the Arctic Research Laboratory were set in fine gravel on the northeast side of the building, and undoubtedly received a higher than normal amount of precipitation from wind eddies and from drip from the roof, but were in relatively low light intensity most of the time. The average height of the vegetation in these cans was four and one-half inches but the total production in aerial parts was only slightly more than that of the cans from the Nuwuk station.

The average height of the vegetation in the cans is not obviously correlated with the climatic gradient under discussion in this thesis. However, the average air-dry weight of aerial plant parts is a reflection of this gradient,

TABLE VI

AVERAGE HEIGHT, NUMBER OF FLOWERING HEADS, AND AIR-DRY WEIGHT OF *DUPONTIA FISCHERI* R. BR. FROM EVAPOTRANSPIRATION CANS

| Station | Can Number | Average height in inches | Number of heads | Weight in grams |
|---|---|---|---|---|
| Nuwuk | 1 | 2.5 | 0 | 1.5 |
| | 2 | 3.5 | 1 | 2.2 |
| | 3 | 3.5 | 2 | 1.9 |
| Average | | 3.2 | | 1.87 |
| Beach Ridge | 1 | 2.5 | 2[a] | 2.3 |
| | 2 | 3.0 | 0 | 2.4 |
| | 3 | 3.0 | 4 | 2.3 |
| Average | | 2.8 | | 2.33 |
| South Barrow Three | 1 | 4.0 | 8 | 2.4 |
| | 2 | 4.75 | 8 | 2.4 |
| | 3 | 4.25 | 4 | 2.0 |
| Average | | 4.3 | | 2.27 |
| Meade River | 1 | 2.5 | 1 | 2.9 |
| | 2 | 5.0 | 1[b] | 2.3 |
| | 3 | 3.0 | 0[b] | 2.3 |
| Average | | 3.5 | | 2.43 |
| Arctic Research Laboratory (Sheltered Site) | 1 | 4.5 | 5 | 1.5 |
| | 2 | 4.5 | 2 | 2.4 |
| | 3 | 4.5 | 4 | 1.9 |
| Average | | 4.5 | | 1.93 |

[a]Plus two *Eriophorum scheuchzeri*.

[b]Plus two *Poa arctica*.

as will become more clear in later sections. It should be noted here that the average production in the cans at Meade River is nearly double that of the cans at Nuwuk.

## Evaporation and Evapotranspiration

It has already been mentioned that travel difficulties prevented the regular visitation of some stations and prevented the visitation of more than two sites on the same dates in most cases. For these reasons the data presented in Figures 8 and 9 require some manipulation before the data from one station can be compared with those from another. The forty-three day period from July 11 to August 23 is the longest period for which data from all stations are available. Average daily rates of evaporation and evapotranspiration can be computed by interpolating on the cumulative graphs the values for the beginning and end of the period and dividing the difference in these two figures by the length of the period. Computation of these figures provides very useful comparative information. The average daily rate of evapotranspiration for this period at the Nuwuk station was 0.108 cm., that for the Beach Ridge station 0.137 cm., that for the South Barrow Three station 0.145 cm., and that for the Meade River station 0.149 cm. The increase in evapotranspiration rate southward and inland from Nuwuk to Meade River is obvious. Similar treatment of the evaporation data reveals that the average daily rate of evaporation during the period

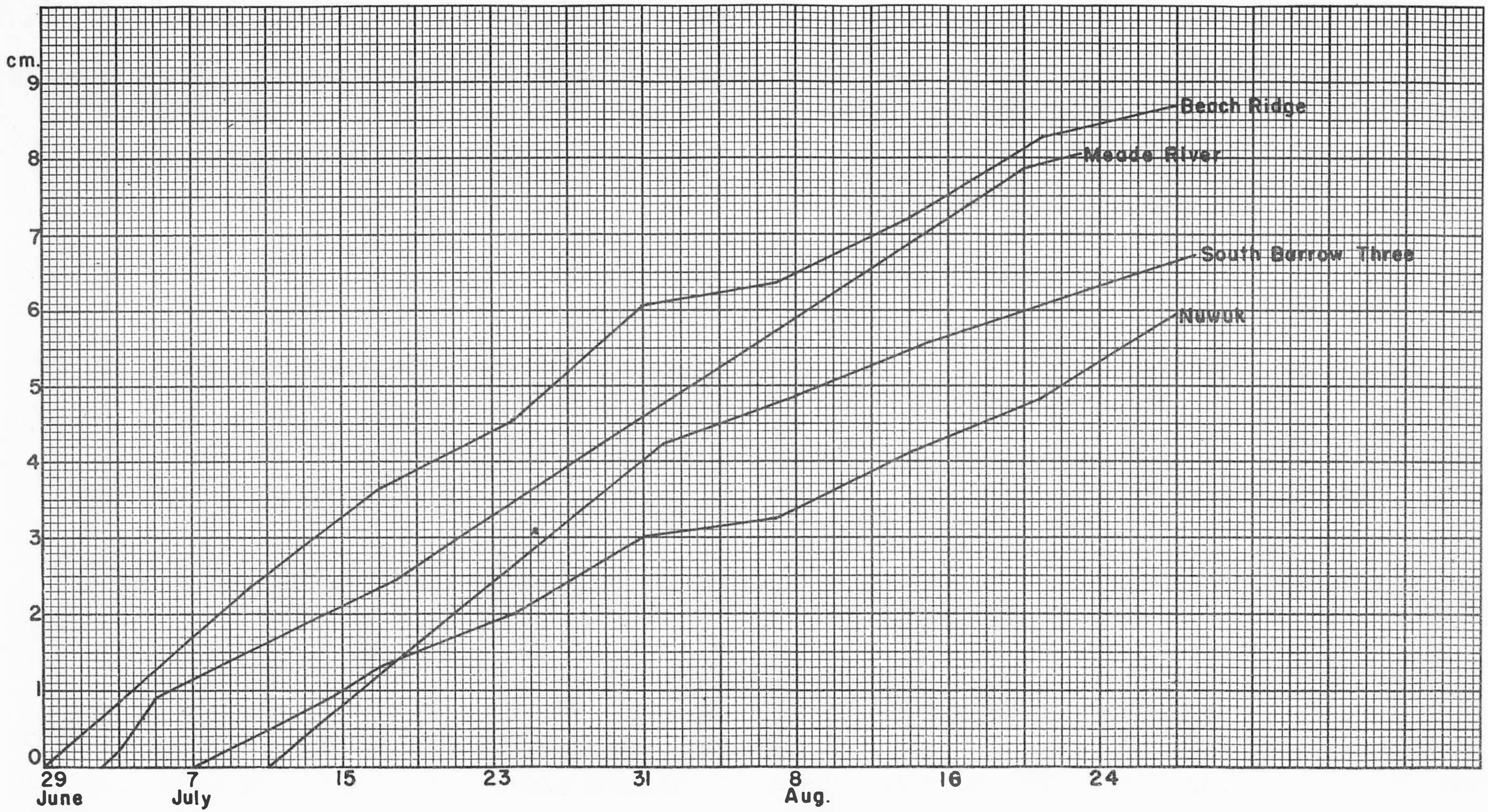


Figure 8. Accumulated evapotranspiration losses (Average of three cans per station).

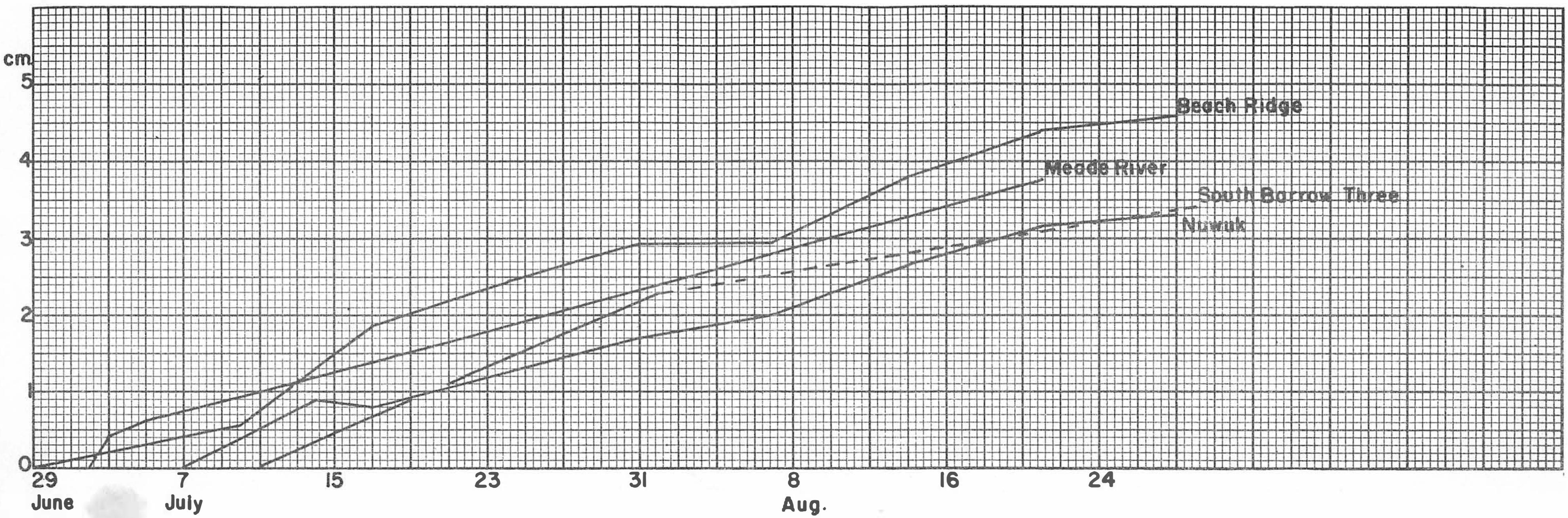


Figure 9. Accumulated evaporation losses.

was 0.066 cm. at the Nuwuk station, 0.087 cm. at the Beach Ridge station, 0.072 cm. at the South Barrow Three station, and 0.070 cm. at the Meade River station. It is suggested that the disproportionately high rate of evaporation at the Beach Ridge station is attributable to the height of the ridge above the surrounding land (up to twelve feet) and to the topographic position of the station and the accompanying increased exposure to persistent winds. The prevailing wind directions and velocities were recorded at the Barrow Weather Bureau station. The prevailing direction during July was southwest, and during August it was northeast. The average velocity for July was 12.1 miles per hour, and that for August 16.7.

If the assumption is made that the evaporation from the open can is equal to the evaporation from the soil surface in the evapotranspirometers, then the transpiration rates for the vegetation in the evapotranspirometers may be estimated for each of the stations. Thus the average daily transpiration rate during the period from July 11 to August 23 was 0.042 cm. at the Nuwuk station, 0.050 cm. at the Beach Ridge station, 0.073 cm. at the South Barrow Three station, and 0.079 cm. at the Meade River station. Re-examination of the three sets of figures for transpiration, evaporation, and evapotranspiration rates for each of the stations reveals that evaporation accounts for nearly two-thirds of the water loss at the Nuwuk and Beach Ridge stations, one-half at the South Barrow Three station, and about one-half at the Meade

River station. Conversely, transpiration accounts for more of the water loss at the two inland stations and for less at the coastal stations. These same inferences may be drawn from a comparison of the evaporation and evapotranspiration data as presented in Figures 8 and 9 for the entire period of observation.

The graphs for each of the processes will now be considered independently. The shapes of the four curves plotted in Figure 8 are indications of changes in the evapotranspiration rates during the entire observation period. The curve for the Nuwuk station is basically a linear one except for the slight upswing in the terminal observation period. The upswing is thought to be due to the fact that the extreme refrigerating effect of pack ice was reduced during this period when there was an open lead in the ocean wide enough to permit ship movement along the coast. The general shape of the curve for the Beach Ridge instruments is steepest in the earlier portion and flattest in the later portion, indicating a higher rate of evapotranspiration during the early part of the season than during the later part. The curve for the Meade River instruments appears to be linear through much of its length but the great interval between observations would mask any changes in its steepness. The curve for the South Barrow Three instruments rises sharply in its earlier portion and is virtually linear through the rest of its length. Similar inferences can be drawn from the curves for the evaporation data presented in Figure 9.

The steepness of the slope of any segment of these curves is an indication of the average rate of the process being considered. The changes in steepness in segments of these curves is thought to be due to short period fluctuations in weather, but this could not be substantiated without more elaborate instrumentation.

Mather and Thornthwaite (1956) used a battery of ten soil-filled fruit juice cans 10.6 cm. in diameter and 17.4 cm. high to measure potential evapotranspiration at sites near the Arctic Research Laboratory, at Britton Manor, and on the crest of the Beach Ridge near the station used in this study. (Potential evapotranspiration, the basic parameter of the Thornthwaite (1948) climatic system, is the amount of water lost by evaporation from the surface of soil in which the moisture level is maintained above field capacity plus that lost by transpiration from plants rooted in that soil.) At their Arctic Research Laboratory station the mean total water loss from eight cans was 5.01 cm. between July 18 and September 6, an average daily rate of 0.050 cm. At their Britton Manor station the mean loss from fourteen cans was 5.75 cm. between June 30 and August 31, an average daily rate of 0.093 cm. The mean loss from ten cans at their Beach Ridge station was 5.61 cm. between July 3 and September 4, an average daily rate of 0.089 cm. The total mean loss at their Beach Ridge station was 2.09 cm. less than the total mean loss at the Beach Ridge station used in the present study from June 29 to August 28.

The water loss varied widely among their sets of cans at all stations, and it is felt that the variability was in large part due to their use of highly variable soil materials containing highly variable vegetation cover. The close uniformity among the cans used in the present investigation at the Beach Ridge station is illustrated graphically in Figure 10.

The excess of precipitation over evapotranspiration for the entire period of measurement at each of the four stations was as follows: Nuwuk, July 7 to August 28, 0.13 cm.; Beach Ridge, June 29 to August 28, 0.88 cm.; South Barrow Three, July 11 to August 1, 1.37 cm.; Meade River, July 2 to August 23, 1.59 cm.

If the Britton Manor precipitation data of Mather and Thornthwaite are compared to their evapotranspiration data, moisture <u>deficiencies</u> are as follows: Arctic Research Laboratory station between July 18 and September 6, 1.92 cm.; Britton Manor station between June 30 and August 31, 1.33 cm.; Beach Ridge station between July 3 and September 4, 0.70 cm. If, on the other hand, those investigators used the official records of the U. S. Weather Bureau station at Barrow, they might have inferred precipitation excesses at each of their stations.

It is inferred from the data of the present investigation that there was no water deficiency during the season, and therefore actual evapotranspiration should have been equal to potential evapotranspiration. Mather and Thornthwaite would

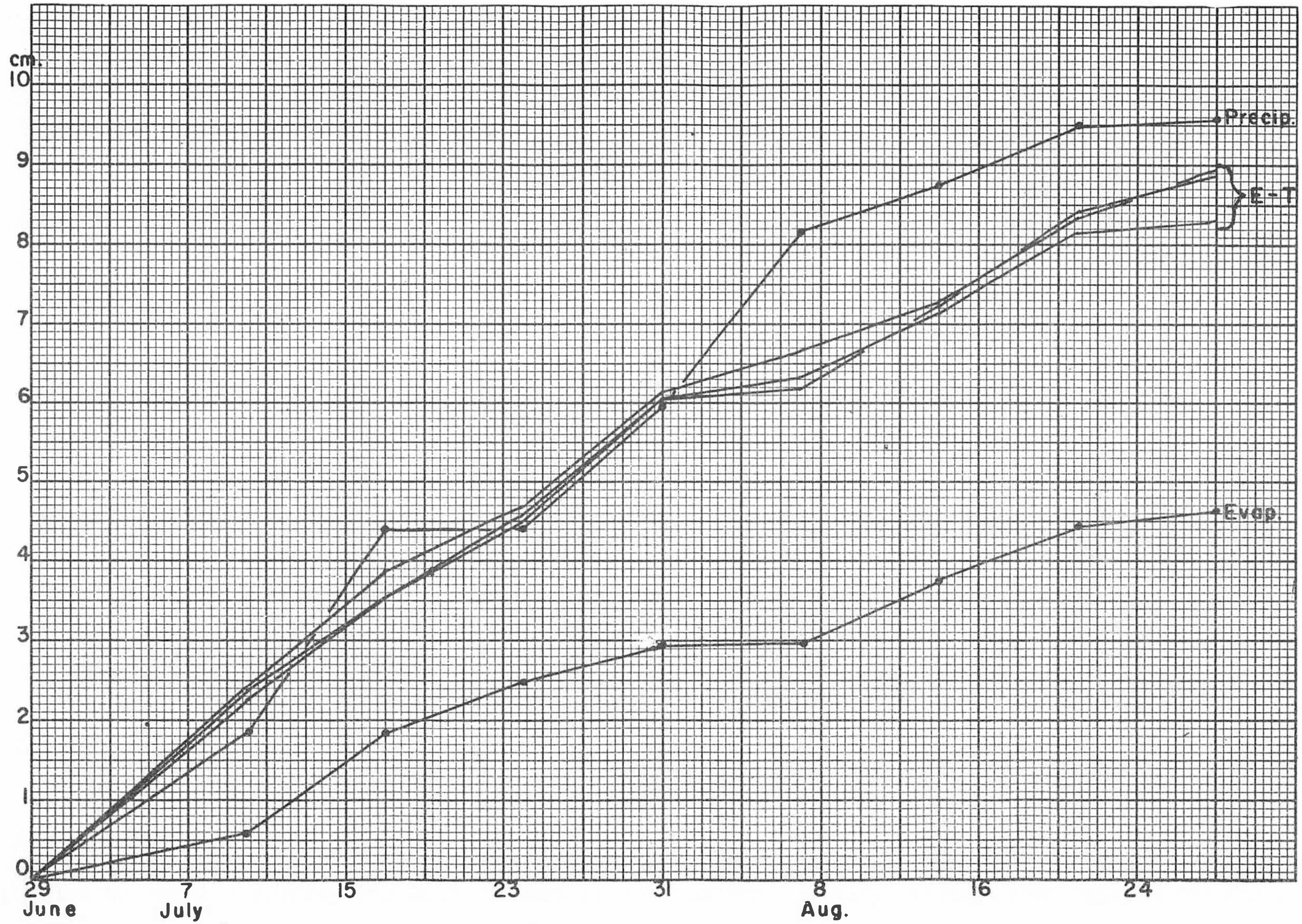


Figure 10. Accumulated precipitation, evapotranspiration, and evaporation (Beach Ridge station).

have been led to a different conclusion on the basis of the precipitation records from their Britton Manor station.

## Vegetation

There are approximately one hundred species of vascular plants known from the vicinity of Barrow and only about one-half of those are frequently encountered in the vegetation. Large areas occupied by grassy flats and the pans of low center polygons are characterized by _Dupontia fischeri_, _Carex aquatilis_, _Eriophorum scheuchzeri_, and _Eriophorum angustifolium_. In places where the water is between one and two meters deep the predominant plant is usually _Arctophila fulva_. On the low ridges surrounding low center polygons and in other situations where drainage is somewhat improved the dwarf willows _Salix pulchra_, _Salix rotundifolia_, and _Salix phlebophylla_ may be characteristic, along with _Petasite frigidus_, _Poa arctica_, and _Luzula confusa_.

The Nuwuk area is unique in the region in the combination of ocean proximity, relatively recent elevation above sea level, and coarse gravelly substrate in a poorly drained position underlying thin sedge peat. The thin peat is relatively fully covered by vascular plants and mosses and lichens occupy much of the space between stems. _Dupontia fischeri_ was by far the most abundant plant in the sampled area and was clearly dominant. The sub-dominants differed in different sections along the line used for placement of samples. It is evident from the frequency data in Table VII that Cochlearia officinalis ssp. arctica and Carex aquatilis are the sub-dominants in the first block of samples but the sub-dominant in the second and third blocks of samples becomes Saxifraga hirculus. Where willows are encountered they ordinarily appear in a large consecutive series of samples because of their creeping form.

The vegetation of the Beach Ridge has been described in detail by Koranda (1954). Suffice it to say here that it is topographically and pedologically unusual enough in the area for this uniqueness to be reflected in the vegetation which covers it. Species such as Dryas integrifolia and Vaccinium vitis-idaea occur on the beach ridges but are not known from other points in the vicinity. The sample data from this area are presented in Table VIII and they indicate that Poa arctica and Carex aquatilis are the dominant plants in the sampled area in general despite the local importance of prostrate willows with associated mosses and lichens on the more exposed spots. There are several species common to either three of the four or all four blocks of samples.

Observable changes in the vegetation during overland travel to the interior from the Beach Ridge seem very gradual and slight, but after rapid transport to a spot such as the South Barrow Three station it is evident that considerable change has taken place over the eleven-mile distance. Woody plants have come to predominate in certain of the better-drained situations, there is an increase in the predominance

TABLE VII

FREQUENCY BY BLOCKS OF SAMPLES AND ANALYSIS OF TOTAL FREQUENCY

NUWUK STATION

| | 1-40 | 41-80 | 81-120 | 121-160 | 161-200 | 201-240 |
|---|---|---|---|---|---|---|
| Dupontia fischeri R. Br. | 37 | 38 | 37 | 38 | 39 | 40 |
| Saxifraga hirculus L. | -- | 15 | 16 | 4 | 4 | 18 |
| Stellaria ciliatosepala Trautv. | 8 | 9 | 9 | -- | -- | 27 |
| Cochlearia officinalis L. ssp. arctica (Schlechten) Hult. | 18 | 9 | 1 | 1 | -- | 1 |
| Carex aquatilis Wahlenb. | 13 | 4 | 7 | -- | -- | -- |
| Salix arctolitoralis Hult. | -- | -- | -- | 1 | 18 | -- |
| Salix phlebophylla Ands. | -- | -- | -- | 16 | -- | -- |
| Saxifraga cernua L. | -- | -- | 5 | 1 | -- | -- |
| Salix rotundifolia Trautv. | -- | -- | -- | -- | 4 | -- |
| Petasites frigidus (L.) D. Don | -- | -- | -- | -- | -- | 4 |
| Chrysosplenium tetrandrum (Lund) Th. Fries | -- | -- | 1 | 1 | -- | 1 |
| Poa arctica R. Br. | -- | -- | -- | -- | 2 | -- |
| Arctophila fulva (Trin.) Anders. | 1 | -- | -- | -- | -- | -- |
| Average number species per sample | 1.9 | 1.8 | 1.9 | 1.5 | 1.7 | 2.4 |
| Number of species common to all blocks | 1 | 1 | 1 | 1 | 1 | 1 |
| Number of species in 5 blocks | 2 | 3 | 3 | 3 | 2 | 3 |
| Number of species confined to this block | 1 | 0 | 0 | 1 | 1 | 1 |

TABLE VII

FREQUENCY BY BLOCKS OF SAMPLES AND ANALYSIS OF TOTAL FREQUENCY

NUWUK STATION (continued)

| | Total out of 240 | Frequency (Percent) | Relative Frequency (Percent) |
|---|---|---|---|
| Dupontia fischeri R. Br. | 229 | 95.4 | 51.1 |
| Saxifraga hirculus L. | 57 | 23.7 | 12.7 |
| Stellaria ciliatosepala Trautv. | 53 | 22.1 | 11.8 |
| Cochlearia officinalis L. ssp. arctica (Schlechten) Hult. | 30 | 12.5 | 6.7 |
| Carex aquatilis Wahlenb. | 24 | 10.0 | 5.4 |
| Salix arctolitoralis Hult. | 19 | 7.9 | 4.2 |
| Salix phlebophylla Ands. | 16 | 6.7 | 3.6 |
| Saxifraga cernua L. | 6 | 2.5 | 1.3 |
| Salix rotundifolia Trautv. | 4 | 1.7 | 0.9 |
| Petasites frigidus (L.) D. Don | 4 | 1.7 | 0.9 |
| Chrysosplenium tetrandrum (Lund) Th. Fries | 3 | 1.2 | 0.7 |
| Poa arctica R. Br. | 2 | 0.8 | 0.5 |
| Arctophila fulva (Trin.) Anders. | 1 | 0.4 | 0.2 |

TABLE VIII

FREQUENCY BY BLOCKS OF SAMPLES AND ANALYSIS OF TOTAL FREQUENCY

BEACH RIDGE STATION

| | 1-40 | 41-80 | 81-120 | 121-150 |
|---|---|---|---|---|
| Poa arctica R. Br. | 38 | 35 | 25 | 24 |
| Carex aquatilis Wahlenb. | 34 | 29 | 25 | 12 |
| Arctagrostis latifolia (R. Br.) Griseb. in Ledeb. | 11 | 24 | 22 | 19 |
| Saxifraga cernua L. | 15 | 10 | 19 | 21 |
| Stellaria laeta Richards. | 16 | 16 | 20 | 7 |
| Senecio atropurpureus (Ledeb.) Fedtsch. | 12 | 8 | -- | 1 |
| Saxifraga punctata L. ssp. nelsoniana (D. Don) Hult. | 2 | -- | 5 | 10 |
| Salix rotundifolia Trautv. | -- | 14 | 1 | 1 |
| Luzula confusa Lindb. | -- | -- | 5 | 4 |
| Saxifraga foliolosa R. Br. | -- | -- | 1 | 1 |
| Ranunculus nivalis L. | -- | -- | -- | 1 |
| Vaccinium vitis-idaea L. ssp. minus (Lodd.) Hult. | -- | 1 | -- | -- |
| Average number of species per sample | 3.1 | 3.3 | 3.1 | 3.3 |
| Number of species common to all blocks | 5 | 5 | 5 | 5 |
| Number of species common to three blocks | 6 | 6 | 7 | 7 |
| Number of species confined to this block | 0 | 1 | 0 | 1 |

TABLE VIII

FREQUENCY BY BLOCKS OF SAMPLES AND ANALYSIS OF TOTAL FREQUENCY

BEACH RIDGE STATION (continued)

| | Total out of 150 | Frequency (Percent) | Relative Frequency (Percent) |
|---|---|---|---|
| Poa arctica R. Br. | 122 | 81.3 | 25.0 |
| Carex aquatilis Wahlenb. | 100 | 66.7 | 20.5 |
| Arctagrostis latifolia (R. Br.) Griseb. in Ledeb. | 76 | 50.7 | 15.6 |
| Saxifraga cernua L. | 64 | 42.7 | 13.1 |
| Stellaria laeta Richards. | 59 | 39.3 | 12.1 |
| Senecio atropurpureus (Ledeb.) Fedtsch. | 21 | 13.9 | 4.3 |
| Saxifraga punctata L. ssp. nelsoniana (D. Don) Hult. | 17 | 11.3 | 3.5 |
| Salix rotundifolia Trautv. | 16 | 10.7 | 3.3 |
| Luzula confusa Lindb. | 9 | 6.0 | 1.8 |
| Saxifraga foliolosa R. Br. | 2 | 1.3 | 0.4 |
| Ranunculus nivalis L. | 1 | 0.7 | 0.2 |
| Vaccinium vitis-idaea L. ssp. minus (Lodd.) Hult. | 1 | 0.7 | 0.2 |

of tussock-forming plants such as Eriophorum vaginatum ssp. spissum, and the number of ericaceous plants in the vegetation is greater. These changes are evidenced in Table XII and in the comparison of Tables VIII and IX with Tables X and XI.

The line along which samples were made at the South Barrow Three station crossed a high center polygon and the vegetation changes associated with microrelief features are reflected in the data in Table IX. No single species is dominant in all four blocks of samples but the heath species Vaccinium vitis-idaea and Cassiope tetragona are clearly dominant in the block of samples from forty-one through eighty.

The line along which samples were made at the Inaru River station crossed a low center polygon near the edge of its central pan. Carex aquatilis, Salix pulchra, and Salix phlebophylla were common to all blocks and considered together comprise nearly 60 percent of the point tallies (relative frequency). The two species of Salix comprise nearly thirty per cent of the relative frequency.

The vegetation at the Meade River site assumes an aspect still different from that at the Inaru River site. The shallow pans of the low center polygons contain a great deal of Carex aquatilis, as do the troughs between the ridges of the polygons. The ridges themselves are covered by a mixture of Vaccinium vitis-idaea ssp. minus, Ledum palustre ssp. decumbens, Eriophorum vaginatum ssp. spissum, Rubus chamaemorus, Betula nana ssp. exilis, and Cassiope tetragona.

TABLE IX

FREQUENCY BY BLOCKS OF SAMPLES AND ANALYSIS OF TOTAL FREQUENCY

SOUTH BARROW THREE STATION

| | 1-40 | 41-80 | 81-120 | 121-150 |
|---|---|---|---|---|
| Carex aquatilis Wahlenb. | 12 | -- | 10 | 30 |
| Eriophorum angustifolium Honckeny | 8 | 11 | 14 | -- |
| Eriophorum scheuchzeri Hoppe | 4 | -- | -- | 27 |
| Eriophorum vaginatum L. ssp. spissum (Fern.) Hult. | 10 | 10 | 8 | -- |
| Vaccinium vitis-idaea L. ssp. minus (Lodd.) Hult. | 8 | 14 | 4 | -- |
| Cassiope tetragona (L.) D. Don | 6 | 15 | -- | -- |
| Luzula confusa Lindb. | 6 | 10 | -- | -- |
| Arctagrostis latifolia (R. Br.) Griseb. in Ledeb. | 11 | 2 | 1 | -- |
| Dupontia fischeri R. Br. | 7 | -- | -- | 1 |
| Petasites frigidus (L.) Fries | -- | -- | 6 | -- |
| Ledum palustre L. ssp. decumbens (Ait.) Hult. | 1 | -- | -- | -- |
| Saxifraga foliolosa R. Br. | -- | -- | -- | 1 |
| Bare ground | -- | 1 | -- | 1 |
| Average number of species per sample | 1.9 | 1.5 | 1.0 | 2.0 |
| Number of species common to all blocks | 0 | 0 | 0 | 0 |
| Number of species common to three blocks | 5 | 4 | 4 | 1 |
| Number of species confined to this block | 1 | 0 | 1 | 1 |

TABLE IX

FREQUENCY BY BLOCKS OF SAMPLES AND ANALYSIS OF TOTAL FREQUENCY

SOUTH BARROW THREE STATION (continued)

| | Total out of 150 | Frequency (Percent) | Relative Frequency (Percent) |
|---|---|---|---|
| Carex aquatilis Wahlenb. | 52 | 34.6 | 21.8 |
| Eriophorum angustifolium Honckeny | 33 | 22.0 | 13.8 |
| Eriophorum scheuchzeri Hoppe | 31 | 20.7 | 13.0 |
| Eriophorum vaginatum L. ssp. spissum (Fern.) Hult. | 28 | 18.7 | 11.7 |
| Vaccinium vitis-idaea L. ssp. minus (Lodd.) Hult. | 26 | 17.3 | 10.9 |
| Cassiope tetragona (L.) D. Don | 21 | 14.0 | 8.8 |
| Luzula confusa Lindb. | 16 | 10.7 | 6.7 |
| Arctagrostis latifolia (R. Br.) Griseb. in Ledeb. | 14 | 9.3 | 5.9 |
| Dupontia fischeri R. Br. | 8 | 5.3 | 3.3 |
| Petasites frigidus (L.) Fries | 6 | 4.0 | 2.5 |
| Ledum palustre L. ssp. decumbens (Ait.) Hult. | 1 | 0.7 | 0.4 |
| Saxifraga foliolosa R. Br. | 1 | 0.7 | 0.4 |
| Bare ground | 2 | 1.3 | 0.8 |

TABLE X

FREQUENCY BY BLOCKS OF SAMPLES AND ANALYSIS OF TOTAL FREQUENCY
INARU RIVER STATION

| | 1-40 | 41-80 | 81-120 | 121-160 | 161-200 |
|---|---|---|---|---|---|
| Carex aquatilis Wahlenb. | 21 | 26 | 35 | 35 | 21 |
| Salix phlebophylla Ands. | 16 | 17 | 5 | 16 | 11 |
| Salix pulchra Cham. | 2 | 12 | 12 | 12 | 18 |
| Dupontia fischeri R. Br. | 4 | 5 | 20 | 7 | -- |
| Polygonum bistorta L. ssp. plumosum (Small) Hult. | 5 | -- | 8 | 13 | 7 |
| Vaccinium vitis-idaea L. ssp. minus (Lodd.) Hult. | -- | 8 | -- | 9 | 10 |
| Stellaria laeta Richards. | 4 | 4 | 2 | -- | 2 |
| Cassiope tetragona (L.) D. Don | -- | -- | 4 | 3 | 4 |
| Petasites frigidus (L.) D. Don | 2 | -- | 1 | 6 | -- |
| Salix reticulata L. | -- | 1 | -- | 3 | 3 |
| Saxifraga punctata L. ssp. nelsoniana (D. Don) Hult. | 4 | 1 | -- | -- | 1 |
| Hierochloe alpina (Sw.) Roem. & Schult. | -- | 3 | -- | -- | 2 |
| Pedicularis capitata Adams | -- | -- | -- | 3 | 3 |
| Poa arctica R. Br. | 1 | -- | 1 | 2 | -- |
| Saxifraga cernua L. | 4 | -- | -- | | -- |
| Cardamine (?) | 1 | 1 | -- | -- | -- |
| Average number species per sample | 1.5 | 2.0 | 2.1 | 1.7 | 1.9 |
| Number of species common to all blocks | 3 | 3 | 3 | 3 | 3 |
| Number of species common to four blocks | 3 | 2 | 3 | 2 | 2 |
| Number of species confined to this block | 1 | 0 | 0 | 0 | 0 |

TABLE X

FREQUENCY BY BLOCKS OF SAMPLES AND ANALYSIS OF TOTAL FREQUENCY

INARU RIVER STATION (continued)

| | Total out of 200 | Frequency (Percent) | Relative Frequency (Percent) |
|---|---|---|---|
| Carex aquatilis Wahlenb. | 138 | 69.0 | 32.8 |
| Salix phlebophylla Ands. | 65 | 32.5 | 15.5 |
| Salix pulchra Cham. | 56 | 28.0 | 13.3 |
| Dupontia fischeri R. Br. | 36 | 18.0 | 8.6 |
| Polygonum bistorta L. ssp. plumosum (Small) Hult. | 33 | 16.5 | 7.9 |
| Vaccinium vitis-idaea L. ssp. minus (Lodd.) Hult. | 27 | 13.5 | 6.4 |
| Stellaria laeta Richards. | 12 | 6.0 | 2.9 |
| Cassiope tetragona (L.) D. Don | 11 | 5.5 | 2.6 |
| Petasites frigidus (L.) D. Don | 9 | 4.5 | 2.1 |
| Salix reticulata L. | 7 | 3.5 | 1.7 |
| Saxifraga punctata L. ssp. nelsoniana (D. Don) Hult. | 6 | 3.0 | 1.4 |
| Hierochloe alpina (Sw.) Roem. & Schult. | 5 | 2.5 | 1.2 |
| Pedicularis capitata Adams | 5 | 2.5 | 1.2 |
| Poa arctica R. Br. | 4 | 2.0 | 0.9 |
| Saxifraga cernua L. | 4 | 2.0 | 0.9 |
| Cardamine (?) | 2 | 1.0 | 0.5 |

TABLE XI

FREQUENCY BY BLOCKS OF SAMPLES AND ANALYSIS OF TOTAL FREQUENCY

MEADE RIVER STATION

| | 1-40 | 41-80 | 81-120 | 121-150 |
|---|---|---|---|---|
| Vaccinium vitis-idaea L. ssp. minus (Lodd.) Hult. | 31 | 16 | 29 | 25 |
| Ledum palustre L. ssp. decumbens (Ait.) Hult. | 30 | 12 | 30 | 21 |
| Eriophorum vaginatum L. ssp. spissum (Fern.) Hult. | 17 | 19 | 21 | 17 |
| Carex aquatilis Wahlenb. | 6 | 22 | 7 | 7 |
| Rubus chamaemorus L. | 22 | 10 | 7 | 1 |
| Betula nana L. ssp. exilis (Sukatch.) Hult. | -- | -- | 8 | 9 |
| Cassiope tetragona (L.) D. Don | -- | 7 | -- | 1 |
| Pedicularis capitata Adams | 3 | 2 | -- | -- |
| Average number of species per sample | 2.8 | 2.2 | 2.6 | 2.0 |
| Number of species common to all blocks | 5 | 5 | 5 | 5 |
| Number of species common to three blocks | 0 | 0 | 0 | 0 |
| Number of species confined to this block | 0 | 0 | 0 | 0 |

TABLE XI

FREQUENCY BY BLOCKS OF SAMPLES AND ANALYSIS OF TOTAL FREQUENCY

MEADE RIVER STATION (continued)

| | Total out of 150 | Frequency (Percent) | Relative Frequency (Percent) |
|---|---|---|---|
| Vaccinium vitis-idaea L. ssp. minus (Lodd.) Hult. | 101 | 67.3 | 26.6 |
| Ledum palustre L. ssp. decumbens (Ait.) Hult. | 92 | 61.3 | 24.2 |
| Eriophorum vaginatum L. ssp. spissum (Fern.) Hult. | 74 | 49.3 | 19.5 |
| Carex aquatilis Wahlenb. | 43 | 28.7 | 11.3 |
| Rubus chamaemorus L. | 40 | 26.7 | 10.5 |
| Betula nana L. ssp. exilis (Sukatch.) Hult. | 17 | 11.3 | 4.5 |
| Cassiope tetragona (L.) D. Don | 8 | 5.3 | 2.1 |
| Pedicularis capitata Adams | 5 | 3.3 | 1.3 |

TABLE XII

RELATIVE FREQUENCIES OF ALL SPECIES ENCOUNTERED IN SAMPLING

| | Nuwuk | Beach Ridge | South Barrow Three | Inaru River | Meade River |
|---|---|---|---|---|---|
| Graminoid Species | | | | | |
| Arctagrostis latifolia | - | 15.6 | 5.9 | - | - |
| Arctophila fulva | 0.2 | - | - | - | - |
| Carex aquatilis | 5.4 | 20.5 | 21.8 | 32.8 | 11.3 |
| Dupontia fischeri | 51.1 | - | 3.3 | 8.6 | - |
| Eriophorum angustifolium | - | - | 13.8 | - | - |
| Eriophorum scheuchzeri | - | - | 13.0 | - | - |
| Eriophorum vaginatum ssp. spissum | - | - | 11.7 | - | 19.5 |
| Hierochloe alpina | - | - | - | 1.2 | - |
| Luzula confusa | - | 1.8 | 6.7 | - | - |
| Poa arctica | 0.5 | 25.0 | - | 0.9 | - |
| Total | 57.2 | 62.9 | 76.2 | 43.5 | 30.8 |
| Shrub Species | | | | | |
| Betula nana ssp. exilis | - | - | - | - | 4.5 |
| Cassiope tetragona | - | - | 8.8 | 2.6 | 2.1 |
| Ledum palustre ssp. decumbens | - | - | 0.4 | - | 24.1 |
| Rubus chamaemorus | - | - | - | - | 10.5 |
| Salix arctolitoralis | 3.6 | - | - | - | - |
| Salix phlebophylla | 3.6 | - | - | 15.5 | - |
| Salix pulchra | - | - | - | 13.3 | - |
| Salix reticulata | - | - | - | 1.7 | - |
| Salix rotundifolia | 0.9 | 3.3 | - | - | - |
| Vaccinium vitis-idaea ssp. minus | - | 0.2 | 10.9 | 6.4 | 26.6 |
| Total | 8.1 | 3.5 | 20.1 | 39.9 | 67.8 |

TABLE XII

RELATIVE FREQUENCIES OF ALL SPECIES ENCOUNTERED IN SAMPLING (continued)

| | Nuwuk | Beach Ridge | South Barrow Three | Inaru River | Meade River |
|---|---|---|---|---|---|
| Forb Species | | | | | |
| Chrysosplenium tetrandrum | 0.7 | - | - | - | - |
| Cochlearia officinalis ssp. arctica | 6.7 | - | - | - | - |
| Cardamine sp. | - | - | - | 0.5 | - |
| Pedicularis capitata | - | - | - | 1.2 | 1.3 |
| Petasites frigidus | 0.9 | - | 2.5 | 2.1 | - |
| Polygonum bistorta ssp. plumosum | - | - | - | 7.9 | - |
| Ranunculus nivalis | - | 0.2 | - | - | - |
| Saxifraga cernua | 1.3 | 13.1 | - | 0.9 | - |
| Saxifraga foliolosa | - | 0.4 | 0.4 | - | - |
| Saxifraga hirculus | 12.7 | - | - | - | - |
| Saxifraga punctata ssp. nelsoniana | - | 3.5 | - | 1.4 | - |
| Senecio atropurpureus | - | 4.3 | - | - | - |
| Stellaria ciliatosepala | 11.8 | - | - | - | - |
| Stellaria laeta | - | 12.1 | - | 2.9 | - |
| Bare soil | - | - | 0.8 | - | - |
| Total | 34.1 | 33.6 | 3.7 | 16.9 | 1.3 |
| Total number of species | 13 | 12 | 12 | 16 | 8 |
| Number of species confined to station | 6 | 2 | 3 | 5 | 2 |
| Number of species common to all stations | 1 | 1 | 1 | 1 | 1 |
| Number of species common to four stations | 1 | 2 | 2 | 2 | 2 |
| Number of graminoid species | 4 | 4 | 7 | 4 | 2 |
| Number of shrub species | 3 | 2 | 3 | 5 | 5 |
| Number of forb species | 6 | 6 | 3 | 7 | 1 |

Complete species lists have not been included for the five study areas, but the floras of the Inaru River and Meade River localities are considerably richer in species than those of the more coastal stations, even though this fact is not reflected in the sample data from typical areas. The increased richness appears to be due to an increase in the variety of habitats as well as climatic shift.

It is readily apparent from the summarized data in Table XII that there is an increase in the shrubby component in the vegetation at the more southerly and inland stations. There was a conscious attempt to select areas for sampling which were representative of the general locality in which they were made, extreme or unusual sites being avoided.

## SUMMARY

This investigation was concerned with the climatic and vegetational gradient in the extreme north of Alaska between Point Barrow, on the coast of the Arctic Ocean, and an inland point sixty-five miles to the southwest. Five localities at irregular intervals along this northeast-southwest line were selected as sites for intensive vegetation studies and four of them were also used as stations for the installation of simple climatic instrumentation. The stations are referred to in north to south order as Nuwuk, Beach Ridge, South Barrow Three, Inaru River, and Meade River. The Inaru River station was the one at which a climatic station was not established.

Extreme temperatures were recorded during irregularly staggered periods of variable length at the four climatic stations and were compared with the daily temperature records of the United States Weather Bureau station at Barrow, Alaska. Maximum temperatures at the Beach Ridge station were irregularly higher than the official temperatures at Barrow. Maximum and minimum temperatures at the other stations were at times higher and at times lower than the official ones.

Accumulated precipitation was measured periodically in six inch diameter cans. The total precipitation for the season was at all stations greater than that recorded by the Weather Bureau. The least deviation was at the Nuwuk station and the deviation became progressively greater at the more

southerly stations; however, the rate of increase was greatest very near the coast and decreased inland.

"Early Alaska" variety garden peas were planted in garden plots at each of the four climatic stations for use in phenological observations. Total growth of the plants was assumed to be an index of the development potential of the environment in which they grew. The total development of the plants was progressively greater in the plots south from the Nuwuk station. Peas in the Meade River plot developed an average of four nodes while those at Nuwuk barely emerged above the soil surface.

Six-inch diameter cans embedded in the soil and partially filled with water were used for evaporation measurements. Similar cans filled with sod plugs covered by a uniform stand of *Dupontia fischeri* were used for evapotranspiration measurements. Interpolated figures were used to calculate these average daily rates of evaporation for the period from July 11 to August 23: Nuwuk, 0.066 cm.; Beach Ridge, 0.087 cm.; South Barrow Three, 0.072 cm.; Meade River, 0.070 cm. The high figure at the Beach Ridge station was inferred to be due to unusual topographic position and exposure to unobstructed winds. Similarly interpolated figures were used to calculate the average daily rate of evapotranspiration for the same period: Nuwuk, 0.108 cm.; Beach Ridge, 0.137 cm.; South Barrow Three, 0.145 cm.; Meade River, 0.149 cm. Equivalence of measured evaporation and evaporation from the soil surface of the evapotranspirometers was assumed, and the difference between evaporation and evapotranspiration was used as the best available estimate of transpiration. The differences are: Nuwuk, 0.040 cm.; Beach Ridge, 0.050 cm.; South Barrow Three, 0.073 cm.; Meade River, 0.079 cm. The average daily rates of evaporation, evapotranspiration, and transpiration for the forty-three day period increased inland from the coast, and transpiration accounted for an increasingly higher proportion of the total water loss toward the interior.

Precipitation exceeded evapotranspiration as follows: Nuwuk, 0.13 cm.; Beach Ridge, 0.88 cm.; South Barrow Three, 1.37 cm.; Meade River, 1.59 cm.

Total production of aerial parts of plants growing in the evapotranspirometers increased away from the coast.

The vegetation was sampled in each of the five areas and the sample data were analyzed. There was a shift in dominance from graminoid to shrubby species toward the interior. This increase in the shrubby component of the tundra vegetation is correlated with a clearly demonstrable summer season amelioration within a short distance of the coast of the Arctic Ocean.

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