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BIOTIC SURVEY OF ROSS LAKE BASIN
Report for
January - December 1972
University of Washington

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Conducted by the Institute of Forest Products, College of Forest Resources, University of Washington, Seattle -- in cooperation with the City of Seattle, Department of Lighting, and the State of Washington Department ment of Game -- under contract with the City of Seattle, Department of Lighting.

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Introduction: This report covers the second year of a field study of the Ross Lake Basin, with the general objective of determining what the effects of raising the lake level on the biota might be and how undesirable effects could be avoided or compensated for. The objectives of the study were worked out in cooperation with the City of Seattle Department of Lighting and the Washington State Department of Game. The Department of Lighting, through the good offices of Mr. Wayne Bishop, has provided all requested assistance, including boat transportation, aerial flights, and living quarters. Mr. Gene Dziedzic has frequently consulted with us on behalf of the Department of Game, and Mr. Arthur G. Stendal has provided information on deer hunting, and taken part in some of the field work.

Objectives:

General:

a) To assess the current situation with regard to wild life populations and develop predictions concerning the probable effects of raising the lake level on them.

b) To develop recommendations for mitigation of anticipated losses, if any.

c) To design post-impoundment studies.

Specific - 1972

a) To verify and correct data on deer numbers and winter distribution.

b) To determine deer winter range productivity and use

c) To determine the effects of the impoundment on valley microclimate

d) To review and correct data on wildlife other than deer.

e) To develop plans for wildlife habitat mitigation

f) To develop plans to study the effects of a rise in the impoundment, if the proposed project is constructed.

Field Activities

Chronology of 1972

Winter (January - March 1972)

1. Delineation of winter distribution and population of deer for comparison with results of 1971.

2. Initiate short and long-term plant productivity and habitat studies before snow melt.

Spring (April - June 1972)

1. Continue 1971's studies on spring deer movement in close cooperation with the Canadian teams.

2. Determination of plant growth patterns and analysis of differences (if any) between North and South, East and West, and various elevations.

3. Continued seasonal population estimates with pellet transects.

4. Continued population composition -- age/sex ratios. Hybrid indices.

5. Continued plant productivity investigations in order to determine carrying capacity in various habitats.

Summer (July - August 15, 1972)

1. Continued seasonal population composition and estimates.

2. Determination of the effects of raising the lake level on the microclimatology of the basin.

3. Determination of plant composition and age-class of the major wintering areas of deer in the basin.

4. Initiation of experimental mitigation techniques [fertilizer plots].

5. Continued investigation into seasonal deer movements.

6. Determination of plant successional stages.

Fall (August 15 - October 1972)

1. Determination of plant productivity of the major wintering areas.

2. Continued micro-climatological studies.

3. Continued seasonal population composition and estimates.

4. Preparation of report of findings for 1972, including suggestions for mitigation.

5. Delineation of further pre-impoundment studies.

Results

Deer Numbers and Winter Distribution: In a largely forested region deer numbers and seasonal distribution cannot be observed directly. A standard index to distribution and abundance is the pellet-group count. This is based on the observation that one deer deposits a known number of pellet groups (about 13 in winter) each day.
The details of the method, type of data, and analysis of results are given in Appendix A.

In general, when this method is applied to determining the population of deer using a certain winter range, the estimated number will tend to be something lower than the true number, for the following reasons:

1.

1. Observers searching sample plots for pellet groups may miss some.

2. The sample plots are cleared in the fall, before all the deer are on the winter range, and read in the spring, after some have left, and so represent an average rather than a maximum winter number.

Remembering then, that these are minimum values, we obtained winter population estimates on known deer concentration areas (main deer winter ranges) for two winters: 1970-71 -- 227 deer; 1971-2 -- 206 deer. Not all the deer are found on the main wintering ranges. At least twenty percent of the total shoreline population is found in small pockets elsewhere around the lake. Our estimate of these made use of the population estimates above, and direct observations. We have found that in mid-winter many deer are fairly near the lake shore and can be observed from a boat. Comparing the number seen with the estimated population for each winter range, we found that we observed 76 per cent in 1970-71 and 87 per cent in 1971-72. We also made a direct count around the whole lakeshore. Assuming that the same percentage of the whole population is observable, we can expand this direct observation to an estimate for the whole lake shore. In 1970-71 this was 305 deer; in 1971-72 it was 250 deer.

Because pellet count indices of abundance give less-than-true estimates, these values are somewhat less than the true ones, as we have seen. But there is still another factor which tends to make this a minimal estimate--that is that the search for deer around the lake shore could not be as intensive as the search for deer on the shores of the more open and more accessible major deer winter ranges.

In addition to the deer around the lake shore, enumerated above, there are some deer which winter on high (3-4000') southerly exposures which are snow-free in winter. We are just now in the process of locating these and attempting population estimates.

In our 1971 report we estimated a Ross Lake Basin deer population of about 400-600 deer. Our 1972 studies show a count of 250 deer, which is substantially below the true value for reasons given above. These population estimates are consistent with each other.

The deer around Ross Lake are not one uniform population, but rather a series of overlapping populations which show a definite pattern of hybridization between mule deer and black tailed deer. This is readily seen in the patterns of hair color on and around the tail, as shown in Figure A-5. By assigning a range of numbers to each of these characters, as in this illustration, one is able to assign a "hybrid" number to any deer he sees. Different populations around the lake show different degrees of hybridization. Apparently mule deer predominate in the northeastern part of the basin. As one moves south along the east shore of the lake, the blacktail element becomes stronger, and someplace downstream on the Skagit pure blacktails will be found. The deer on the west side of the lake are strong in blacktail characters, showing that there is little interchange around the northern perimeter of the lake or across the lake, although individual deer do make these movements. See Appendix A for further details.

Our data on deer numbers permit us to compare total populations in one winter with those in another. Since the same methods are used in both winters, the results are comparable.

The population estimate for 1970-71 was 305 deer. If we assume a population increase of about 20 per cent, we would find some 360 in the following year. But we actually estimated only 250. It seems that the deer population is limited by some environmental factor, which operates even in ordinary years. The most logical supposition would be that winter range is limiting. As yet we do not have enough information on this point, although there is certainly evidence of heavy forage use in some areas, and also evidence that conifers are beginning to crowd out forage plants.

Deer Winter Range Studies:

There are several deer winter range problems which we are studying. Some winter ranges are located on shrubby areas which were swept earlier by fire; others are located in the mature forest. On shrub ranges it is important to learn the dynamics of the situation -- the competitive relations between the individual plants at present, and the effects of the invading conifers on the forage plants. Preliminary data (Appendix B) indicates that conifers are probably competitive with forage plants at the present time and will become more so as time goes on.

While the results are preliminary, several significant points are evident. The shrub species, as they presently exist, are of sprout origin. Their height growth is very rapid at first but this slows very quickly and the individual sprout has a relatively short life compared to the main sprouting head or root collar. The conifer tree species reproduction, on the other hand, is exclusively of seedling origin and tends to have a much slower initial rate of height growth. Thus, if shrub sprouts and conifer seedlings come into competition early in life and both are relatively intolerant (of shading), the shrubs have a decided advantage. On the other hand,the conifers are ultimately much longer lived and taller than the shrubs and if they escape early elimination, will overtop the shrubs (and hardwood tree species as well) and eliminate them. This early advantage to the shrub sprouts and later advantage of the trees is intensified by site quality increase. In fact,on very dry exposed sites there is some evidence that a light partial overstory of trees may well improve the environment for understory shrubs.

The above-mentioned relationships of course will possibly not hold if the shrubs have to invade and occupy an area after disturbance, through seed. We have obtained no information on the dynamics under these conditions, which of course would occur if succession, before disturbance, had progressed to a point where a dense complete canopy of trees had occupied an area for a sufficient length of time to reduce the shrubs. This occurs primarily on good sites with long periods of no disturbance -- a combination of circumstances infrequently found in the study area. The data also clearly indicated that the conifer seedlings occurred in definite age classes. This is probably related to some favorable combination of seed crop and conditions for early survival and growth.

It does appear that the initial stages of succession dominated by shrub species may last for several decades without further disturbance before the conifers take over the major role. This does not necessarily mean though that the shrubs are ideal for deer browse during this entire period.

The productivity of present shrub ranges, and the winter consumption of new growth by deer are being studied through measurements and photographs. Each species of shrub has different place on the deer preference list, each individual is influenced by its site, the plants which surround it, the age of its root crown, the age of its shoots, and possibly other factors.

Mature forest winter ranges seem deficient in forage; commonly the forest floor is open and the shrubs which protrude above the snow are heavily used. But the real source of deer food in these forests is evidently not the understory vegetation, -- it is the canopy. Douglas fir foliage is eagerly taken by deer when a branch or a tree falls, and in addition the tree branches and trunks have lichens growing on them. On the winter of 1971-72 we investigated these lichens, to determine the species which were present, their relative place on the deer preference list, their abundance, and their distribution. The details are given in Appendix C.

The importance of arboreal lichens as forage has been demonstrated on similar forest ranges for blacktail deer on Vancouver Island, B. C. The present study indicated species of only one genus of lichen, Alectoria (hair moss), was utilized heavily. This lichen grows in branches and trunks of trees. Deer eat the tree-trunks clean on winter ranges, actually to the extent of creating a "browse line". Where deer do not winter this "browse line" effect is not found.

Lichens utilized by the deer were found to be closely associated with the climatic conditions characteristic of the given forest conditions. Three conditions appear to be highly productive for the lichens utilized most by the deer during the critical winter periods; mature age, relative open-ness in the stand, and high humidity. Areas of mature forest adjacent to the lake shore are particularly productive.

During the 1972-3 winter we are further investigating the production of both hairmoss lichen and Douglas-fir foliage as it falls from the forest canopy and becomes available as winter forage for deer. It seems evident that the pattern of this fall-out from the canopy must be influenced by winter storms and the way that wind acts within the canopy. Thus the elements of the problem include the abundance of potential deer foods, the annual increment in these foods, and the times at which these foods become available to deer. All three of these are probably influenced by the biotic and physical characteristics of the forest.

Climatology

A prime question, throughout our study of the Ross Lake Basin has been: does the presence of the impoundment influence the microclimate of the lake shore. Almost from the first it was evident that the Ross Lake shore differed from the valley of the Skagit in Canada in being much more nearly snow-free. But to determine the reasons for this required study. This took two forms--one consisted of a mass of observational evidence and the other consisted of a controlled series of climatic measurements along two transects.

Winter observations show that on deer winter ranges snow is relatively shallow up to a certain level -- perhaps 2500 feet -- and then becomes abruptly deeper. Also, many times when it is snowing in the uplands it is raining at the lake shore. In the spring the plants around the lake start growing and produce leaves and flowers about the same time all around the lake, whereas above the upper limit of the deer winter range the same species of plants bloom a month later. One would hypothesize from such observations that the lake warmed its vicinity during the winter.

In order to examine this hypothesis quantitatively, two transects made up of microclimatic recording devices were set up in Ross Lake Basin. One transect consisted of one slope on each side of the impoundment. The other consisted of two comparable slopes, one on each side of a small stream.

The results obtained thus far are presented in Appendix D. It appears that the slopes which include the lake basin are warmer, and have a greater diurnal temperature range than do the slopes which do not include a lake basin. This could be due to the presence of the lake itself or to the greater width of the Ross Lake basin, which permits more daily sunlight, or to both. Analysis of the data is continuing.

In addition to these climatic measurements, we have devised a method of measuring hours of daily sunlight for any desired point. This depends upon slope, aspect, and surrounding higher ground which may intercept the sun's rays. Using this approach we are mapping winter-warm sites (potential winter ranges) and determining their present vegetation and winter deer use. This information will be useful in developing deer winter range mitigation plans.

Wildlife other than Deer:

In our 1971 report we stated that raising the lake level would probably reduce the 35 beavers of Big Beaver Valley to about 18, and might reduce deer winter carrying capacity by flooding the lower part of the winter range. Evidence of beaver outside of Big Beaver was noted this past year in the Lightning Creek drainage below the 1725 foot elevation. To establish whether it is a permanent colony or not will require verification in 1973.

As for other wildlife, we said (p.13) that,

"For the other mammal and bird species around the shores of Ross Lake, it seems that a rise in the lake level will flood a small part of their total range, thus disposessing a small part of their total populations."

We still believe that this is a fair assessment for most wildlife species in the Ross Lake Basin. However, there are a few species which, like the beaver, are found in lowland plant communities. These communities of sedges, willows, cottonwood, birch or aspen are small in area but mostly located below the 1725 foot line, and so would be flooded if the reservoir were raised. This would eliminate much of the habitat, around Ross Lake, for Traill's Flycatcher, Chestnut-backed Chickadee, Orange-crowned Warbler, Western Kingbird, Yellow Warbler, Black-throated Gray Warbler, Song Sparrow, Warbling Vireo, and Downy Woodpecker.

The areas of habitat in question, of course, are but a tiny fraction of the total habitat for these essentially lowland species in western Washington.

During the current year we made many additional bird observations (see Appendix E). In addition, we noted bear, goats, and elk whenever possible. 1972 was not a good year for bears. Far fewer were observed than in the previous year, and hunters took fewer. On the other hand, elk are slowly becoming more evident in the Basin. If, as one would expect, the introduced Rocky Mountain elk, continues to increase in Ross Lake Basin as it has in much of the rest of the western slope of the Cascades, the elk probably will one day be the dominant big game animal in the Ross Lake Basin.

Plans for Mitigation:

One of our objectives, in the current study, has been to develop plans for wildlife habitat mitigation -- that is, the improvement of habitat to replace any that might be lost by flooding. Our attention thus far has largely been focussed on the successional shrub winter ranges. There, from what we now know, the potential winter range area will advance upward at the same time that its lower edge is being flooded by the rising waters of the lake. The extent of upward advance is not yet known. On the shrub winter range, shrub productivity could be enhanced by the use of controlled fire, which induces sprouting, and by removal of competing vegetation. In addition, fertilization might be a practical way to increase productivity.

Plans for post-impoundment studies are being pursued in 1973. Particular attention is being given to the identification and delineation of the abrupt increase in snow depth which marks the present upper level of the deer winter range. This will provide a base point from which to measure any upward displacement during a rise in the lake level.

APPENDIX A

DEER POPULATION AND RANGE SURVEY

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Objectives

1. To estimate deer distribution and numbers seasonally by pellet-group counts on known deer concentration areas.

2. To estimate deer numbers around the whole lakeshore by direct observation.

3. To determine the chronological pattern of plant growth, comparing a variety of species and winter ranges.

4. To study productivity of known deer winter ranges.

5. To study deer movements, using marked deer.

6. To infer deer movements through observation of hybrid deer.

One method for estimation of deer use and population size is the pellet-group count. This technique was first described in the literature in 1940 by Bennett et.al., and since then has been widely used and much refined. Pellet-group counting has been defined as "the process of estimating by fecal pellet-group counts the actual or relative numbers of big game animals, or their days of use, in a given area" (Neff, 1968:59). In the following paragraphs the technique and its drawbacks are described and its mode of implementation at Ross Lake is outlined.

The procedure followed in pellet-group counting is basically simple. First, a number of sample plots are staked out on the area to be sampled. The plots are then cleared of all pellet-groups. A known number of days later they are cleared again, but this time the number of pellet groups found on each plot is recorded. With this data, an estimate of the number of deer-days or the deer population can be obtained if an estimate of the mean daily defecation rate (i.e., average number of pellet-groups deposited by one deer per day) is known. The computation is as follows:

1. Pellet-groups/acre $= \dfrac{\text{Total \# groups counted}}{\text{Total area contained by sample plot}}$

2. Deer-days/acre $= \dfrac{\text{Pellet-groups/acre}}{\text{Defecation rate}}$

3. Deer/acre $= \dfrac{\text{Deer-days/acre}}{\text{\# days in use period}}$

4. Total # deer $=$ (Deer/acre)x(#acres in sample area)

In our case, these calculations are made (1) for each transect (Tables A-1, A-2), (2) for the major winter ranges (Table A-4), and (3) for the Ross Lake basin as a whole (Table A-3).

The major questions which must be answered in the preparation of a pellet-group sampling system are concerned with : (1) shape of the sample units, (2) size of the units, (3) number of units, and (4) distribution of the units.

Many difficulties are involved in answering these questions since there are no hard and fast rules to follow. The nature of the field conditions, the accuracy desired in the population estimates, and the available manpower must all be taken into account. It was decided that belt transects would be the most efficient sample unit shape in this study. Each transect consists of three (occasionally two) long narrow plots, each plot being 109 feet long by four feet wide (equal to .01 acre). Approximately 60 belt transects were established along the shores of Ross Lake in virtually all habitat types both above and below 1725 feet elevation (see Figure A-2). The transects were distributed in a subjective manner since the magnitude and accessibility of the area to be sampled precluded the possibilities of distributing the transects in a random or systematic fashion. Pellet groups were counted and removed from the transects in April-June, July 13-14, and October 5-12, 1972. In this manner, deer usage and population estimates were obtained for winter 1971-1972, spring, and summer 1972.

There are several sources of error associated with the pellet-group count technique. Probably the most baffling problem is observer error. Human error involves personal factors such as fatigue, boredom, visual acuity, and and experience, which are difficult to evaluate (Neff, 1968). Observer error has been found to arise chiefly from missed groups. Often, especially in areas of dense vegetation errors of this type result in estimates of deer densities which are underestimates of the actual numbers. Van Etten and Bennett (1965) found that missed groups played a large part in making their pellet-group survey an underestimate. Hence, because of missed groups, it can be concluded that pellet-group density estimates will almost always be less than true density (Neff, 1968)

Other sources of human error involve difficulties in determining and standardizing what constitutes a group and in methods of dealing with peripheral groups (i.e. pellet-groups lying on the border of the plots). The minimum number of pellets to be counted as a group must be decided upon and standardized if fairly consistent results are to be obtained. Also, a method of dealing with peripheral groups must be adhered to. The problem of determining how many different groups are present when several groups are found close together is one which must be solved subjectively by the observer.

In order to eliminate as much observer error as possible, the following procedure was adopted for the Ross Lake Study. A pellet-group was considered to be within the plot if three or more pellets were within the four-foot wide strip. Thus the area actually sampled was greater than the original 0.01-acre plot. In order to compensate for this a correction factor was calculated This was obtained by measuring the distance from the edge of the plot to the outside edge of the pellet-group (Figure A-4). These distances were summed for all of the pellet-groups which were partially, but not entirely, within the plot. By averaging these measurements, the width of the area not included in the four-foot wide plot was calculated. This was then doubled to account for both sides of the transect, and added to the original transect width to obtain a corrected width. For the 1972 data this corrected width was calculated to be 6.062 feet which resulted in a corrected area of 0.0152 acre (= 109' x 6.062').

The daily defecation rate of deer is possibly another source of error in the pellet-group count technique. Much evidence indicates that the mean defecation rate varies with changes in the diet and between populations with different age structures (Dasmann and Taber, 1955; Smith, 1964; Neff, 1968). But a defecation rate of 12.7 or 13.0 groups per deer per day (13.0 was used in this study) has been commonly assumed as the average in most pellet-group surveys (McCain, 1948;Dasmann and Taber, 1955; Brown, 1961; Smith et. al., 1972).

It appears that this rate is close to the true value especially when deer are feeding upon dormant vegetation. This occurs during the winter at Ross Lake and is the period upon which the maximum population estimates are based. Hence, we believe, that the winter population estimates are not greatly affected by error from this source.

The loss of pellet-groups due to insect attack and to washing rains has been reported by some authors as resulting in considerable error in the pellet-group count (Robinette et. al., 1958; Wallmo et. al. 1962). But these sources of error are not considered to be important at Ross Lake.

Where the terrain is steep, considerable error in deer population estimates can result because of the discrepancy between the actual acreage on the ground and the estimated acreage figured from a map of the study area. This error is not involved when densities are estimated since the total acreage of the study area is not used. But the error can be important in total population estimates and will tend to make the estimates too low.

During the course of the pellet surveys, it was found that several transects had deteriorated over the winter in that the marking ribbon and/or the survey stakes had either disintegrated or had disappeared. Ribbon disintegration or disappearance apparently was caused by both cold temperatures and by deer eating the ribbon (several members of the study group have repeatedly observed this phenomenon). Stakes disappear when broken off by deer, bear, or snow and the remaining stubs covered by falling litter and debris. Because of this problem, several pellet transects could either not be found or, if found, proved to be inadequately marked for accurate re-use. Deteriorated transects outside the known deer winter ranges were replaced with new transects within areas of heavy deer winter use. Those transects which had deteriorated, but were located on known winter ranges were re-run. These could not usually be completely read down the entire length since parts of the transect parts were no longer marked. However, in every case, at least one portion of the transect was readable and data was obtained for the area. To be readable, of course, a transect must have been cleared at a previous reading and to be clearly marked at the time of present reading.

Finally, readings for winter use determination were spread over a two-month period (6April-4 June 1972) since many transects were not readable early in that period because of snow on the plots. As the snow melted, the transects were read. Areas with deepest snow showed least pellet accumulation.

From the foregoing, it may be seen that there are several errors in use of the pellet-group count to determine deer numbers on a winter concentration area:

1. Observer error, which tends to reduce the total count.

2. Possible error in the estimate of the number of pellet groups produced each day by the average deer---this estimate could be on either side of the true value.

There is still another sort of error. Pellet-group plots are cleared in the fall, before all the deer are on the winter range, and read in spring, when some may have left the winter range. The pellet accumulation during the period between these two clearings is the average use during the period, which is somewhat less than the maximum intensity of use during the period.

The tendency of two of these three errors is to give a deer population estimate lower than the true value; the tendency of the remaining error is unknown. From present knowledge, then, it seems reasonable to suppose that our population estimates involving pellet-group counts are definitely below the true value.

The estimates are probably of greatest significance when they are used as indicators of relative abundance between winter ranges and different elevations since the errors discussed above do not influence the technique when it is used in this manner.

In the major winter areas (see Figure A-1) we estimate 206 deer to be the mean population with a confidence limit from 187 to 224 (see Table A-4)

Secondly, it was determined from the pellet transects that the deer in the Ross Lake basin utilize the area above 1725 feet elevation more than that below 1725 feet. In winter, the level of utilization below 1725 feet is about 30 percent, while, over the entire year, the utilization is about 40 percent of the use of the winter range above 1725 feet (see Table A-3).

Estimate of Deer Numbers Thru Direct Observation

During January and February, deer drop down close to the lake shore, and thus become more visible from the lake than usual. Direct counts may be made from a boat at this time, although the drawdown of the lake for power generation may hamper navigation around the north end.

When direct counts on winter ranges are compared to deer actually counted as the same winter range, we get the following:

	Deer On Winter Ranges (By Pellet-Group Count)	Deer Observed On Same Areas	Percent Observed
Winter of 1970-71	227	172	76
Winter of 1971-72	206	178	86

Thus, in one winter we actually observed 76 percent of the estimated deer population, and in the second winter we actually observed 86 percent of the estimated deer population, on the same areas of known deer concentration.

This information can be combined with the results of direct deer counts around the whole lake shore, as follows:

	Deer Observed All Around Lake	Percentage of Total Deer Around Lake	Total Deer Around Lake*
Winter of 1970-71	232	76	305
Winter of 1971-72	215	86	250

*First column divided by second column times 100.

It will be recalled that these estimates of the total deer around the lake are probably underestimates because the estimate of deer on the winter range (as shown by pellet-group counts) is probably an underestimate.

In addition, the direct count of deer around the lake shore as a whole, because of the vagaries of navigation and shoreline cover, is probably not as complete as the count of visible deer on known winter ranges. This, too, would tend to give an underestimate.

Finally, not all deer winter close around the lake shore. Those which do are of greatest interest in this study, because they are most likely to be affected by a change in lake level. But in the interest of determining the deer population of the Ross Lake Basin as a whole, we must consider the possibility that some deer winter further up the slopes, on steep south-facing slopes which are largely snow-free in winter. Certainly appreciable numbers of deer winter in such situations in Canada, as is shown by the findings of our Canadian counterparts.

While we have searched the Basin from the air in winter, and seen the occasional deer, the country is so extensive and broken that some more effective means of investigating this problem has been needed. Now we have two further aids.

The movements of radio-marked deer show some of them drawing near to a high southerly face just west of Lake Hozomeen. So one high winter range is located. Further south around the lake we do not have radio-marked deer to guide us. But we have been determining the amount of solar radiation, which helps pinpoint the areas which are "hottest" during the winter and hence potential winter ranges.

Phenology Investigations

Considerable effort was directed toward the flora of Ross Lake as a preliminary to measuring the carrying capacity of the various ranges and habitats of the Ross Lake Basin, both before and after raising Ross Dam. Preparatory to productivity studies, differential rates of growth, if any, had to be determined both above and below 1725 feet elevation and in various areas around the Lake. Thus, in early April, 22 phenology plots were established to gather quantitative data on comparative calendar growth. Seven plots were located above 1725 feet while 15 plots were below; all plots above 1725 feet had at least one matching plot directly below it on the slope at 1600 feet (see Figure A-3 for location of plots). Four species of plants were selected as those occurring in the most number of areas around the Lake: Vine Maple (Acer circinatum), Douglas-fir (Pseudotsuga menziesii, saplings only), Mountain Oregon Grape (Berberis nervosa), and Prince's Pine (= Pipsissewa, Chimaphila umbellata). As much as possible, all plots were set in similar environments: under moderate (25 to 50 percent) canopies, in moderately well-drained (but not arid) areas, and on relatively flat terrain (although most plots had a slight slope toward the lake).

Within each plot (plot sizes ranged from about 20 to 50 feet diameter), six representative plants of each of the four study species were selected, measured, and marked with flagging. Where fewer individual plants were found, fewer were sampled. Only one species, Mountain Oregon Grape, was found in all study areas. After the initial measurement, readings were taken approximately every two weeks through the middle of July when spring growth ended. All raw data is maintained on file at the University of Washington in Seattle.

As a result of the phenological investigations, it was determined that there is no discernable growth differences between the north and south ends of the lake and between 1600 and 1725 feet elevation. This is to say that spring growth started, progressed, and finished at approximately the same time (within two weeks at either extreme). Significant differences in growth patterns were not found until about 3000 feet elevation where the start of the growing season appeared delayed by about one month, evidently due to colder temperatures and, consequently, lingering snow patches. In a similar manner, no obvious difference trends were found between east and west sides.

Phenologically, then, Ross Lake appears to be uniform in its seasonal growth patterns in the areas proximate to the lake shore up to elevation about 3000 feet. Most areas along the lake were free of snow in early April; those that were not (such as the creek valleys and avalanche chutes) may be assumed to follow growth patterns similar to the higher elevations and thus are not of immediate importance to the study of winter ranges. These results suggest that the growth pattern along the lake shore is a function of the overall climate of the valley which appears to be generally uniform at the lower elevations. We are further investigating the small differences we found within this general pattern.

Productivity Investigations

Those major browse species selected for study include Serviceberry (Amelanchier alnifolia), Red-stemmed Ceanothus (= Buckbrush, Ceanothus sanguineus), Bitter Cherry (Prunus), Vine Maple (Acer circinatum), and various Willows (Salix spp.), in order of their considered relative importance. Relative importance estimates are based on abundance and degree of deer use of the plant species.

Satisfactory results from plant productivity analysis could not be obtained if the deer browsed the plants during the study. Therefore, in early June, 25 exclosures (five in each area) four feet high by six feet square were erected in five winter ranges: Ruby Horse Pasture and vicinity, Roland Bay (east side), Pumpkin Mountain brushfield (southeast quadrant), Skymo brushfield, and Lightning Creek. Each exclosure contained representative plants, including specimens of all principal browse species. The effectiveness of these exclosures has already been observed: in several areas, comparable plants outside the exclosures have been browsed by resident summer deer while those inside have not been touched except along the edges of the fencing.

In late September 1972, each of these exclosures and a matching plot outside were photographed. This is a technique whereby photographs are taken of the plants inside the exclosures from a set distance and of comparable plants of the same species outside the fencing at the same distance. It is planned that in April 1973, another series of photopoints will be taken. A comparison of these photographs will give one measure of winter consumption of shrub forage by deer.

Certain items may be noted (without quantitative confirmation) in reference to browse species availability and abundance. First, it would appear that Serviceberry (Amelanchier alnifolia) is the most widespread food plant in the Ross Lake basin available to deer and, from other studies, is known to be a highly preferred deer food (White, 1960). It's estimated abundance in various winter ranges is: Lightning Creek - Desolation Mountain (widely abundant), Skymo brushfield (abundant, but growing out of reach of deer - about 4.5 feet), Pumpkin Mountain brushfield (common, but mostly too tall), Roland Bay (sparse and heavily browsed), and Ruby Pasture vicinity (very sparse). Red-stemmed Ceanothus (Ceanothus sanguineus) appears to be the next most important (and consequently relied upon) browse species, but occurs only in Skymo brushfield (extremely abundant), Lightning Creek - Desolation Mountain (moderately abundant), and Pumpkin Mountain (sparse and heavily browsed). It would seem from this preliminary assessment, Lightning Creek - Desolation Mountain winter range is most capable of supporting a large deer population followed (in order) by Skymo brushfield, Pumpkin Mountain, Roland Bay, and Ruby Horse Pasture. What is not known at this point, however, is the specific amounts of deer the areas will potentially support, the proportion of available winter forage actually consumed, or the degree to which the ranges will be affected if the lake level is raised. These are all under study.

A small experiment to determine the effects of nitrogen fertilization on browse production was begun. In early April urea was applied to plots on four deer winter ranges. Treated and comparable untreated areas have been fenced to protect the new growth from deer browsing through the winter.

The dynamics of plant succession is important in deer winter range ecology, because the brushy areas created by fire are usually invaded by tree seedlings. As the trees mature, they compete with the shrubs, lowering shrub productivity. Our initial studies of this dynamic process are presented in Appendix C.

Another field of productivity investigation currently being undertaken is the production and consumption of forage by deer which winter within the mature forest. Early in winter 1972, it was noticed that a "browse-line" of lichens growing on trees occurred in Roland Point and Ruby Arm areas. An initial survey in March showed that several tons per acre of lichens grow in the trees between Roland Point and Ruby Arm and are potentially available to deer. These lichen studies are detailed in Appendix D. It been determined how much of this lichen falls to the ground each winter and thus becomes actually available for forage. It is not inconceivable that lichens constitute the major portion of the diet of those deer wintering in the southeast section of Ross Lake since other food sources are in short supply in the area and lichen is known to be heavily utilized in areas of high food stress (Cowan, 1945). On the mature forest winterranges which produce lichen, Douglas-fir foliage may also prove to be animportant winter food. This will be investigated in the winter of 1973.

Other studies involved with productivity include applied techniques whereby measurement of yearly growth in pounds per acre for each browse species is determined. One technique, as described in the 1971 report, utilizes a weight-per-twig-length curve. It has been found that this curve differs somewhat from plant to plant. The reasons for this are being investigated, with the aim of developing an accurate means of estimating shrub forage production.

Observational Study

The winter deer surveys provided preliminary data regarding doe/fawn ratios. However, it is interesting to note that two surveys (January and February) on Ross Lake produced doe/fawn ratios 1 : 1.21 and 1 : 1.29 (mean of 1 : 1.25). Two similar concurrent surveys on nearby Diablo Lake where the deer are being artificially fed showed 1 : 1.15 and 1 : 1.35 (mean of 1 : 1.25). These surveys were taken in a period of time (January - February) when the effects of winter possibly had not yet been felt by the deer. Although commonly used as a rough index of herd productivity (with ratios of over 1.1 considered satisfactory), the doe/fawn count contains a hidden source of error which may influence the results. This is the presence in the population of a non-producing group, the yearling does (which have not yet produced fawns). If the fawn crop of the previous year was good, then the number of yearling females the current year is high, reducing the doe/fawn ratio. This tends to mask the difference between ranges of high and medium productivity, although those of low productivity are still distinguishable. We would judge that productivity in Ross Lake deer is not low.

It is known from the 1971 investigations that the deer herd of Ross Lake consists almost entirely of intergrade Mule - Blacktail Deer (Odocoileus hemionus hemionus X O. h. columbianus) (see Figure A-5). One of the immediate objectives of the project was determination of the degree of interbreeding within the population and particularly whether the degree of hybridization could be used to identify sub-populations as a help in reconstructing seasonal movements. During 1972, continous direct observation provided considerable data for computation and quantitative analysis of the intergrade population. This data is summarized in Table A-7.

Certain trends may be noted, especially with regard to genetic flow from the east (mule deer) and west (blacktail) when the intergrade composition data is compared with known seasonal deer movements.

First, from Figure A-6, it would appear that Mule Deer genetic influx is from the north and east while Blacktail influx is from the south and west; and that a genetic gradient extends from one end of the impoundment to the other on the east side.

Breeding takes place in November. At this time hybridzation could take place between the mule deer populations lying eastward in the Pasayten and the blacktail populations lying downstream in the Skagit Valley. The pattern of hybridization (figure A-6) suggests that the major influx of mule deer blood enters from the northeastern region, and then passes southward along the eastern shore of the lake, around the foot of the lake, and up the western shore. This argues that there is little mingling of deer in the northwest.

The hybridization of deer is quite interesting from the scientific point of view, particularly since collections in the northeast have shown deformation of unborn fawns, for which a possible explanation is genetic incompatibility. However, we do not see how the situation would be materially affected by a change in the lake level, particularly since deer have been seen swimming across the lake.

Direct observation proved to be the only effective method of locating deer in some inaccessible areas in both winter and summer. In these instances, it proved sufficient just to find signs to indicate the presence or absence of deer. Three major backpack trips were made during 1972 with the intention of locating deer: Big Beaver Valley on 1 - 4 March, Hozameen Lake via Lightning Creek trail on 1 - 2 July, and Freezeout Basin via Lightning Creek trail on 28 - 29 July.

The Big Beaver trip was made on snowshoes under the worst possible weather conditions: snow depth ranged from six feet (within forest) to eight feet (in open areas) and the temperature hovered at 32 degrees thus producing a wet snow through which a snowshoe sank one to two feet making hiking extremely difficult. It took us four days just to hike the six miles out of the valley (after having been dropped by helicopter at Ten-mile shelter). During this time, we sighted marten, mink, several resident avian species, hare, coyote and cougar tracks, but not a single sign of deer until we reached about 200 yards from the mouth of Big Beaver Creek where the snow depth abruptly decreased to about two feet. We concluded that deer do not utilize Big Beaver Valley in the winter. It should be noted that deer signs were not observed in the valley until mid-May by then the snow had melted enough to permit deer travel.

The Hozameen Lake trip was made in an attempt to locate deer signs and, if possible, any tagged deer along the route. Pellets and fresh tracks were observed along the trail as far back as two miles into Lightning Creek valley after which no signs were sighted until we reached the Hozameen Lake area. Generally, the valley is heavily forested and provides little available browse.

Deer tracks and pellets were first observed about 1/2 mile southeast of the Hozameen Lake trail intersection. Around Hozameen Lake itself, deer signs were abundant and several fishermen said that they had seen deer in camp.

The Freezeout Basin trip had a similar mission to that of the Hozameen Lake trip: determination of the presence or absence of deerand, in this case, possible repetition of a 1971 sighting of large number of deer summering in the Basin. Again, no deer signs were evident deep inLightning Creek valley past the two-mile mark on the southern section of trail. Tracks were found, however, in abundance along the Freezeout trail after leaving the Nightmare Camp intersection. Within the Basin itself, many fresh tracks were found, but no deer sighted. However, it is probable that, in view of the evidence of deer signs from Hozameen to Nightmare to Freezeout, that some deer from the northern section of Ross Lake summer in Freezeout Basin. The movements of radio-marked deer show that in summer some deer do indeed move from the head of the lake up into the high country of the Pasayten.

Miscellaneous

Several smaller projects with regard to deer were accomplished at Ross Lake in 1972. In May and June, ten deer were captured, tagged, and released in the Lightning Creek - Dry Creek Point areas. Nine of these were does and the tenth a small buck (six inch antlers in velvet). The method of capture was simply to stretch a noose on the ground and jerk it tight when one of these campground deer stepped into it. Tagging was with color-coded ear streamers and numbered metal tags. Most of these deer stayed in the same general area until early August.

As in 1971, an attempt was made to gather deer harvest information. The Canadian researchers of Slaney, Ltd. ran a game check station during the early and regular deer hunting seasons while the University of Washington study group ran hunter censuses on the lake on 14 - 20 September, 13-15 October. In addition, Washington State Game Department ran a weekend check station near Lyman on State Route 20. From these sources, it was determined that a total of about four deer were killed in the Ross Lake area during both the regular hunting season and the early "high hunt". This is in comparison with the estimated 14 deer taken in 1971. An estimated 18 different hunters spent about 90 hunter-days in the Ross Lake basin in 1972. Thus, it would appear that the Ross Lake area is not heavily hunted and the annual harvest probably has practically no impact on the population.

Discussion and Summary

First, we have a minimal estimate of 250 - 300 deer around the lake shore in winter.

Second, we confirmed our 1971 identification of the deer winter ranges and quantified various aspects regarding these areas. Some 74 - 82% of the total deer population uses these main deer winter ranges. Areas outside these winter ranges generally accumulate snow in too great a depth or forage levels are too low for deer use. By and large, the major winter areas are brushfields or open forests (mostly second-growth) proximal to the lake where the snow depth is the least.

Third, the eventual outlook for the Ross Lake area insofar as deer are concerned, if left undisturbed by either man or nature, is not good. The remaining brushfields which support most of the wintering deer are growing out of their usefulness and, in a few years, will not be capable of supporting the current level of deer numbers (refer to Appendix C for age/class structures of the brushfields). An excellent example of this occurrence is Skymo brushfield in which there are many browse plants which have already grown too high to be reached by deer.

Even if a rise in the lake level causes a rise in the shallow-snow zone around the lake, successional ranges will still tend to revert to forest. Their perpetuation as productive deer wintering areas will require some husbandry. At present some combination of cutting and burning, and perhaps fertilization, seems worthy of further study.

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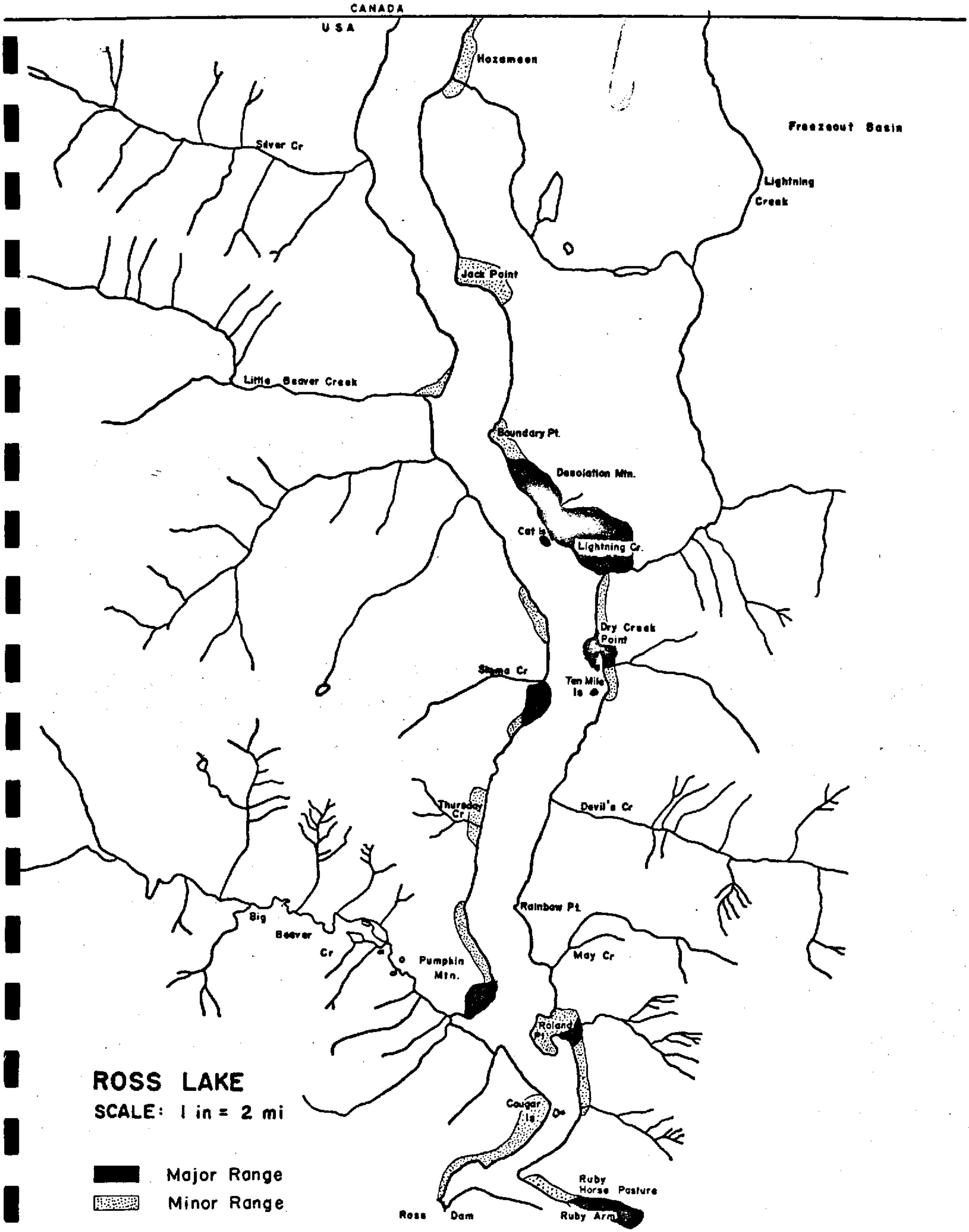
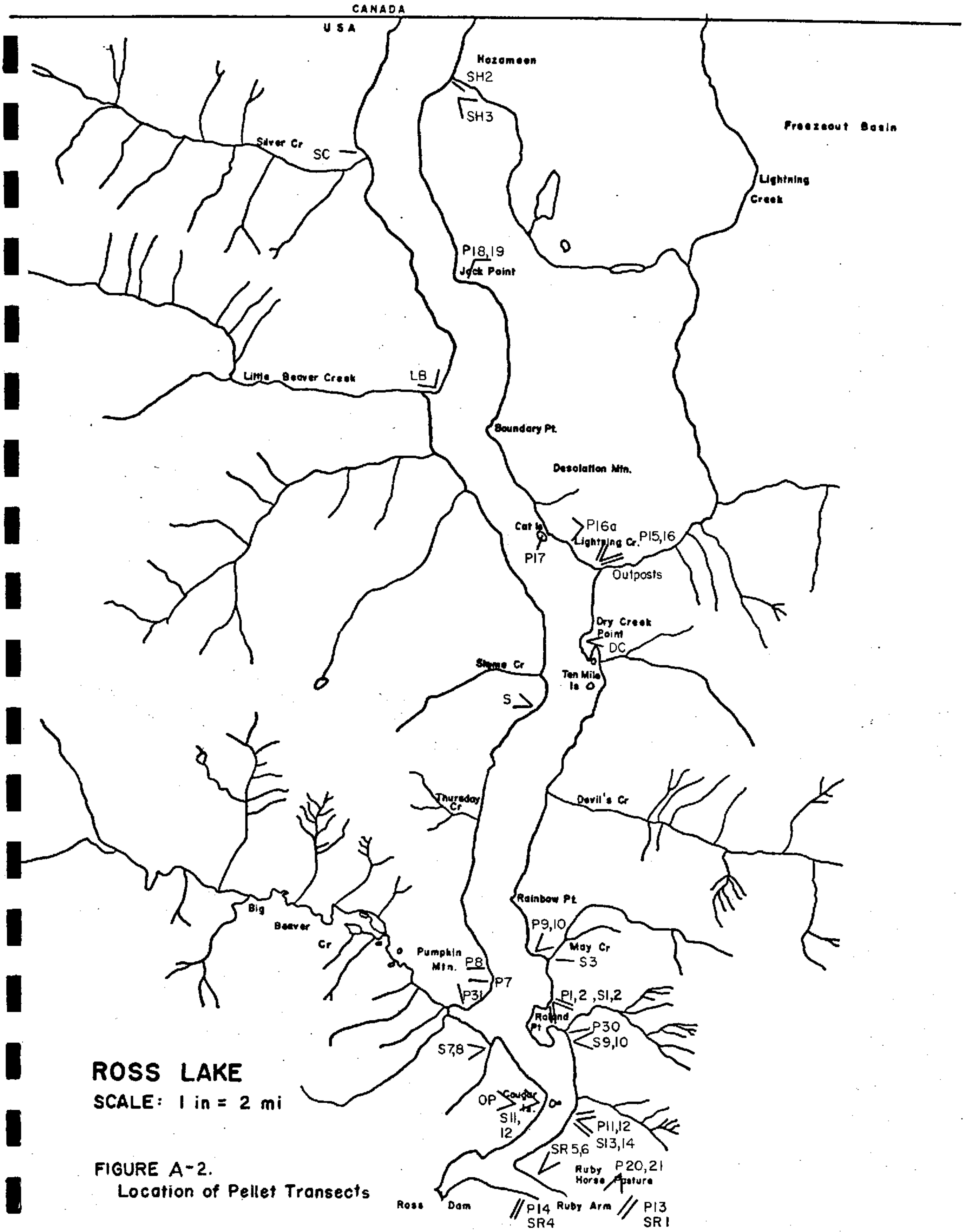
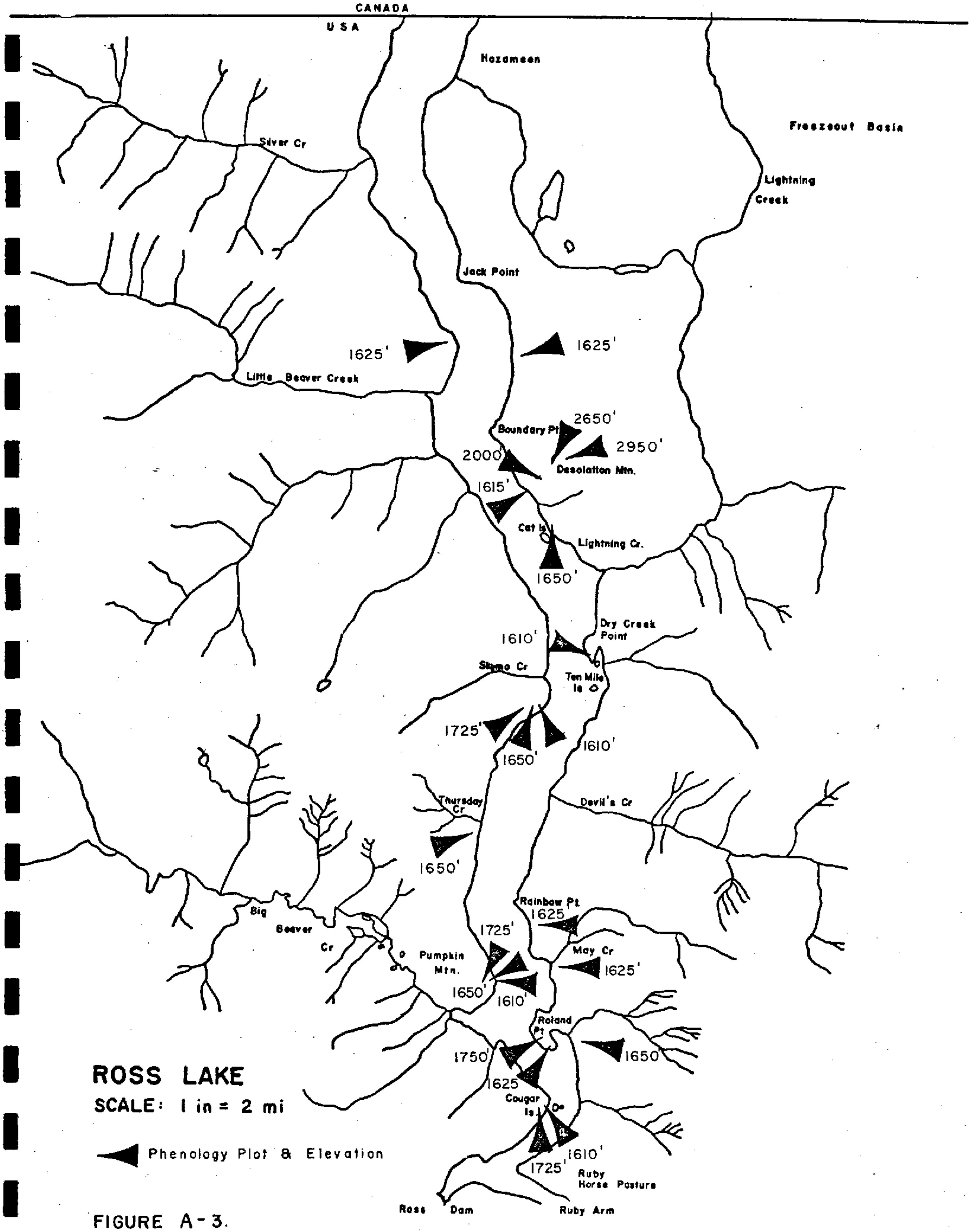


FIGURE A-1. Deer Winter Ranges



ROSS LAKE
SCALE: 1 in = 2 mi

FIGURE A-2.
Location of Pellet Transects



ROSS LAKE

SCALE: 1 in = 2 mi

Phenology Plot & Elevation

FIGURE A-3.
Location of Phenology Plots

Table A-1. Estimates of deer per acre for U.W. pellet transect 1972

	Deer Per Acre		
Transect[1]	Nov. 71 - April 72	April 72 - July 72	July 72 - October 72
Below 1725'			
P1, P2	.047	.000	.001
P7	.032	.018	.000
P8	.011	.038	.060
P9, P10	.001	*2	.000
P11, P12	.037	.019	.010
P13	*2	.000	.030
P14	.000	.000	.000
P16a in	.192	.021	.018
P17	.297	.233	.018
P18	.028	*2	.000
P30	.038	*2	.000
P31	.160	*2	.018
Above 1725'			
P16a out	.182	.288	.018
P15, P16	.048	.000	.028
P19	.076	*2	.010
P20	.696[3]	.037	.000
P21	.284[3]	.111	.000

[1] See Figure A-2 for location of pellet transects.

[2] For one reason or another, these transects were not read in July. (usually due to delayed winter reading in June).

[3] See note 3 at bottom of Table A-4

Table A-2. Estimates of deer per acre for State Game pellet transects.

Deer Per Acre

Transect[1]	Nov 71 - April 72	April 72 - July 72	July 72 - October 72
Below 1725'			
S1, S2	.032	.010	.027
S3	.000	.028	.056
S7, S8	.004	*2	.000
S9, S10	.016	.009	.000
S11, S12	.239	.123	.040
S13, S14	.048	.093	.020
SR1	.008	*2	.015
SR4	.000	.018	.000
SR5, SR6	.011	.000	.010
SH2	.052	*2	.022
Dry Creek	.122	.241	.028
Little Beaver Cr.	.231	.056	.020
Silver Cr.	.008	*2	.000
Skymo	.188	.056	.019
Above 1725'			
Sh3	.000	*2	.000
Lightning OP	.075	.066	.018
Cougar Is. OP	.209	*2	.041

[1] See Figure A-2 for location of pellet transects.

[2] For one reason or another, these transects were not read in July (usually due to delayed winter reading in June).

Table A-3. Estimated deer per acre for all pellet transects 1972.

Elevation	Yearly deer/acre	Seasonal deer/acre		
		Winter	Spring	Summer
1600 - 1725'	.044	.081	.047	.019
Above 1725'	.106	.249	.084	.019

Table A-4. Estimated deer per acre on winter ranges. Ross Lake, 1971 - 1972

Area Name	Acrease	Deer/Acre	Calculated No. of deer (1971)	Deer Actually Observed	Deer/Acre (1972)	Calculated No. of deer (1972)	Deer Actually Observed
Jack Point	100.0	0.076	7.6	18	0.040	4.0	--
Little Beaver	103.0	0.106	10.9	6	0.231	23.8	3
Boundary Point	17.2	0.142	2.4	18	-----	----	10
Lightning Creek	642.0	0.142	91.2	53	0.124	79.6	54
Cat Island	8.0	0.481	4.0	3	0.297	2.4	1
Dry Creek	80.4	0.126	10.1	6	0.122	9.8	12
Skymo	91.8	0.142	13.0	5	0.188	17.3	30
Pumpkin Mtn.	167.5	0.127	21.3	23	0.16	26.8	23
Roland Point	287.0	0.070	20.0	9	0.040	11.5	13
Cougar Is. and Point	114.7	0.152	17.4	15	0.224	25.7	19
Ruby Arm and Pasture	114.8	0.254	29.2	16	0.590***	67.0***	13
Pumpkin Mt. to Thursday Creek***	167.5	- ---	----	23	- ---	----	14
Other**	-----	-----	----	37	-----	----	23
Total Deer			227.1*	232.0		271.1 (233.3)	215

*1971 Minimum estimates - see Vol. I (1971 Report, p. E-15).
**Not within winter ranges; no pellet transects established.
***In Feb., 1972, a windstorm blew several large conifers directly on top of the pellet transects near Ruby Horse Pasture; as a result, many deer concentrated for several days (or weeks) in the area thus producing an unrealistically high bias in the pellet counts. Use 1971 counts for realistic estimates.

Table A-5. Deer Sightings by Elevation and Area, January - February 1972*

Area	Lake-1724	1725-1824	1825-1924	1925-2024	2025-2124	2125-2224	2225-2324	2325-2424	2425-2524	2525-2624	Above 2625
Ross Dam to Green Point	11	--	--	--	--	--	--	--	--	--	--
Green Point to Cougar Is.	23	2	--	--	--	--	--	--	--	--	--
Cougar Is. to Big Beaver Cr.	16	7	--	--	--	--	--	--	--	--	--
Big Beaver Cr. & Pumpkin Mt.	18	1	2	--	--	--	4	--	4	--	6
N. of Pumpkin Mt. to Thursday Cr	40	3	--	--	--	--	--	--	--	--	--
Thursday Cr. to Skymo Cr.	35	11	--	--	--	--	--	--	--	--	--
Skymo Cr. to Little Beaver Cr.	2	6	--	--	--	--	--	--	--	--	--
Little Beaver N. to border and border S. to Jack Point	8	2	--	--	--	--	--	--	--	2	--
Jack Pt. and Boundary Bay	3	5	--	--	--	--	--	--	--	--	--
Boundary Pt. to Cat Is.	21	--	4	1	--	--	--	--	--	--	--
Cat Is. to Ten-Mile Is.	45	12	--	--	2	--	9	--	2	--	--
Ten-Mile Is. to Rainbow Pt.	4	--	--	--	--	--	--	--	--	--	--
Rainbow Pt. to N. of Roland Pt.	5	--	--	--	--	--	--	--	--	--	--
Roland Pt. to Ruby Pt.	32	--	--	--	--	--	--	--	--	--	--
Ruby Arm and Jeep Rd. to Ross Dam	4	3	5	--	--	--	--	--	--	--	--
Totals	275	52	11	1	2	0	13	0	6	2	6

*Includes duplicate sightings, recounts, and by all means of transportation

Table A-6. 95 Percent Confidence Limits for estimated deer populations on six general winter ranges and on remainder of lake areas using results from pellet transects and from sight-index.*

Area	Pellet Transects		Sight-Index	
	T_u	T_l	T_u	T_l
Lightning-Desolation	102.63	88.97	230.47	32.87
Skymo	20.32	14.28	63.37	39.97
Pumpkin	28.36	25.24	100.23	53.10
Cougar	28.72	22.68	73.47	26.53
Roland	12.45	10.55	66.80	19.87
Ruby	32.22	26.18	**	**
Other Areas	101.58	98.62	187.03	46.30
Totals	326.28	286.52	721.37	218.64

*T_u indicates upper confidence limit of the estimate: T_l indicates lower confidence limit.

**Sight-Index in Ruby winter range was too low to apply to the formula, due mostly to inaccesibility of area.

Explanation of Confidence Limits

It is highly desirable that a statement of accuracy accompany estimates of deer population since exact measures of wildlife populations are practically impossible. A common means of doing this is the use of confidence limits delineating the outside intervals of a population in which there is a given chance (in this case, 95%) the actual population falls inside. The general formula (from Snedecor and Cochran, 1967) is:

$$P\left\{\bar{x}-t\frac{a}{2}\frac{s^2}{n} \leq m \leq \bar{x}+t\frac{a}{2}\frac{s^2}{n}\right\} = 95\%$$

where:

m = population mean (the actual population, a theoretical unknown).

= sample mean as determined by pellet transects and sight-index.

t = tabled value at a given level of significance (from tables at 95% significance).

a = level of significance (95%).

s^2 = estimated variance for each area sampled, obtained from formula:

$$s^2 = \sum \frac{(\bar{X}_1^2 + \ldots + \bar{X}_1^{-2})}{n-1}$$

n = sample size, i.e. number of pellet transects or sight-counts in each range.

Thus, this formula would read: "The probability (P) that the actual population (m) lies between the calculated lower and upper limits is 95 percent.

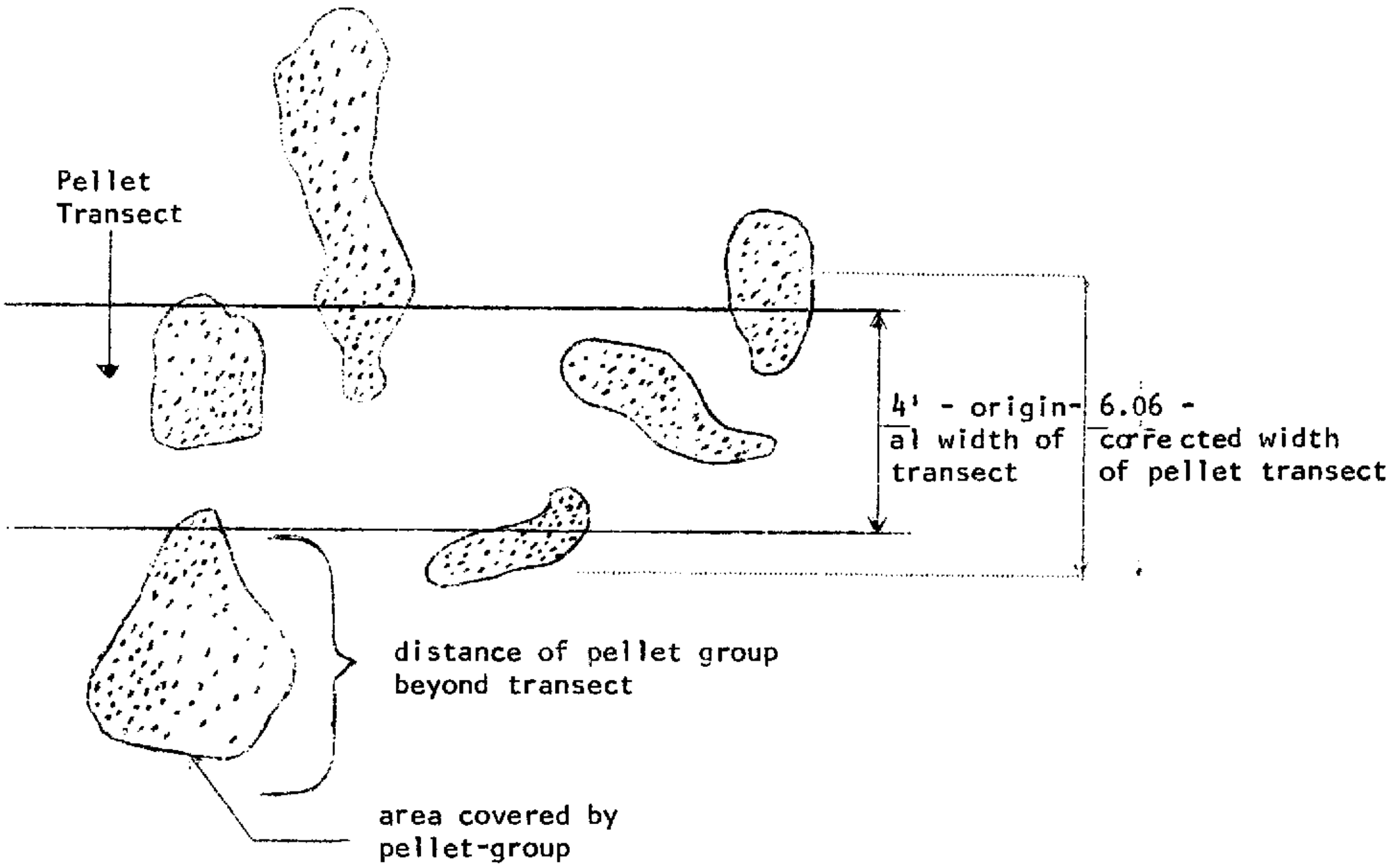


Figure A-4 Calculation of edge effect for pellet transect. The distance beyond the edge of the pellet transect was measured for 102 pellet-groups and averaged. This average was doubled (the transects have two sides) and added to the original width to make the corrected pellet transect width. Since the diameter of the average pellet-group is large with respect to thewidth of the additional strip calculated in this way, the chance of a group being within the additional strip but not touching the main pellet transect is low.

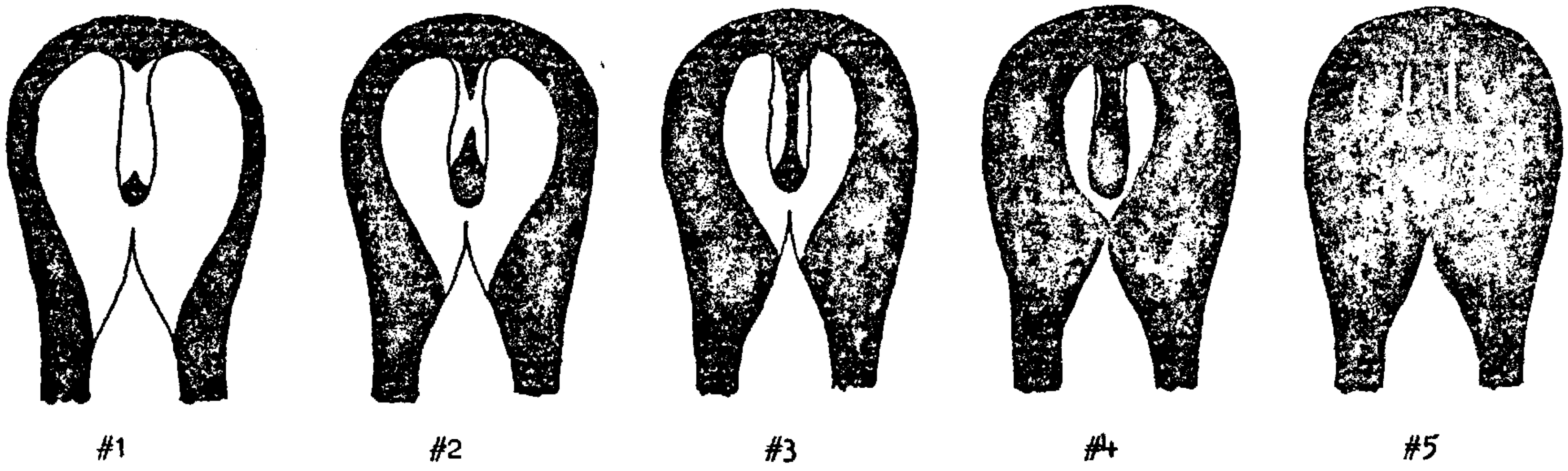


FIGURE A-5

TAIL AND RUMP-PATCH CLASSES IN ROSS LAKE DEER (Odocoileus hemionus subspp.)

Tail and rump-patch patterns are recorded together, but separated by a slash to give a hybrid index for each deer. For example, an individual with a #2 tail, but with a #4 rump patch would be recorded as a 2/4 (tail/rump).

These indices are ultimately added together to indicate the degree of intergrade; low values show trend toward mule deer while high values indicate black-tailed deer. Information on each index should include, if possible, date, sex, age, and, most importantly, location.

Table A-7. Frequency Distribution of Tail/Rump Index by area.

Tail/Rump Index Total	Area[1] A	B	C	D	E	F	G	H	I	J	Total
# 3				1	1						2
4				19	7			5	1	1	33
5	3	1	1	14	7	3	3	19	6	3	60
6	2	6	5	15	k0	20	2	18	24	1	103
7	7	6	3	8	2	3	1	14	14		58
8	13	12	3	1	2	2	1	4	12	1	51
9	1							1		1	3
Total	26	25	12	58	29	28	7	61	57	7	310
Mean	7.27	7.16	6.67	5.24	5.38	6.11		5.93	6.53	6.00	6.12

[1] Area Descriptions

A = South of Big Beaver Creek to Ross Dam

B = Big Beaver Creek to Thursday Creek

C = North of Thursday Creek

D = North of Lightning Creek to Hozameen Road's end

E = Lightning Creek to Rainbow Point

F = Rainbow Point to Ruby Arm

G = Ruby Arm South to Ross Dam

H = Neck of Diablo Lake North from Light 5 to Ross Dam

I = Body of Diablo Lake South from Light 5

J = Canada South to Hozameen Road's end Updated thru 14 Sep 72

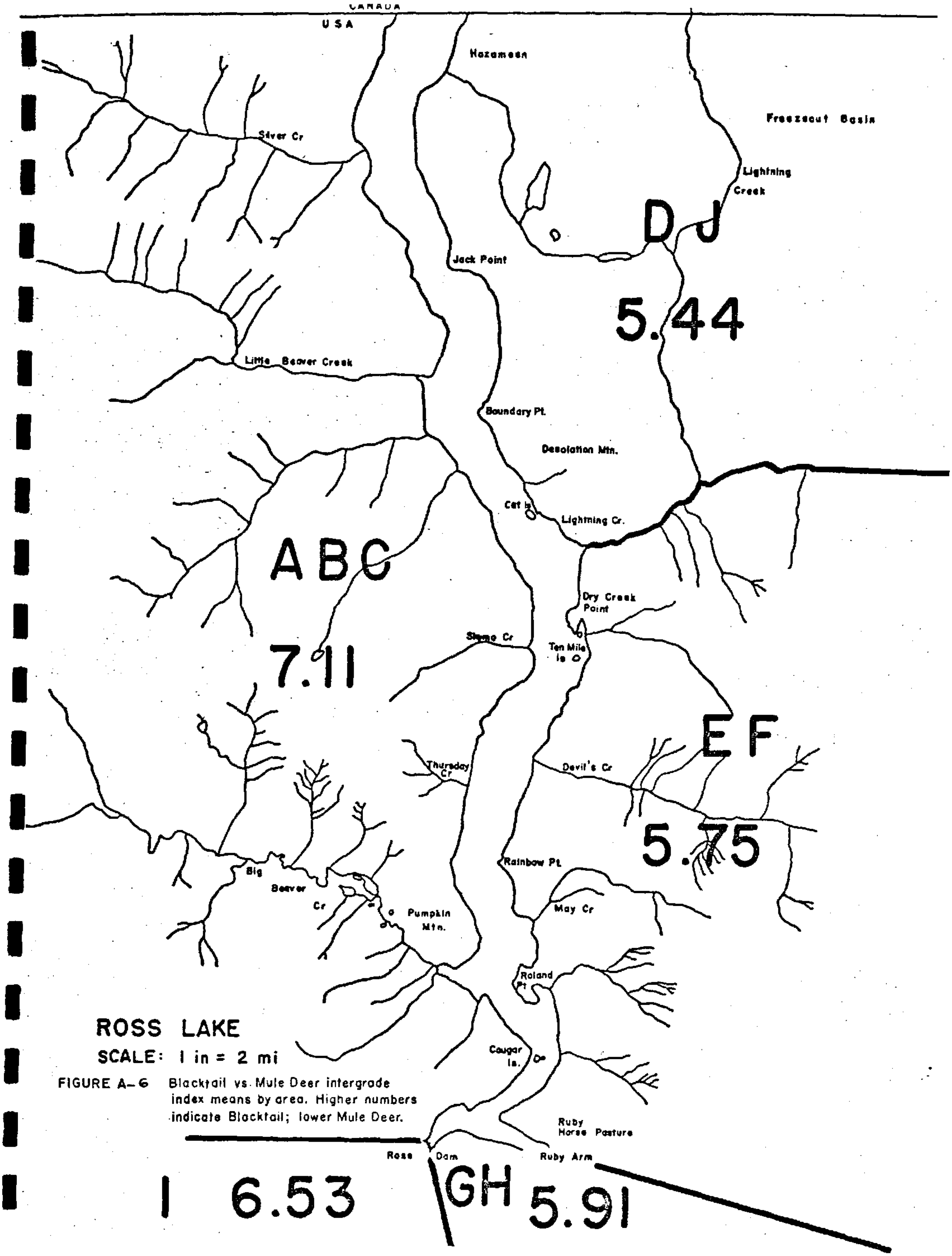


FIGURE A-6 Blacktail vs. Mule Deer intergrade index means by area. Higher numbers indicate Blacktail; lower Mule Deer.

APPENDIX B

DYNAMICS OF SHRUB SUCCESSION FOLLOWING DISTURBANCE

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TABLE OF CONTENTS

INTRODUCTION

The re-establishment of a forest canopy following fire or other disturbance and the resultant reduction in shrub productivity is thought to influence the size and migration of deer populations in the Ross Lake Basin. An understanding of plant succession and growth dynamics is therefore required before plant-animal population relationships can be completely delineated.

Scott, Long, and Barber (Biotic Survey of Ross Lake Basin, 1971) ordered the plant communities surrounding Ross Lake into seven broadly defined categories: rock outcrop type, hardwood type, Douglas-fir type, brush type, lodgepole pine type, hemlock type, and Douglas-fir climax type. The hardwood, brush, and Douglas-fir types are most pertinent here, since the winter deer range is now concentrated in areas characterized by these three community types.

The purpose of the present study was to investigate and reconstruct the successional patterns of plant communities or vegetation types in areas reported to be the centers of Ross Lake's winter deer population. Application of current patterns and growth dynamics determined by the study should allow the length of seral stages and the types of communities that can be expected to follow fire disturbance to be predicted for sites other than those studied here.

Since it is the apparent successor of brush seral communities, Douglas-fir is a critical factor from the standpoint of brush productivity. Evidence of the invasion of brush communities by Douglas-fir is widespread throughout the Ross Lake area. So while density and growth estimates of brush species are important measures of browse productivity in an area, it is the density, distribution, and growth dynamics of Douglas-fir saplings and seedlings which will determine the future productivity of browse species.

METHODS

Sampling was random within the areas typed as brush, hardwood, and immature Douglas-fir. Plot sites were located on Pumpkin Mountain, the brushfields south of Skymo Creek, the Lightning Creek-Desolation Mountain area, and the Silver Creek Delta. With the exception of Silver Creek Delta, these areas have all been identified as the winter feeding areas to which the deer population migrates. The Roland Bay area has also been identified as a major winter deer range, but the predominant browse is thought to be Douglas-fir foliage and lichens growing within mature Douglas-fir stands (Boehm, 1971). But due to the scarcity of shrubs reported as favored browse species and the relatively advanced successional stage of the Douglas-fir community, the Roland Bay area was not included in this study. The Silver Creek Delta was chosen because there were abundant saplings and shrub species there. Most plot sites were below 561 meters (1,850 feet) above sea level; all were either within the zone of flooding or no more than 125 feet above the proposed high water level.

Each site was sampled within a 5X25 meter plot based on a variation of the design used by Daubenmire. The base corner of each plot was randomly chosen and the long axis of the plot established parallel to the contour.

Altitude, aspect, slope, and topography were determined at each site, and a general description including fire history, browse evidence, presence of deer trails, and other prominent features was recorded for each area. The overstory, understory, and ground coverage were estimated for each plot. The frequency and cover of herbs and shrubs were also recorded, and cross-sectional stem samples and borings were taken in order to age the woody species and to measure stem elongation.

Individual trees within each plot were identified by species and their diameter at breast height (dbh) measured to the nearest 2 inches. Individuals dbh's were then converted to basal area and the basal area expressed in metric units. Heights and ages of selected trees were also determined. Individuals whose dbh was greater than 2 inches and/or trees more than 12 feet high were tallied as trees. Specimens more than 12 feet high but less than 2 inches in diameter at breast height were categorized as saplings. Seedlings were defined as trees under 12 feet high and less than 2 inches in dbh, and were recorded only in terms of ground cover estimates.

A total of 25 microplots were established contiguously along the long sides of each plot, and the coverage and frequency of all species of tree seedlings, shrubs, and herbs were determined for each microplot. Coverage estimates were divided into six classes: (1) 0-5%; (2) 5-25%; (3) 25-50%; (4) 50-75%; (5) 75-95%; and (6) 95-100%.

Deer are thought to browse most heavily on the following plant species; Amelanchier alnifolia, Ceanothus sanguineus, Rubus gymnocarpa, Berberis nervosa, Acer circinatum, and Acer glabrum. Although the latter two species and Amelanchier alnifolia often appear as single-stemmed individuals which sometimes exceed 2 inches in diameter at breast height, they were all referred to as shrubs in this study. The variations in size and form of Salix spp., Prunus emarginata, and Betula papyrifera posed similar problems in classification. Prunus emarginata and Salix spp. were observed most frequently in clumps of stems less than 2 inches dbh, but they also occurred as single-stemmed individuals with 2-6 inch diameters at breast height. Salix spp., Prunus emarginata, Betula papyrifera, Corylus cornuta var. californica, Acer glabrum, Acer circinatum, and Amelanchier alnifolia were defined as shrub species for the purpose of the present study

The heights and ages of large clumped or single-stem shrubs were sampled, and their density was recorded as coverage class estimates based on the 25 microplots within each plot. The number of clumps and single-stemmed individuals inside a given plot but outside the microplots were usually recorded as well.

The trees and shrubs of each area were sampled and aged either on randomly located 5X25 meter plots or within already established sampling plots, and this information was then used to reconstruct the dynamics of plant growth in each area. Cross-sectional areas of the stems were collected and the number of rings counted at meter, half-meter, or quarter-meter intervals depending on the size of the shrub. When possible, the leader and internode lengths from recent years elongation were also measured. It was then possible to draw growth curves approximating shoot elongation per year with the y-axis representing the number of meters and the x-axis the number of rings per year following the Skagit fire in 1926. This fire, which swept the forests surrounding Ross Lake, was the last major disturbance in the area, so that 1927 is the point of origin on the x-axis and indicates the initiation of secondary plant succession. Where there was evidence of more recent origin, growth curves were adjusted so that the point of origin corresponded to the appropriate year.

All the tree species but only the larger shrub species, represented in the plot areas were sampled for age and growth data. _Berberis nervosa_ and _Rosa gymnocarpa_, for example were not sampled, despite the fact that there was some evidence of deer browsing. Shrub species which were sampled included _Amelanchier alnifolia_, _Acer circinatum_, _Acer glabrum_, _Ceanothus sanguineus_, _Ceanothus velutinous_, _Holodiscus discolor_, _Philadelphous lewisii_, _Prunus emarginata_, _Corylus cornuta var. californica_, _Shepherdia_ [illegible], and _Salix_ spp.

Slight changes in the methodology used in the plant ecology research were made between the 1971-72 seasons. These alterations were a matter of convenience because of the increased emphasis on the earlier successional stages in 1972. The method used in 1972 is fully outlined above.

TAXONOMY

Plants were identified by species in accordance with the nomenclature used by Hitchcock et. al. (1955-1964), but some annuals could not be identified with certainty because they were collected from July through September. Identification was attempted for genus, however. No vouchers were kept after identification, and no attempt was made to differentiate grasses and bryophytes by taxa.

LOWER DESOLATION AREA

Located along the shoreline east of Cat Island, the Lower Desolation Area faces southwest and has a moderately steep slope (15-20°) with shallow rocky soil. The area, which Scott, Barber, and Long (1971) have classified as brush type, was logged and burned during dam construction activities. No fire scars were found upslope from the lake shore, which suggests a relatively confined burn. Charred logs and stumps along the shoreline do indicate a 150-200 year old stand of Douglas-fir prior to logging operations. This indicates a stand similar to the unburned climax Douglas-fir community upslope. Fire scars on an 85-year-old ponderosa pine within the area of established plots indicate a disturbance about 41 years ago. This was probably the Skagit fire, 45 years ago.

There is a 5-6 meter tall overstory composed mostly of clumped *Salix spp.*, *Acer circinatum*, *Acer glabrum*, and *Prunus emarginata*. These 20-25 year-old shrubs have not grown more than .25 meters per year in recent years. Of these species *Salix spp.* occurs most commonly and has greatest coverage. There are also numerous Douglas-fir saplings 10 feet tall and at least 9 years old. Further upslope, in the transition zone between the brush type and the Douglas-fir community, there are Douglas-fir seedlings and saplings 4 or 5 years old. A few Douglas-fir not more than 15 years old have overtaken some of the overstory shrubs, but most are still found in the understory. Total overstory coverage is 20-35 percent.

Ceanothus sanguineus is the dominant understory species in plot areas, having coverage percentages of 14, 27, 27, and 41 on four different sites. Other species with large coverage values in the Lower Desolation Area are Berberis nervosa, Rosa Gymnocarpa, and, in the ground cover, Spirea betulifolia. Each of these also occurs with a high degree of frequency, especially Spirea betulifolia, which was present in 100% of the microplots on three or four plot sites. Trientalis latifolia and Fragaria virginiana do not have large coverage values but occur more frequently than other ground cover species.

A clump of Ceanothus sanguineus was sampled and the number of rings at the base of each stem varied from 11 to 23. One stem was found to have grown quickly for 3 years and then slowed down to less than .10 meters a year. Because the root of the shrub was rotten in the center, no age could be determined for the whole shrub, however.

Although Shepherdia canadensis does not occur frequently in the area, its growth figures resemble those of Salix and Prunus emarginata. A sample with 26 rings at its base indicates that Shepherdia canadensis was one of the first species to invade the site following its disturbance in 1945, but its initial growth was not as fast as might have been expected from a pioneering species. Both Shepherdia canadensis and Salix spp. took 16 years to grow 4 meters; Prunus emarginata grew to the same height in 14 years. Stem elongation for Shepherdia canadensis stems has been between .25 and .30 meters a year in recent years, which is comparable to the leader length of Prunus emarginata and Salix spp.

Amelanchier alnifolia, a favored deer browse species, is also common in this area (with frequency percentages of 16, 8, 8, and 16 on four plots,) but its coverage values are not high. Various individuals were determined to be 17, 18, and 22 years old, and, as with Prunus emarginata, Salix spp., and Shepherdia canadensis, it took between 5 and 6 years for this species to grow 2 meters. Recent stem growth has been less than .075 meters per year, however,

LOWER DESOLATION PLOT AREA SUMMARY

There are at least two age groups of coniferous trees and saplings in the Lower Desolation area. Douglas-fir saplings are 11 to 13 years old and 30 to 35 years old. Lodgepole pine were estimated by whorl count to be 18 and 19 years old, and one older lodgepole was determined through increment boring to be 31 years old.

Density values of Douglas-fir, ponderosa pine, and lodgepole pine were not taken. Despite this lack of quantitative data, however, the closing in of the plot by Douglas-fir from the upslope area and from the sides of the dense thicket can be clearly distinguished, Height growth data on Douglas-fir and lodgepole pine were not collected, but the growth of a Douglas- fir 20 feet tall indicates that closure of the trees will occur within 10-15 years. Growth curves available for the shrub species indicate a corresponding leveling off pattern in rates of stem elongation.

LIGHTNING AREA

The Lightning Creek area faces south-southwest and has a steep slope (20-35°) and shallow, rocky soil. It is located east of the Lightning Creek campground and upslope between 50 and 90 meters (160-

300 feet) above lake level. Scott, Barber, and Long (1971) described the larger area in which the plots under consideration were established as a climax Douglas-fir type with scattered rock types. The area is a mosaic of dry exposed rocky sites, dense brush understories beneath scant overstories, and patchy clumps of Douglas-fir, lodgepole pine, and ponderosa pine. This mosaic pattern is reflected in plot data.

Plot E_1: An extremely dry site with a 32° slope, E_1 is a rock outcrop with no overstory or understory and sparse ground cover (15 percent). The presence of such dry site species as *Balsamorhiza sagittata*, *Achillea millefolium*, and *Allium spp.* emphasizes the xeric conditions on this site. *Achillea millefolium* occurs frequently, and *Fragaria virginiana* and *Allium spp.* are common, but none of these three exceeds a coverage value of 6 percent.

As might be inferred, growth rates are quite slow. The stem of one sample of *Ceanothus velutinus* was found to have taken 14 years to grow to a height of 1 meter. A small *Ceanothus sanguineus* sampled had not reached the 1 meter mark in its first 7 years of growth, and a stem of *Prunus emarginata* had required 6 years to grow its first meter in height. A sample of *Salix spp.* took 5 years to grow to 2 meters in height, but an additional 2 years passed before it grew the next .5 meters.

Plot E_2: Plot E_2 was located in a 35 year old stand of lodgepole pine. The overstory, which is 9-12 meters high, has a coverage of approximately 75 percent. The understory is comprised of Amelanchier alnifolia, Salix, Prunus emarginata, and Douglas-fir between 6 and 8 meters high. This understory is rather thin in comparison to the overstory, since it has only 5 percent coverage. Spirea betulifolia (6%), Trientalis latifolia (6%), and Berberis aquifolium (7%) contribute the greatest amount of ground cover and occur frequently. Much of the ground is covered with leaf litter and dead branches.

The stand of lodgepole pine is 36.2 m^2/hectare. Douglas-fir and ponderosa pine (.53 and 1.07 m^2/hectare respectively) are unimportant in the stand. Douglas-fir saplings 24, 15, and 12 years old were all under 4 meters tall, and no seedlings of any conifer were found inside the plot.

The individual Douglas-fir sampled had a 3 inch dbh and was 7 meters tall. It had taken 21 years to grow 1 meter tall, and had required 7 more years to reach a height of 2 meters. Its recent growth has been about 1 meter every 2 years, however. This is comparable to the recent growth rate of the lodgepole pine sampled, except that the lodgepole has had a slight advantage over the past 2 years (1.20 meters in 2 years versus .80 meters in 2 years for the Douglas-fir).

Stem elongation per year on the sample from a 35 year old, 8 meter tall Salix spp. clump was comparable to the Salix from E_1 for the first 2 meters. It took 4 years for the Salix in E_2 to grow to the 2 meter mark, and an additional 8 years to grow to the 4 meter mark. Seventeen more years passed before the 7 meter mark was reached. In the last 5 years, the stem has grown approximately 1 meter, and stem elongation for the last 2 years has been .20 and 1.7 meters respectively.

A sample of Prunus emarginata 24 years old grew faster than the Salix spp. stem. Although it took 14 years to grow to a height of 4 meters, it grew the next 3 meters in only 7 years. The leader length was .32 meters.

A 7 meter tall, 23 year old Amelanchier alnifolia, which occurred in single stems in this plot, had taken only 9 years to grow its first 4 meters. Like the Salix stem, however, stem elongation per year decreased to the point where it required 12 years to grow from 4 to 7 meters in height.

Plot E_3: E_3 is interrupted by a rock ledge which is exposed and very dry. The entire site has a steep slope, and the soil is rocky and shallow. There are Philadelphus lewisii and low-form Amelanchier alnifolia, Apocynum androsaemifolium, and Achillea millefolium on the exposed ledge, and Balsamorhiza spp., Ceanothus sanguineus, Amelanchier alnifolia, Spirea betulifolia, Fragaria virginiana, Rosa gymnocarpa, Prunus emarginata and Berberis aquifolium are found in the dense thicket below the ledge.

The only overstory is a single 6-8 meter ponderosa pine on the edge of the plot whose basal area was determined to be 2 m^2/hectare. No coniferous seedlings or saplings were present.

There is a dense understory on this plot, of which Ceanothus sanguineus makes up 16% of the cover, Amelanchier alnifolia 13%, Prunus emarginata 6% and Rosa gymnocarpa 5%. Amelanchier alnifolia and Ceanothus sanguineus occur most frequently (32 and 40% respectively). The plot's location within the transition zone from dense thicket to rock outcrop probably means that the percentages given above indicate slightly lower values than is actually the case.

There is a fairly dense ground cover (50%) below the understory. Trientalis latifolia and Spirea betulifolia occur frequently, covering 7 and 2% respectively. Fragaria virginiana and Berberis aquifolium both have coverage values of 3% and are also common species.

The individual ponderosa pine, which was determined to be 31 years old, had grown approximately .40 meters per year for the last 3 years. Its overall growth is comparable to that of the lodgepole pine in E_2 for the first 6 meters. It took 17 years to grow the first 2 meters, an additional 5 years to reach a height of 4 meters, and 5 more years passed before it was 6 meters tall.

The stem samples show that *Prunus emarginata* and *Salix* began initial growth above the base at lower rates of stem elongation than did the samples of the same species in E_2.

Plot E_4: E_4 was located about 300 feet above lake level in the vicinity of scattered 30 meter tall Douglas-fir and 25 meter tall ponderosa pine. In the more immediate area of the plot are 12 meter tall Douglas-fir, 8-9 meter tall ponderosa pine, and 6 meter tall lodgepole pine, all 30 years old. There are four age groups of Douglas-fir and ponderosa pine saplings and trees: 11-13, 17-19, 22-25 and 30-35 year old ponderosa pine saplings and 11-13, 16-17, 25, and 30-35 year old Douglas-fir saplings. No seedlings or saplings of Douglas-fir, ponderosa pine, or lodgepole pine under 10 years old were found, nor were any coniferous trees, saplings or seedlings tallied within the plot.

The scant overstory within the plot (5%) is composed of two clumps of *Salix* 5-6 meters high. The understory is quite dense, however, and accounts for about 80% of the plot's coverage. *Amelanchier alnifolia* is especially frequent and has an average coverage of 28%. *Ceanothus sanguineus* (20%), *Rosa gymnocarpa* (19%), *Holodiscus discolor* (17%), and *Salix* (9%) provide the amounts of coverage and, with the exception of *Salix*, occur frequently. *Amelanchier alnifolia*, *Rosa gymnocarpa* and *Ceanothus sanguineus* occur in more than 60% of the plots.

The ground coverage is approximately 50 percent. Rosa gymnocarpa (18.7%), Spirea betulifolia (3.3%), Fragaria virginiana (3.9%), Trientalis latifolia (2.7%) Lonicera ciliosa (2.2%), and Pachystima myrsinites (2.7%) comprise the majority of the ground cover. Trientalis latifolia, Spirea betulifolia, Rosa gymnocarpa, and Fragaria virginiana occur in over 33% of the microplots.

A Douglas-fir and ponderosa pine on the edge of the plot were sampled. The Douglas-fir was 11 meters high and 31 years old. The ponderosa pine was 8 meters high and 28 years old. Both trees had required 18 years to reach the height of 4 meters. The Douglas-fir had taken an additional 3 years to become 6 meters tall, and the ponderosa pine had taken additional 5 years to reach this height. For the last 3 years the Douglas-fir has grown .50 meters more per year than has the ponderosa pine.

A 5 meter tall stem from a clump of Salix spp. was sampled and determined to be 17 years old. It had taken 12 years to grow to 4 meters in height, and 4 additional years to reach 5 meters. Recent stem elongation has been at the rate of .10 meters per year.

A stem of Prunus emarginata was also determined to be 17 years old. It had grown to a height of 3 meters in 9 years, a growth rate comparable to that of the Salix spp. sample for the corresponding height interval. The rate of stem elongation decreased sharply after the 3 meter mark, however, and it took another 8 years for the stem to grow an additional meter. Leader length was measured as .30 meters.

Holodiscus discolor was sampled inside the plot. It had grown 2 meters the first 3 years, and was determined to be 7 years old.

A single stem from Ceanothus sanguineus was found to have grown very slowly. It was 16 years old and only 1 meter tall from the end of the leader to the base. The root of this sample was extracted and a rought count of the root cut indicated 28 rings.

Amelanchier alnifolia stems displayed greater rates of stem elongation than the samples of *Ceanothus sanguineus*. One stem sampled 17 years old and had grown 1 meter in the first 3 years. It had than taken an additional 4 years to grow a second meter in height. Stem growth then slowed considerably and the next 8 years produced only another half meter of stem growth.

LIGHTNING AREA PLOT SUMMARY

There appeared to be four definite and similar age classes of Douglas-fir and ponderosa pine in the Lightning area: 11-13, 16-17, 25, and 30-35 year old Douglas-fir; 11-13, 17-19, 22-25, and 30-35 year old ponderosa pine. Lodgepole pine occurs in a 35 year old even aged stand. These age classes are not limited to coniferous species: *Prunus emarginata* occurs in two age classes, 18 and 25 years old, and *Salix spp.* was observed in three different groups: 12-13 22, and 35 years old.

A possible successional history may be constructed from this data. Following a disturbance in a mature stand of Douglas-fir which might have been approaching an edaphic climax, ponderosa pine and Douglas-fir seedlings became established from the fire-damaged trees or from the adjacent, undisturbed stand upslope from the Lightning area. Lodgepole pine seedlings were established in clusters, possibly around a fire-killed parent, and displayed higher initial growth rates than the Douglas-fir or ponderosa pine. Conditions were quite dry on the steep rocky slope of the area so that, with the exception of the densely clumped lodgepole seedlings, there were only scattered individuals of woody species. *Salix spp.* had an even greater rate of stem elongation than lodgepole and established a scattered overstory of isolated clumps which was not overtaken in height by lodgepole pine and Douglas-fir for 25 years. Relatively few shrubs developed under the dense canopy of lodgepole pine. The shrub species grew in a single-stemmed, tree-like form which varied considerably from their open-grown forms.

Ten years after the establishment of the first age group, which was then approximately 1 meter tall, a second group of ponderosa pine and Douglas-fir seedlings became established. It is not clear why this happened but possibly this was the next time that a good seed year and reasonable conditions for seedling growth and survival occurred simultaneously. Since *Salix* spp. and *Prunus emarginata* also became established at this time, it would seem that the controlling factor must have been the quality of the growing season. (Note: Possibly plant seedlings became established more successfully during periods of low deer numbers).

The third age group of Douglas-fir and ponderosa pine seedlings became established 16 or 17 years after the establishment of the first age group, as did *Salix* spp., *Prunus emarginata*, *Ceanothus sanguineus*, and *Amelanchier alnifolia*. This is indicated by the fact that the densest thickets of brush occur not on dry exposed sites but close to isolated 35 year old Douglas-fir and ponderosa pine.

The youngest shrubs in the area are found on the driest, steepest slopes which occur on the rock outcrops. This is not always the case for all shrub forms, however, since a 35 year old stem of *Pachystima myrsinites* was noted on the rock site. The density and coverage values of shrub species on rock outcrops are quite low.

Although no coniferous trees, saplings or seedlings occurred on plots characterized by dense thickets of shrubs, it is apparent that the conifers established in the less dense, adjacent areas will overtop the shrubs and reduce them greatly in importance. The height growth of these shrub species always levels off. Amelanchier alnifolia, Prunus emarginata, Holodiscus discolor, and Ceanothus sanguineus all exhibited levelled-off growth curves.

The restoration of a forest canopy, then, depends upon the continued growth of saplings as well as on seed production by the two coniferous age groups which have already reached the reproductive stage. If they follow the observed growth patterns of the 35 year old Douglas-fir and ponderosa pine age classes, the 11-13 year old age group will be 6 meters tall in 10 years.

SILVER CREEK DELTA

Silver Creek Delta is a flat, low-lying area on the western shore of Ross Lake. It faces east, has a gentle slope, and is divided by shallow, fast-flowing Silver Creek. The area was logged and burned during dam construction activities in 1950-51. Western redcedar snags over 150 years old are widely distributed, especially toward the back of the delta, and cut stumps and charred logs litter the area. At the time of the 1951 fire, the area was covered by a mixed stand of western red cedar and Douglas-fir. The western red cedar were 150 years old and 15-25 meters tall, with diameters at breast height between 10 and 12 inches. The Douglas-fir were 150-250 years old, 30 meters tall, and 18-24 inches in diameter at breast height. The Douglas-fir were apparently cut before the fire, and the western red cedar were killed by the fire which followed. A finger of Douglas-fir and western red cedar in the middle of this area runs from the western slopes behind the delta to the lake shore. These Douglas-fir are 200 years old and 30 meters tall. Tree samples showed fire scars from twenty years ago, the time of the logging and burning; 45 years ago, the time of the Skagit fire; and 120 and 180 years ago.

The delta includes a number of exposed sites which are strewn with rocks and charred logs. There is little or no overstory, although scattered Douglas-fir, Populus trichocarpa, and Betula papyrifera over 6 meters tall form a scant overstory on some sites. Populus trichocarpa is confined to the lakeshore, and Betula papyrifera is found on dry sites toward the back of the delta.

The understory coverage is also sparse, with coverage values varying from 0 to 25 percent for Douglas-fir, Prunus emarginata, Acer circinatum, Acer glabrum, Salix spp., Corylus cornuta, and Ceanothus velutinus. All the hardwood species occur as clumped stem forms, and none of the shrubs occur frequently.

The ground cover is composed largely of Pachystima myrsinites, which occurred in 35 to 60 percent of the microplots. Rosa gymnocarpa, Arctostaphylos uva-ursi, and Rubus parviflorus make up the rest of the ground cover, and the former two occur commonly.

Young Douglas-fir trees and saplings are abundant throughout the [illegible] Creek Delta. They were tallied in all but one of the established plots, and the basal area computed as being 2.15, 4.10, 1.35 and 1.82 m^2/hectare on four of the plots. Young trees had diameters as large as 6 inches at breast height, and a 12 year-old, 6-7 meter tall Douglas-fir on the lake shore had a dbh of more than 4 inches. Another Douglas-fir toward the middle of the delta was 1[illegible] years old, 7 meters tall, and more than 4 inches in diameter at breast height. The Douglas-fir saplings were 7 to 9 years old and 2 to 4 meters high.

Western red cedar saplings also occur frequently in this area. Their basal areas were determined to be .37, .16, .12, and 0.0 m^2/hectare for the same four plots where Douglas-fir saplings and trees were tallied. The red cedar saplings were between 14 and 16 years old and less than 3 meters high.

There are also western white pine and western hemlock saplings in the area, and numerous Populus trichocarpa saplings were found along the lake shore. The presence of Alnus rubra seedlings toward the middle of the delta may be of some significance, since it is generally associated with hardwood types on mesic sites (Scott, Long and Barber, 1971).

Stem samples from the two Douglas-fir mentioned above exhibited quite similar rates of stem elongation. The older Douglas-fir was further back on the delta and closer to the stand of mature Douglas-fir and western red cedar than was the younger one. It was determined to be 18 years old, and had taken 8 years to grow to a height of 2 meters. This contrasts with the Douglas-fir sampled at the lake shore, which took only 5 years to grow the first 2 meters. But both trees required only 6 more years to reach 7 meters in height. The Douglas-fir at the lake shore is now 12 years old and 8 meters high. Its leader length was .90 meters; the 1972 leader was missing from the 18 year old Douglas-fir, but it was .89 meters long in 1971.

Western red cedar and western hemlock saplings were cut and their rings counted at half meter intervals. The western red cedar sampled took 13 years to grow 2.5 meters tall. Stem elongation has been relatively uniform throughout the sapling's like. The western hemlock took 12 years to grow 2.5 meters tall, but its growth rate has increased in recent years -- it only required 2 years to grow from 1 to 2 meters in height, and an additional 1 year to grow the last half meter. Its 1972 leader was .62 meters long, and the 1971 height growth had been .61 meters.

Five meter tall Betula papyrifera and Salix spp. stems were sampled for age and rate of stem elongation. Both had required 14 years to reach 5 meters in height. The Betula papyrifera sampled had grown .70 meters in the last 2 years, which suggests that its growth curve has not yet levelled off.

A 10 meter tall, 16 year old Populus trichocarpa exhibited rapid growth. It reached a height of 5 meters in 7 years, as compared to 14 for both Salix and Betula papyrifera, and 11 and 19 years for the two samples of Douglas-fir. The Popylus trichocarpa sample took 4 years to grow from 5 to 6 meters tall, and an additional 5 years to grow from 6 to 10 meters tall. This indicates that its growth curve has not yet levelled off.

Prunus emarginata and Acer circinatum specimens showed initial growth rates comparable to those of Douglas-fir, Salix spp., Populus trichocarpa, and Betula papyrifera. The growth of both levelled off quickly after the second or third meter in height. The leader of Acer circinatum was .16 meters and the previous year's had been .08 meters long. The Prunus emarginata sampled was 8 years old and had not yet reached a height of 3 meters.

Ceanothus velutinus occurred in large diameter clumps throughout the area. All 20 individual stems of the shrub sampled were either 8 or 9 years old. The underground portion of the shrub was extracted and found to be 11 or 12 years old. Stem growth had been quite fast: it had taken one stem 5 years to grow 2 meters in height, and only 1 additional year to reach 2.5 meters.

SILVER CREEK DELTA PLOT SUMMARY

The speedy establishment of Douglas-fir seedlings and saplings following a disturbance in the Silver Creek Delta area may be due to the mature Douglas-fir capable of seed bearing in the stand which runs from the lake shore to the back of the delta. Other factors may have been the area's eastern aspect and gentle slope (5-10°) both of which suggest favorable moisture conditions. And finally, the presence of red alder seedlings in plot areas seems to indicate a more mesic site than that normally found on brush types.

Based on the current growth rates of Douglas-fir in the Silver Creek Delta, the 7-9 year old saplings will be over 7 meters tall in 5 years. In 5-10 years, these saplings will probably have overtaken <u>Salix spp.</u>, <u>Betula papyrifera</u>, <u>Prunus emarginata</u>, and other shrubs. At the same time, it is likely that <u>Populus trichocarpa</u> will continue to grow and to reproduce along the lake shore.

SKYMO CREEK BRUSHFIELD

Plots were established between 33 and 52 meters (110-175 feet) above lake level south from Skymo Creek on the western shore of Ross Lake. They were located on steep (15-34°), southeast-facing slopes in an area which Scott, Long and Barber (1971) have designated as a brush type. One plot was located on a rocky ledge above a 30 meter (100 foot) cliff overlooking the lake, All the plot sites had rocky shallow soil. Charred Douglas-fir snags and logs were found along the slopes above the plots. Forty year old lodgepole pine and 35 year old Douglas-fir in the brushfield area indicate the influence of the 1926 Skagit fire.

Reproduction of Douglas-fir on the Skymo brushfield has been poor in comparison to that on the other study areas. The few 35-40 year old lodgepole pine and 20-25 year old Douglas-fir which are present are confined to the 30 meter high shelf. Elsewhere, Douglas-fir which can be found in three age groups: 2-4 year old saplings, 9-10 year old saplings, and 15-16 year old trees. The three age classes of Douglas-fir on the shelf are: 9-10 year old saplings, 15-16 year old trees, and 20-25 year old trees. There are no Douglas-fir seedlings on the shelf. Lodgepole pine saplings occur infrequently in the area; those that were observed fell into one of two age groups: 9 or 16 year old saplings.

The scant overstory and denser understory of the area is composed of Ceanothus sanguineus, Amelanchier alnifolia, Salix spp., Acer glabrum, Acer circinatum, Prunus emarginata, Corylus cornuta, and Holodiscus discolor. Amelanchier alnifolia occurred in 12-20 percent of the microplots and had coverage values of 10, 4, 3, and 6 percent over the four plots. Salix spp. had slightly greater coverage values on three of the four plots at 20, 8, 5, and .6 percent.

Spirea betulifolia, Berberis nervosa, and Trientalis latifolia were present on all the plots and comprised a large part of the ground cover. Spirea betulifolia, which occurred in over 60% of all microplots on the four plots, had coverage values of 22, 7, 7, and 9 percent. Berberis aquifolium occurred commonly but had smaller coverage values than Spirea betulifolia at 2, 3, 4, and 20 percent. This last value was determined on one of the southeasterly-facing plots; Berberis aquifolium was represented in 86% of the microplots within this plot. Trientalis latifolia appeared infrequently only in the plot located on the rock ledge. In the other plots it was present in 28-76 percent of the microplots, whereas its coverage values were 5, 8, 3, and .6 percent on the rock shelf.

The aspect and slope of the four plots were as follows: F_1, ESE 24°; F_2, SE 15°; F_3, SE 34°; and F_4, S 25°. The frequency and coverage values for certain species varied between the east (i.e. F_2 and F_4) and south-facing (F_1 and F_3) plots. Understory and ground coverage were particularly dense on F_1 and F_3. On the more southerly facing plots, F_2 and F_4, Apocynum androsaemifolium was found in over 60% of the microplots, and had coverage values of 8 and 10 percent respectively. On the more easterly-facing plots, F_1 and F_3, Apocynum androsaemifolium was not found. Acer glabrum, Acer circinatum, Corylus cornuta, and Symphoricarpus albus occurred in F_1 and F_3 but not in F_2 and F_4. Rosa gymnocarpa had coverage values of 10 and 11 percent on F_1 and F_3 but only 3 percent on F_4; it did not occur at all on F_2. Berberis nervosa occurred in F_1 where it had a coverage value of 9 percent, but was not found on the other plots.

A Douglas-fir sapling and tree were sampled near plot F_1. The 9 year old, 2 meter tall sapling had grown .30 meters a year during the past 3 years. In the 3 years previous to that, it had grown between .15 and .20

meters per year. Thus it grew 1.4 meters in the past 6 years. The Douglas-fir tree sampled was 14 years old and over 5 meters high, and had grown 2.20 meters in the last 3 years.

A 35 year old Douglas-fir and an adjoining 38 year old lodgepole pine, both located on the rock ledge, were sampled and their growth rates compared. The lodgepole pine had taken 13 years to grow to a height of 4 meters, while the Douglas-fir had taken 17 years to grow to the same height. The Douglas-fir had grown another 4 meters in the next 10 years, however, while it took the lodgepole pine 15 years to reach the same height.

SKYMO CREEK BRUSHFIELD AREA PLOT SUMMARY

The Skymo Creek Brushfield area is one of the largest brush communities in the Ross Lake area, and is also the largest brush community within 100 meters (300 feet) elevation of present lake level. There are not many Douglas-fir saplings in this area, and browse damage on saplings and seedlings is quite extensive. Many of the saplings and seedlings ovserved in the area were missing leaders, for example. Salix, on the other hand, covers a larger area than on the other sites, and forms an overstory 5 to 6 meters high. This coverage is still sparse, but the low density of and damage to Douglas-fir saplings in the area suggests that the Salix overstory may well increase. According to the growth rates of the Douglas-fir and Salix spp. sampled, the Douglas-fir saplings may exceed the height of the Salix shrubs in 10 years. But it is unlikely that Douglas-fir will be able to close in the overstory within the next 15 years.

The situation on the rock ledge is somewhat different, since a high density of 8-10 year old Douglas-fir saplings was observed there. Based on the growth rates of the 35 year old Douglas-fir toward the back of the plot area, these saplings will be approximately 5 meters tall in 10 years, and 8 meters tall in 15 years, at which time they will probably form a closed canopy.

PUMPKIN MOUNTAIN

The Pumpkin Mountain area is a mosaic of dry, open areas, patches of lodgepole pine and Douglas-fir, and hardwood stands. The lower mountain slopes adjoining the lake vary in aspect from south to east. Their slopes are moderately steep to steep (20-30°), and soil conditions range from rocky, shallow soil on the south and southeast-facing slopes to deeper soils and/or humus layers on the east-facing slopes.

Evidence of a major fire disturbance is widespread on Pumpkin Mountain. The charred logs and stumps of decayed Douglas-fir cover the dry open slopes above the lake level. Scattered old Douglas-fir 120 feet tall and 20-40 inches dbh are streaked with fire scars. Several borings of these trees indicated fire scars about 46 years old. The oldest lodgepole pine observed in the area was 42 years old. Various stems of Salix spp. Acer circinatum, Acer glabrum, and Prunus emarginata were found to be 40 years old, and one stem of Acer circinatum was 46 years old.

Lodgepole pine, Douglas-fir, and various shrubs form a continuous overstory extending slightly upslope and around the lake shore to the east-facing slope. At higher elevations there are pure even-aged stands of lodgepole pine. On intermediate slopes, dry exposed sites form a patchwork with 35-40 year old lodgepole pine and various age classes of Douglas-fir saplings and trees. To the east of Big Beaver Valley and away from the south-facing slopes there is a dense hardwood stand dominated by Salix spp.

For the purpose of comparison, plots were divided into two categories: those facing southeast and those facing east. One south-facing plot with a gentle slope and relatively closed canopy was placed in the same category as the east-facing plot sites.

DRY SOUTHEAST FACING SLOPES

There was little if any overstory on these rocky sites, which were 27 to 76 meters above lake level. Where there was an overstory, it was composed of Prunus emarginata, Acer glabrum, Salix spp., Acer circinatum, Douglas-fir, and lodgepole pine. The hardwood species, which form an overstory 4-7 meters high on open sites and an understory on more closed-in sites, are from 30 to 42 years old; the Douglas-fir and lodgepole pine are 7 to 12 meters high. The coverage value of the understory is somewhat greater under the scant lodgepole or Douglas-fir overstory than on open sites, and is composed of Ceanothus sanguineus, Corylus cornuta, Holodiscus discolor, and Amelanchier alnifolia. On more open sites Holodiscus discolor, Philadelphus lewisii, and Amelanchier alnifolia comprise the understory.

The density of shrubs on these dry, southeast-facing slopes was low. No Amelanchier alnifolia, Holodiscus discolor, or Acer glabrum were found on any of the microplots, and Ceanothus sanguineus, Salix spp. and Acer circinatum were found on the microplots of only one 5X25 meter plot. Ceanothus sanguineus had a coverage value of 6.7 percent on the plot where it was present, and Philadelphus lewisii occurred in two of the four plots.

Ground cover consisted mostly of Berberis aquifolium, Achillea millefolium, Apocynum androsaemifolium, Fragaria virginiana, Allium spp., Trientalis latifolia, and Spirea betulifolia. Achillea millefolium was found on all four plots, and occurred with a high frequency in the microplots: 58, 50, 32, and 12 percent. Spirea betulifolia was also found on all the plots, but occurred less frequently at 4, 13, 52 and 44 percent. Apocynum androsaemifolium, Fragaria virginiana, and Trientalis latifolia were present on only half of the plot areas, but had frequency values between 20 and 83%.

Berberis aquifolium (4, 7, and 3%), Apocynum androsaemifolium (7.5 and 10%) Achilla millefolium (7, 9, 3, and 0.0%), and Spirea betulifolia (9, 4, 0.0, and 0.0%) contributed most to the ground cover, which totaled from 10 to 25 percent.

Douglas-fir saplings in the area were usually between 7 and 11 years old. An occasional 13 or 6 year old sapling was found, but none exceeded 3 meters in height. Few lodgepole saplings and seedlings were found on these open sites.

EAST FACING SLOPES

Overstory coverage was greater than 60% on these five sites, despite the fact that its composition differed greatly from plot to plot. Lodgepole pine dominated the overstory of two plots, Salix spp. and Betula papyrifera formed the overstory of another, Douglas-fir dominated the overstory of the fourth plot, and the overstory of the remaining plot was composed of Douglas-fir and western hemlock. Salix spp., Acer circinatum, Betula papyrifera, Prunus emarginata, and Acer glabrum formed an understory of 10-20% on four of the plot sites. On the fifth plot these hardwoods mixed with western red cedar and western hemlock to form a 90% understory.

Amelanchier alnifolia and Ceanothus sanguineus were infrequent in the understory of these plots. Berberis nervosa, Trientalis latifolia, Rosa gymnocarpa, Rubus spp., and Pachystima myrsinites made up the ground cover. Berberis nervosa occurred in over 56% of the microplots, and was the dominant ground cover with values of 13 to 39 percent.

There were two even-aged lodgepole pine stands 88 meters (290 feet) above lake level. Both stands were 42 years old and 15 meters high, and had basal areas of 40 and 32 m^2/hectare. An 8 meter tall stem of *Acer circinatum* on one plot was 46 years old, and the understory of *Salix spp.*, *Acer circinatum*, and Douglas-fir was around 30 years old.

The two plots with lodgepole pine dominated anerstories differed in slope and aspect. One plot, B_6, was located on a slope no steeper than 5 degrees and facing south. It had no Douglas-fir seedlings or saplings, and the apparent lodgepole pine saplings which were present were actually suppressed 3-4 meter tall, 40 year old trees. The understory was composed of *Acer circinatum*, and the ground cover was mostly *Berberis nervosa*, *Linnea borealis*, and *Pteridium aquilinum*.

The second plot with lodgepole overstory, B_1, faced east and had a moderately steep slope (20°) at the same elevation as B_6. There was a cover of moss and litter on the ground, and *Berberis nervosa* was the dominant ground species. Other major ground species were *Pachystima myrsinites*, *Rosa gymnocarpa*, and *Spirea betulifolia*. Douglas-fir "saplings" found on B_1 were 20-30 years old and under 4 meters high. Two tree size Douglas-fir 5-6 meters high were 30 years old. The understory was composed of these saplings and trees and of 30-35 year old *Salix spp.* and *Acer circinatum* 5-8 meters tall.

B_7 is an east facing plot located 18 meters above lake level. *Salix spp.*, *Betula papyrifera*, and *Prunus emarginata* form an overstory 12 meters high. Salix spp. probably had the greatest basal area in the vicinity, and was the dominant overstory species. The *Prunus emarginata* and *Salix spp.* sampled were 40-46 years old, and a *Betula papyrifera* sampled was 30 years old and 12 meters tall. *Acer circinatum*, *Acer glabrum*, *Corylus* cornuta, and Prunus emarginata formed a limited understory. There was dense ground cover dominated by Berberis nervosa, although a high density of Acer circinatum was also observed, Douglas-fir became established in this area about 25 years ago. The 20-25 year old Douglas-fir were 6-12 meters tall, and several had broken through the hardwood overstory. Saplings and 3-5 year old seedlings were numerous. Dead stems and shrubs of Ceanothus sanguineus were found underneath the hardwood canopy. The ages of these stems varied from 10-18 years.

Plot B_8 was established on a steep northeast-facing slope north along the lake shore from B_7 and 9 meters above lake level. Here there was a dense "understory" of Douglas-fir and western hemlock 9-18 meters tall under a few 40 meter tall Douglas-fir. The Douglas-fir comprising this understory were up to 30 years old; the western hemlock were between 30 and 40 years old. There was also a second, dense understory of Salix spp., Alnus rubra, A. macrophyllum, and Acer glabrum which is over 12 meters high. Western red cedar forms a third dense understory of 30-35 year old, 1-4 meter tall saplings. No Douglas-fir seedlings were found in the area, but there were numerous western red cedar seedlings more than 6 years old. Basal areas for the coniferous trees were: Douglas-fir, 18 m^2/hectare; western red cedar, 2m^2/hectare; and western hemlock, 4 m^2/hectare.

Plot B_{12} was located 70 meters above lake level and about 2.5 kilometers north of plots B_1 and B_8. It faced east and had a moderately steep slope. The highest basal area found for Douglas-fir was on this plot: basal area for the dense overstory of 35-40 year old Douglas-fir over 12 meters tall was approximately 20 m^2/hectare.

The following three Douglas-fir trees were cut and sampled on southeast facing slopes: (1) a 12 meter tall, 30 year old Douglas-fir from plot B_4; (2) a 7 meter tall, 19 year old from the area of plot B_5; and (3) a 5 meter tall, 13 year old from the vicinity of plot B_2. The first two of these had taken 14 years to grow 4 meters in height, and the Douglas-fir from B_2 had taken 10 years to reach the same height. All three had required at least 6 years to reach the height of 1 meter.

After the 1 meter mark the youngest Douglas-fir grew 3 meters in 4 years. Internode lengths for the last 2 years indicate an approximate rate of .75 meters a year.

The 19 year old Douglas-fir took 10 years to reach the 2 meter mark, and its last 4 meters had been added in 7 years. The growth rate during the 2-6 meter interval was greater than that for the equivalent interval in the growth of the 30 year old Douglas-fir. Internode lengths for the last 2 years have been .50 meters per year.

The 30 year old Douglas-fir also took 10 years to reach the 2 meter mark, then 9 years to grow the next 4 meters and 6 more years to grow to a height of 10 meters. Its leader matches the growth rate of the 6-10 meter interval at about .60 meters per year for the last 2 years.

Two lodgepole pines were also cut and their stems analyzed. One was a 38 year old which had reached a height of 10 meters in 28 years; the other, a 36 year old which had grown 10 meters in 33 years. The older lodgepole pine took 10 years to grow its first 4 meters in height, and then grew the next 4 meters over a period of 9 years. The 36 year old reached the 4 meter mark in 21 years, and grew from 4 to 8 meters in height in an additional 8 years. This younger tree then grew another 2 meters in 4 years, and has a current growth rate of .40 meters per year. But the older lodgepole required 7 years to grow from 8 to 10 meters tall, and its growth has slowed to a rate of .25 meters per year.

Salix spp. exhibited growth rates similar to those of coniferous trees for the first 4 meters of growth. The two specimens sampled took 11 and 12 years to reach the 4 meter mark. These rates have slowed in the more recent part of stem growth, however. One stem, for example, took 2 years to grow from 0 to 1 meter in height, 6 years to grow the next meter, and 11 years to grow the next 2 or 3 meters.

Two other components of the overstory and understory were cut and sampled as well. These included two stems of Prunus emarginata, which exhibited very slow rates of stem elongation. One stem was 39 years old, the other 38 years old, and they had taken 20 and 24 years respectively to grow 4 meters in height. Neither stem had grown an additional meter in the last 19 and 14 years, respectively.

Acer glabrum appeared in multiple-stemmed clumps in this area. One sample was 42 years old and had taken 26 years to grow 4 meters and another 15 years to reach the 8 meter mark.

Two stems from separate clumped shrubs of Ceanothus sanguineus were 17 and 15 years old and had taken 11 and 13 years to grow 2 meters tall. The leader of one was .40 meters long and that of the other stem was .13 meters.

The growth rates of Amelanchier alnifolia also varied. Three different stems had required 14, 18, and 27 years to reach a height of 3 meters. The leader length of two of the stems was .06 meters, and last year's leader for the third was .27 meters.

Two 42 year old lodgepole pine were cut on plots located 87 meters above lake level. In 42 years both had grown 14 meters. The specimen on plot B_6 had taken 13 years to reach the 4 meter mark; its rate had then slowed in comparison to the growth rate of the lodgepole pine on plot B_2. This lodgepole had required 20 years to reach the 4 meter mark, but then grew another 10 meters in the next 20 years.

A 31 year old Douglas-fir and a 29 year old Douglas-fir were also cut and sampled on these same plots. The 31 year old, from B_1, had reached the 2 meter mark in 16 years as compared to 20 years for the llodgepole on the same plot. It then took 17 years to reach 10 meters in height -- 3 less than the lodgepole. The leader of the Douglas-fir was .65 meters long, about .10 meters longer than that of the lodgepole pine. The Douglas-fir on plot B_6 had grown only 4 meters in 24 years. Its leader length for both of the last 2 years had been .30 meters.

A 23 year old Douglas-fir and an adjoining 34 year old _Betula papyrifera_ were sampled on plot B_7, which was located 18 meters above lake level. The _Betula papyrifera_ had taken 11 years to grow 2 meters tall, while the Douglas-fir had taken 10 years to reach the same height. The Douglas-fir then required 9 years to grow the next 6 meters, and the _Betula papyrifera_ took 16 years to attain the same height. The Douglas-fir has been growing at a rate of 1 meter per year for the last 11 years, and is now 3 meters taller than the single-stemmed _Betula papyrifera_.

PUMPKIN MOUNTAIN AREA PLOT SUMMARY

The Pumpkin Mountain area is somewhat unique in that it is comprised of dense clumps of trees about 10-15 meters tall and intervening areas made up almost entirely of brush species. The tree clumps apparently grew slowly for the first 10 years, but when they had attained a height of 3-4 meters and an age of 10-15 years, overtopped and severely retarded further brush species development. The present brush areas are not being rapidly invaded by tree species, however, and should not close for at least another one or possibly two decades. While the mosaic of tree clumps and brush appears ideal for deer habitat, the overall poverty of the site, which is probably due to its S-SE exposure and shallow soil, makes for low browse production.

LOWER DESOLATION AREA

PLOT A_1 July 29, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Spirea Betulifolia	29	100
Rosa gymnocarpa	17	64
Berberis aquifolium	13	52
Fragaria virginiana	16	72
Trientalis latifolia	3	60
Ceanothus sanguineus	41	72
Prunus emarginata	1.5	4
Apocynum androsaemifolium	2.4	8
Salix spp.	4.0	4
Pachystima myrsinites	6	24
Berberis nervosa	3	8
Amelanchier alnifolia	11	16
Lonicera ciliosa	0.2	8
Acrtostaphylos uva-ursi	0.6	4

BASAL AREA (square meters/hectare) for coniferous trees: 0

LOWER DESOLATION AREA

PLOT A_2 July 29, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Spirea betulifolia	34.3	100
Rosa gymnocarpa	9	68
Trientalis latifolia	3	40
Ceanothus sanguineus	26.6	72
Berberis aquifolium	1.2	8
Epilobium angustifolium	0.7	8
Pachystima myrsinites	1.6	24
Acer circinatum	0.1	4
Berberis nervosa	18.2	60
Salix spp.	9.3	12
Symphoricarpus albus	2.2	12
Amelanchier alnifolia	1.6	8
Fragaria virginiana	0.6	4
Rubus parviflorus	0.6	4
Shepherdia canadensis	3.1	12
Chimophila umbellata	0.1	4
Arctostapylos uva-ursi	0.6	4

BASAL AREA (square meters/hectare) for coniferous trees: undetermined

LOWER DESOLATION AREA

PLOT A_3 July 29, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Berberis aquifolium	1.6	8
Amelanchier alnifolia	2.1	8
Acer glabrum	0.7	8
Arctostapylos uva-ursi	4.6	12
Rosa gymnocarpa	12.1	44
Berberis nervosa	12.7	32
Trientalis latifolia	5.4	56
Rubus parviflorus	8.6	36
Spirea betulifolia	6.1	32
Lonicera ciliosa	0.2	8
Ceanothus sanguineus	13.6	44
Salix spp.	3.1	8
Pachystima myrsinites	1.4	16
Fragaria spp.	0.7	8
Chimophila umbellata	0.6	4

BASAL AREA (square meters/hectare) for coniferous trees: 0

LOWER DESOLATION AREA

PLOT A_4 August 5, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Fragaria spp.	1.4	16
Fragaria virginiana	7.8	64
Rubus spp.	1.5	4
Spirea betulifolia	25.6	76
Pachystima myrsinites	7.3	56
Rosa gymnocarpa	7.5	48
Amelanchier alnifolia	5.6	16
Acer circinatum	10.4	20
Trientalis latifolia	7.3	60
Berberis nervosa	10.8	64
Ceanothus sanguineus	26.4	68
Salix spp.	6.3	24
Apocynum androsaemifolium	3.4	20
Berberis aquifolium	2.1	24
Sorbus sitchensis	1.5	4
Lonicera ciliosa	0.7	8
Rubus parviflorus	2.2	12
Epilobium angustifolium	1.2	8

BASAL AREA (square meters/hectare) for coniferous trees: undetermined

PUMPKIN MOUNTAIN AREA

PLOT B_1 August 23, 1973

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Pachystima myrsinites	2.1	44
Berberis nervosa	24.3	80
Spirea betulifolia	6.7	60
Trientalis latifolia	2.6	20
Chimaphila umbellata	0.6	4
Rosa gymnocarpa	3.8	36
Amelanchier alnifolia	0.1	4
Acer circinatum	4.1	12
Lonicera ciliosa	0.1	4
Rubus spp.	0.6	4
Linnaea borealis	0.6	4

BASAL AREA (square meters/hectare) for coniferous trees:

Lodgepole pine	39.56
Douglas-fir	0.936

PUMPKIN MOUNTAIN AREA

PLOT B_2 August 25, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Fragaria virginiana	12.7	83.3
Achillea millefolium	7.0	58.3
Rosa gymnocarpa	0.1	4.1
Pachystima myrsinites	0.1	4.1
Allium spp.	0.1	4.1
Spirea betulifolia	0.1	4.1
Prunus emarginata	0.6	4.1
Philadelphus lewisii	0.6	4.1
Salix spp.	0.1	4.1

BASAL AREA (square meters/hectare) for coniferous trees:

Douglas-fir	0.08

PUMPKIN MOUNTAIN AREA

PLOT B_3 August 30, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Berberis aquifolium	3.75	12.5
Fragaria virginiana	0.52	20.8
Achillea millefolium	8.75	50
Spirea betulifolia	0.31	12.5
Allium spp.	0.21	8.3
Philadelphus lewisii	1.56	4.1

BASAL AREA (square meters/hectare) for coniferous trees:

Douglas-fir	0.16

PUMPKIN MOUNTAIN AREA

PLOT B_4 August 30, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Achillea millefolium	2.8	32
Spirea betulifolia	9	52
Berberis aquifolium	6.7	40
Rosa gymnocarpa	2.8	16
Lonicera ciliosa	0.6	4
Trientalis latifolia	3.8	52
Ceanothus sanguineus	6.7	24
Pachystima myrsinites	0.1	4
Apocynum androsaemifolium	7.5	36
Berberis nervosa	7.5	48
Fragaria virginiana	10.8	64
Mianthemum unifolium	0.1	4

BASAL AREA (square meters/hectare) for coniferous trees: undetermined

PUMPKIN MOUNTAIN AREA

PLOT B_5 August 31, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Berberis aquifolium	3.6	28
Spirea betulifolia	4	44
Apocynum androsaemifolium	10	76
Fragaria virginiana	1.4	16
Trientalis latifolia	2.1	24
Rosa gymnocarpa	0.8	12
Achillea millefolium	0.3	12
Rubus spp.	1.3	12
Acer circinatum	0.6	4
Pachystima myrsinites	0.7	8
Corylus cornuta var. californica	0.7	8
Symphoricarpos albus	1.2	8

BASAL AREA (square meters/hectare) for coniferous trees:

Douglas-fir	3.24
Lodgepole pine	0.04

PUMPKIN MOUNTAIN AREA

PLOT B_6 August 30, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Acer circinatum	7.5	32
Apocynum androsaemifolium	1.8	16
Berberis nervosa	16.9	64
Rosa gymnocarpa	6.8	44
Spirea betulifolia	2.1	44
Linnaea borealis	12.4	72
Trientalis latifolia	2.8	52
Rubus spp.	1.1	24
Pachystima myrsinites	0.2	8
Gaultheria spp.	0.7	8
Amelanchier alnifolia	0.1	4

BASAL AREA (square meters/hectare) for coniferous trees:

Lodgepole pine 31.54

PUMPKIN MOUNTAIN AREA

PLOT B_7 September 1, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Berberis nervosa	53.3	100
Acer glabrum	0.2	8
Acer circinatum	1.1	24
Trientalis latifolia	4	60
Corylus cornuta var. californica	0.6	4
Symphoricarpus albus	0.6	4
Pachystima myrsinites	0.7	8
Rubus spp.	1.4	16
Apocynum androsaemifolium	0.1	4
Rubus parviflorus	0.1	4

BASAL AREA (square meters/hectare) for coniferous trees:

Douglas-fir 0.16

PUMPKIN MOUNTAIN AREA

PLOT B_8 September 1, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Berberis nervosa	38.9	96
Vaccinium spp.	1.3	12
Rosa gymnocarpa	2.8	16
Pachystima myrsinites	0.2	8
Acer glabrum	1.5	4
Linnaea borealis	0.1	4
Fragaria cirginiana	0.1	4
Trientalis latifolia	0.1	4

BASAL AREA (square meters/hectare) for coniferous trees:

Douglas-fir	18.42
Western Red Cedar	1.88
Western Hemlock	3.62

PUMPKIN MOUNTAIN AREA

PLOT B_{12} July 30, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Berberis nervosa	11.5	56
Trientalis latifolia	1.5	20
Rosa gymnocarpa	1.8	16
Rubus parviflorus	0.6	4
Amelanchier alnifolia	3.4	4
Shepherdia canadensis	0.6	4
Acer circinatum	1.3	12
Rubus pedatus	0.1	4
Chimaphila umbellata	0.6	4
Betula papyrifera	0.1	4

BASAL AREA (square meters/hectare) for coniferous trees:

Douglas-fir 20.472

SILVER CREEK DELTA

PLOT D_1 July 31, August 18, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Pachystima myrsinites	14.4	48
Salix spp.	5	12
Prunus emarginata	6.4	24
Berberis nervosa	0.7	8
Spirea betulifolia	0.1	4
Rosa gymnocarpa	2.4	20
Acer circinatum	0.7	8
Rubus parviflorus	1.5	4
Amelanchier alnifolia	0.6	4
Trillium spp.	0.1	4
Ribes spp.	0.1	4

BASAL AREA (square meters/hectare) for coniferous trees:

Douglas-fir	2.15
Western Red Cedar	0.16

SILVER CREEK DELTA

PLOT D_2 July 31, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Pachystima myrsinites	7.7	36
Prunus emarginata	4.3	20
Rosa gymnocarpa	2.7	12
Arctostaphylos uva-ursi	9.3	12
Ceanothus velutinus	4.9	8
Rubus pedatus	0.6	4
Amelanchier alnifolia	0.6	4

BASAL AREA (square meters/hectare) for coniferous trees: undetermined

SILVER CREEK DELTA

PLOT D_3 July 31, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Pachystima myrsinites	14.2	52
Acer circinatum	7.1	16
Acer glabrum	3.2	12
Lonicera ciliosa	1	20
Trientalis latifolia	0.1	4
Arctostaphylos uva-ursi	0.2	4
Ceanothus sanguineus	4.0	4
Chimophila umbellata	0.2	4
Sorbus sitchensis	0.1	4
Vaccinium parvifolium	0.6	4

BASAL AREA (square meters/hectare) for coniferous trees:

Douglas-fir	4.10
Western Red Cedar	0.37

SILVER CREEK DELTA

PLOT D_4 August 6, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Berberis nervosa	3.9	40
Ceanothus sanguineus	6.5	12
Vaccinium parvifolium	1.2	8
Pachystima myrsinites	20.2	60
Arctostaphylos uva-ursi	4.1	12
Acer circinatum	5.9	8
Spirea betulifolia	1.5	4
Linnea borealis	0.6	4
Prunus emarginata	1.5	4

BASAL AREA (square meters/hectare) for coniferous trees:

Douglas-fir 1.25

SILVER CREEK DELTA

PLOT D_5 August 6, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Berberis nervosa	0.2	8
Spirea betulifolia	2.5	20
Lonicera ciliosa	0.1	4
Salix spp.	5	8
Ceanothus sanguineus	1.2	8
Rosa gymnocarpa	0.1	4
Rubus parviflorus	0.6	4
Pachystima myrsinites	11.6	44
Amelanchier alnifolia	1.5	4
Arctostaphylos uva-ursi	13.6	32
Vaccinium parvifolium	0.6	4
Linnae borealis	1.3	12
Gaultheria ovatifolia	2.1	8
Alnus rubra	3.5	8

BASAL AREA (square meters/hectare) for coniferous trees:

Douglas-fir	1.32
Western Red Cedar	0.1[illegible]
Western Hemlock	0.08

LIGHTNING CREEK AREA

PLOT E_1 September 4, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Amelanchier alnifolia	5.7	16
Allium spp.	1	20
Fragaria virginiana	3.5	24
Berberis aquifolium	0.7	8
Achillea millefolium	4.5	40
Rosa nutkana	0.1	4
Balsamorhiza spp.	0.7	8
Ceanothus velutinous	2.5	4
Ceanothus sanguineus	1.5	4

BASAL AREA (square meters/hectare) for coniferous trees: 0

LIGHTNING CREEK AREA

PLOT E_2 September 5, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Pachystima myrsinites	0.2	8
Spirea betulifolia	6.2	76
Trientalis latifolia	5.7	68
Berberis aquifolia	6.9	44
Ceanothus sanguineus	0.9	16
Rosa gymnocarpa	3.4	20
Amelanchier alnifolia	0.1	4

BASAL AREA (square meters/hectare) for coniferous trees:

Lodgepole pine	36.17
Ponderosa pine	1.07
Douglas-fir	0.53

LIGHTNING CREEK AREA

PLOT E_3

September 5, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Amelanchier alnifolia	12.8	32
Ceanothus sanguineus	15.8	40
Rosa nutkana	2.1	8
Spirea betulifolia	2.3	32
Fragaria virginiana	2.9	20
Fragaria spp.	0.2	8
Berberis aquifolium	2.7	12
Prunus emarginata	6.1	16
Achillea millefolium	1.3	12
Allium spp.	0.6	4
Rosa gymnocarpa	5.2	16
Philadelphus lewisii	1.2	8
Balsamorhiza spp.	0.6	4
Holodiscus discolor	0.6	4
Apocynum androsaemifolium	0.6	4
Lonicera ciliosa	0.1	4
Trientalis latifolia	7.2	40

BASAL AREA (square meters/hectare) for coniferous trees:

Ponderosa pine 1.984

LIGHTNING CREEK AREA

PLOT E_4 September 6, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Amelanchier alnifolia	28.1	64
Holodiscus discolor	17	36
Trientalis latifolia	2.7	48
Rosa gymnocarpa	18.7	64
Spirea betulifolia	3.3	36
Ceanothus sanguineus	20.2	60
Pachystima myrsinites	2.7	12
Berberis aquifolia	1.3	12
Fragaria virginiana	3.9	40
Symphoricarpus albus	2.2	12
Prunus emarginata	2.5	4
Lonicera ciliosa	2.2	12
Salix spp.	9.3	12

BASAL AREA (square meters/hectare) for coniferous trees: 0

SKYMO CREEK BRUSHFIELD

PLOT F_1 September 7, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Ceanothus sanguineus	21.7	68
Rosa gymnocarpa	9.8	48
Berberis aquifolium	19.4	86
Spirea betulifolia	22.5	92
Berberis nervosa	9.2	56
Amelanchier alnifolia	9.5	20
Trientalis latifolia	5	44
Prunus emarginata	2.2	12
Rubus pedatus	2.1	8
Corylus cornuta	4.9	8
Epilobium angustifolium	0.1	4
Chimaphila umbellata	0.1	4
Acer circinatum	0.2	4
Pachystima myrsinites	0.2	4
Fragaria virginiana	0.1	4
Acer glabrum	3.0	8
Symphoricarpos albus	3.1	24
Salix spp.	19.8	32

BASAL AREA (square meters/hectare) for coniferous trees:

Douglas-fir	0.36
Lodgepole pine	0.04

SKYMO CREEK BRUSHFIELD

PLOT F_2 September 7, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Apocynum androsaemifolium	7.8	60
Spirea betulifolia	6.9	60
Amelanchier alnifolia	4.1	12
Berberis aquifolium	1.9	16
Trientalis latifolia	0.6	4
Holodiscus discolor	5	4
Ceanothus sanguineus	0.6	4
Salix spp.	8.3	12

BASAL AREA (square meters/hectare) for coniferous trees:

Douglas-fir 1.42

SKYMO CREEK BRUSHFIELD

PLOT F_3 July 16, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Acer circinatum	6.7	20
Trientalis latifolia	8.3	76
Rosa gymnocarpa	10.6	60
Ceanothus sanguineus	18.3	48
Salix spp.	5.1	16
Berberis nervosa	[illegible]9.2	60
Spirea betulifolia	6.6	64
Acer glabrum	2.7	12
Berberis aquifolium	2.5	24
Symphoricarpos albus	2.7	12
Corylus cornuta var. californica	0.7	8
Fragaria virginiana	0.6	4
Rubus spp.	1.7	4
Shepherdia canadensis	0.1	4
Pachystima myrsinites	0.1	4
Holodiscus discolor	3.4	4
Amelanchier alnifolia	2.8	16

BASAL AREA (square meters/hectare) for coniferous trees: 0

SKYMO CREEK BRUSHFIELD

PLOT F_4 July 17, 1972

SPECIES	AVERAGE COVERAGE %	FREQUENCY %
Ceanothus sanguineus	8.3	28
Apocynum androsaemifolium	9.9	64
Spirea betulifolia	9.4	68
Trientalis latifolia	2.6	28
Berberis aquifolium	3.8	20
Rosa gymnocarpa	2.9	20
Amelanchier alnifolia	5.6	12
Salix spp.	0.6	4
Achillea millefolium	1.2	4

BASAL AREA (square meters/hectare) for coniferous trees:

Douglas-fir	0.37
Lodgepole pine	1.02

GROWTH DYNAMICS

LOWER DESOLATION AREA (AREA A)

Prunus emarginata

Height	No. of rings
at base	25
1 meter	22
2 m.	19
3 m.	17
4 m.	11
5 m.	4
Leader	0.25 meters
Previous year's growth[1]	0.18 meters

Salix spp.

Height	No. of rings
at base	21
1 meter	19
2 m.	16
3 m.	12
4 m.	5
Leader	.25 meter
Previous year's growth	.10 meters

Acer circinatum

Height	No. of rings
at base	22
1 m.	17
2 m.	14
Leader	.025meters
Previous year's growth	.025meters

Ceanothus sanguineos

Height	No. of rings
at base	9
1 m.	9
2 m.	8
3 m.	7
Leader	.025meters
Previous year's growth	[illegible]meters

[1] last year's leader length.

LOWER DESOLATION AREA (AREA A)

Amelanchier alnifolia

Height	No. of rings
at base	14
1 meter	12
2 m.	9
Leader	.02 meters
Previous year's growth	.075meters

Shepherdia canadensis

Height	No. of rings
at base	26
1 meter	22
2 m.	20
3 m.	14
4 m.	8
Leader	.27 meters
Previous year's growth	.30 meters

Corylus cornuta var. californica

Height	No. of rings
at base	13
1 meter	11
2 m.	9
3 m.	3m
Leader	.20 meters
Previous year's growth	.20 meters

PUMPKIN MOUNTAIN AREA

AREA B, PLOT B1

Psuedotsuga menziesii (Douglas-fir)

Height	No. of rings
at base	31
1 meter	25
2 m.	21
3 m.	17
4 m.	15
5 m.	13
6 m.	11
7 m.	9
8 m.	7
9 m.	6
10 m.	4
11 m.	2
Leader	.64 meters

PUMPKIN MOUNTAIN AREA
AREA B, PLOT B_1

Pinus contorta (Lodgepole Pine)

Height	No. of rings
at base	42
1.5 meters	34
2 m.	28
3 m.	25
4 m.	22
5 m.	20
6 m.	17
7 m.	14
8 m.	12
9 m.	10
10 m.	8
11 m.	6
12 m.	4
13 m.	4
14 m.	2
Leader	.53 meters

AREA B PLOT B

Prunus emarginata (outside plot)

Height	No. of rings
at base	21
1 meter	20
2 m.	17
3 m.	16
4 m.	14
5 m.	11
6 m.	9
7 m.	6
8 m.	4
9 m.	2
Leader	?

Salix spp. (outside plot)

Height	No. of rings
at base	32
1 meter	28
2 m.	19
3 m.	16
4 m.	15
5 m.	14
6 m.	11
7 m.	9
8 m.	4
Leader	.41 meters

PUMPKIN MOUNTAIN AREA

AREA B, PLOT B_1

Acer circinatum

Height	No. of rings
at base	33
1 meter	30
2 m.	24
3 m.	16
4 m.	10
5 m.	4
Leader	.07 meters

Ceanothus sanguineus

Height	No. of rings
at base	17
.5 meters	14
1 m.	9
1.5M	8
2 m.	6
3 m.	0
Leader	.13meters

AREA B, PLOT B_2

Douglas-fir

Height	No. of rings
at base	13
1 meter	7
2 m.	6
3 m.	4
4 m.	3
Leader	.78 m.
Previous year's growth	.71 meters

Acer glabrum

Height	No. of rings
at base	41
1 meter	39
2 m.	28
3 m.	21
4 m.	15
5 m.	12
6 m.	10
7 m.	5
7.5m.	

PUMPKIN MOUNTAIN AREA

PLOT B_2

Salix spp.

Height	No. of rings
at base	19
1 meter	16
2 m.	12
3 m.	12
4 m.	11
5 m.	9
6 m.	6

Prunus emarginata

Height	No. of rings
at base	39
1 meter	33
2 m.	28
3 m.	24
4 m.	19

Holodiscus discolor

Height	No. of rings
at base	14
.5 meters	10
1.0 m.	8
1.5 m.	6

Salix spp

Height	No. of rings
at base	19
1 meter	17
2 m.	11
Leader	10 m.

Plot B_3

H. discolor

Height	No. of rings
at base	17
.5 meters	11
1 m.	9
1.5 m.	6
2 m.	3
Leader	.09 meters

PUMPKIN MOUNTAIN AREA
AREA B, PLOT B_3

Amelanchier alnifolia

Height	No. of rings
at base	22
.5 m.	20
1 m.	18
1.5 m.	14
2 m.	12
2.5 m.	8
3 m.	4
Leader	.05 meters
Previous year's growth	.06 meters

Salix spp.

Height	No. of rings
at base	14
.5 meters	10
1.0 m.	9
1.5 m.	9
2.0 m.	9
2.5 m.	8
3.0m.	5
3.5 m.	4
4.0 m.	3
Leader	.29 meters

Amelanchief alnifolia

Height	No. of rings
at base	18
.5 meters	15
1.0 m.	12
1.5 m.	11
2.0 m.	10
2.5 m.	7
3.0 m.	4

PUMPKIN MOUNTAIN AREA

AREA B, PLOT B_4

Lodgepole Pine

Height	No. of rings
at base	36
1 meter	28
2 m.	24
3 m.	18
4 m.	15
5 m.	14
6 m.	11
7 m.	9
8 m.	7
9 m.	5
10 m.	3
11 m.	0
Leader	.39 meters
Previous year's growth	.39 meters

Douglas-fir

Height	No. of rings
at base	30
1 m.	22
2 m.	20
3 m.	18
4 m.	16
5 m.	13
6 m.	11
7 m.	9
8 m.	8
9 m.	6
10 m.	5
11 m.	3
Leader	.66 meters
Previous year's growth	.51 meters

Ceanothus sanguineus

Height	No. of rings
at base	15
.5 meter	13
1 m.	8
1.5 m.	4
2 m.	2
Leader	.40 meters

PUMPKIN MOUNTAIN AREA

AREA B, PLOT B_4

Salix spp.

Height	No. of rings
at base	27
1 meter	19
2 m.	17
3 m.	14
4 m.	7
Leader	.05 meters

Amelanchier alnifolia

Height	No. of rings
at base	39
.5 meters	33
1 m.	29
1.5 m.	27
2 m.	23
2.5 m.	14
3 m.	7
Leader	.06 meters
Previous year's growth	.27 meters

Prunus emarginata

Height	No. of rings
at base	38
1 meter	33
2 m.	24
3 m.	19
4 m.	14

AREA B, PLOT B_5

Douglas-fir

Height	No. of rings
at base	19
1 meter	13
2 m.	9
3 m.	8
4 m.	5
5 m.	4
6 m.	2
Leader	.55 meters
Previous year's growth	.49 meters

PUMPKIN MOUNTAIN AREA

AREA B, PLOT B_5

Lodgepole Pine

Height	No.of rings
at base	98
1 meter	37
2 m.	32
3 m.	30
4 m.	28
5 m.	26
6 m.	24
7 m.	21
8 m.	19
9 m.	15
10 m.	12
11 m.	9
Leader	.23 meters
Previous year's growth	.25 meters

AREA B, PLOT B_6

Lodgepole Pine

Height	No. of rings
at base	42
1 meter	38
2 m.	36
3 m.	32
4 m.	29
5 m.	25
6 m.	23
7 m.	20
8 m.	18
9 m.	15
10 m.	13
11 m.	11
12 m.	8
13 m.	5
14 m.	2
Leader	.42 meters
Previous year's growth	.41 meters

PUMPKIN MOUNTAIN AREA

AREA B, PLOT B6

Douglas-fir

Height	No. of rings
at base	29
1 meter	21
2 m.	15
3 m.	11
4 m.	5
Leader	.28 meters
Previous year's growth	.28 meters

Acer circinatum

Height	No. of rings
at base	46
1 meter	40
2 m.	31
3 m.	26
4 m.	22
5 m.	21
6 m.	14
7 m.	9
8 m.	5
Leader	.31 meters

Salix spp.

Height	No. of rings
at base	30
1 meter	29
2 m.	27
3 m.	26
4 m.	22
5 m.	19
6 m.	16
7 m.	13
8 m.	10
9 m.	8
10 m.	4

Salix spp.

Height	No. of rings
1 meter	2
Leader	.60 meters

PUMPKIN MOUNTAIN AREA

AREA B, PLOT D_7

Douglas-fir

Height	No. of rings
at base	23
1 meter	17
2 m.	13
3 m.	11
4 m.	10
5 m.	9
6 m.	8
7 m.	6
8 m.	4
9 m.	3
10 m.	2
Leader	.91 meters
Previous year's growth	.94 meters

Betula papyrifera

Height	No. of rings
at base	34
1 meter	24
2 m.	23
3 m.	19
4 m.	17
5 m.	17
6 m.	13
7 m.	10
8 m.	7
Leader	.36 meters

PUMPKIN MOUNTAIN AREA

AREA B, PLOT B_7

Prunus emarginata

Height	No. of rings
at base	46
1 meter	40
2 m.	36
3 m.	30
4 m.	27
5 m.	21
6 m.	17
7 m.	13
8 m.	10
9 m.	7
10 m.	5
Leader	.33 meters
Previous year's growth	.17 meters

AREA B, PLOT B_8

Western Hemlock

Height	No. of rings
1 meter	25
2 m.	21
3 m.	18
4 m.	15
5 m.	13
6 m.	11
7 m.	8
8 m.	6
9 m.	4
10 m.	2
Leader	.50 meters

Douglas-fir

Height	No. of rings
at base	29
1 meter	21
2 m.	17
3 m.	13
4 m.	10
5 m.	8
6 m.	4
7 m.	3
Leader	.62 meters
Previous year's growth	.55 meters

PUMPKIN MOUNTAIN AREA

AREA B

PLOT B_8

Western Red Cedar

Height	No. of rings
at base	20
.5meters	15
1m.	12
1.5m.	8
2m.	6
2.5m.	3

SILVER CREEK DELTA

AREA D

PLOT D_1

Populus trichocarpa

Height	No. of Rings
at base	17
1meter	15
2m.	13
3m.	12
4m.	

Salix spp.

Height	No. of rings
at base	17
1meter	13
2m.	10
3m.	9
4m.	7
5m.	3

Prunus emarginata

Height	No. of rings
at base	12
1meter	10
2m.	8
leader	.31
previous year's growth	.31

Ceanothus velutinus

Height	No. of rings
at base	9
.5 meters	8
1m.	6
1.5m.	5
2m.	4
2.5m.	3
leader	.50

SILVER CREEK DELTA

AREA D

PLOT D_1

Acer circinatum

Height	No. of rings
at base	14
1 meter	10
2m.	8
3m.	5
leader	.16
previous year's growth	.08

Western Hemlock

Height	No. of rings
at base	14
.5meters	9
1m.	5
1.5m.	4
2m.	3
2.5m	2
leader	.62
previous year's growth	.61

Western Red Cedar

Height	No. of rings
at base	16
.5 meters	12
1m.	10
1.5m.	6
2m.	4
2.5m.	3
leader	.35

Douglas-fir

Height	No. of rings
at base	12
1 meter	9
2m.	7
3m.	6
4m.	5
5m.	3
6m.	2
leader	.90

SILVER CREEK DELTA

AREA D

PLOTS D_3 and D_5 AREA

Betula papyrifera

Height	No. of rings
at base	19
1 meter	15
2 m.	13
3 m.	11
4 m.	8
5 m.	5
leader	.38
previous year's growth	.28

Douglas-fir

Height	No. of rings
at base	18
1 meter	13
2m.	10
3m.	9
4m.	8
5m.	7
6m.	5
7m.	4
8m.	3
leader	missing
previous year's growth	.78

LIGHTNING CREEK AREA

AREA E

PLOT E_1

Ceanothus sanguineus

Height	No. of rings
at base	7
.25 meters	5
.5 m.	4
.75 m.	3

Ceanothus velutinous

Height	No. of rings
at base	20
.25 meters	16
.5m	10
.75m	8
1m	6

Philadelphus lewisii

Height	No. of rings
at base	5
.25 meters	3
.5m	2
.75m	1
1m	1

LIGHTNING CREEK AREA

AREA E

PLOT E_1

Prunus emarginata

Height	No. of rings
at base	18
0.5meters	14
1 m.	12
1.5m	8

Salix spp

Height	No. of rings
at base	13
0.5 meters	11
1 m	11
1.5 m	10
2 m.	8
2.5 m	6

LIGHTNING CREEK

AREA E

PLOT E_2

Lodgepole Pine

Height	No. of rings
at base	35
1 meter	28
2 m	25
3 m	21
4 m	17
5 m	13
6 m	10
7 m	7
8 m	5
9 m	4
10m	2
leader	.58
previous year's growth	.64

LIGHTNING CREEK AREA

AREA E
Plot E_2

Amelanchier alnifolia

Height	No. of Rings
at base	23
1 meter	20
2 m.	17
3 m.	15
4m.	14
5 m.	10
6 m.	6
Previous year's growth	.32 meters
Leader	.08 meters

Salix spp.

Height	No. of Rings
at base	35
1 meter	34
2M.	31
3M	26
4M	23
5M	15
6M	11
7M	6
Leader	.17meters

LIGHTNING CREEK AREA

AREA E

PLOT E_2

Douglas-fir

Height	No. of rings
at base	33
1 meter	19
2m	12
3m	9
4m	6
5m	4
6m	2
leader	.43
previous year's growth	.37

Prunus emarginata

Height	No. of rings
at base	24
1 meter	21
2m	16
3m	14
4m	10
5m	8
6m	5
7m	3
leader	.32

LIGHTNING CREEK AREA

AREA E

PLOT E_3

Ponderosa Pine

Height	No. of rings
at base	31
1 meter	18
2m	14
3m	11
4m	9
5m	6
6m	4
Leader	.47
Previous year's growth	.37

Salix spp.

Height	No. of rings
at base	22
1 meter	18
2m	15
3m	12
4m	6
Leader	.14
previous year's growth	.19

LIGHTNING CREEK AREA

AREA E

PLOT E_3

Prunus emarginata

Height	No. of rings
at base root	29
at base stem	25
-----	17
1.5m	15
2m	13
-----	10

Ceanothus sanguineus

Height	No. of rings
at base	16
.5 meters	10
1 m	present
leader	.23 m(?)

Salix spp.

Height	No. of rings
at base	17
1 meter	16
2 m	14
3 m	9
4 m	5
leader	.12
previous year's growth	.10 m

Holodiscus discolor

Height	No. of rings
at base	7
.5 meters	5
1 m	5
1.5 m	4
2 m	4

LIGHTNING CREEK AREA

AREA E

PLOT E_4

Prunus emarginata

Height	No. of rings
at base	18
1 meter	15
2m	13
3m	9
leader	.30

SKYMO CREEK BRUSHFIELD

AREA F

PLOT F_1

Douglas-fir

Height	No. of rings
at base	13
1 meter	8
2m	5
3m	4
leader of 2 years previous	.55
leader	.65
previous year's leader	.95

A 9 year, 6 foot tall Douglas-fir

leader	.30 meters
last year's	.33 m
2 years ago	.30 m
3 years ago	.15 m
4 years ago	.21 m
5 years ago	.19 m

Corylus cornuta

Height	No. of rings
at base	12
1 meter	11
2 m	8
3 m	6

Salix spp.

Height	No. of rings
at base	25
1 meter	23
2 m.	17
3 m.	15
4 m.	12
5 m.	10
6 m.	7

Acer glabrum

Height	No. of rings
at base	25
1 meter	21
2 m.	17
3 m.	11

Acer circinatum

Leader	.06m
Previous year's growth	.07m.

SKYMO CREEK BRUSHFIELD

AREA F

PLOT F_1

Prunus emarginata

Height	No. of rings
at base	21
1 meter	18
2 m.	14
3 m.	9
4 m.	4
leader	.06 m
previous year's growth	.11 m

Ceanothus sanguineus

Height	No. of rings
at base	16
.5 meters	14
1 m.	10
1.5 m.	5
2 m.	3

SKYMO CREEK BRUSHFIELD

AREA F

PLOT F_2

Douglas-fir

Height	No. of rings
at base	35
.82 meters	31
1.64 m	27
2.46 m	24
3.28 m	21
4.10 m	18
4.92 m	16
5.74 m	13
6.56 m	11
7.33 m	9
8.20 m	8
9.02 m	6
9.89 m	5

Lodgepole Pine

Height	No. of rings
at base	38
.82 meters	36
1.64 m	32
2.46 m	30
3.28 m	27
4.10 m	25
4.92 m	23
5.74 m	19
6.56 m	15
7.33 m	13
8.20 m	10
9.02 m	8
9.84 m	7
10.66 m	3

Prunus emarginata

Height	No. of rings
at base	24
.5 meters	23
1 m	22
1.5 m	20
2.0 m	15
2.5 m	5
3.0 m	2

Amelanchier alnifolia

Height	No. of rings
at base	20
.5 meters	18
1.0 m	17
1.5 m	13
2.0 m	12
2.5 m	6

APPENDIX C: MATURE FOREST WINTER RANGE LICHEN STUDY

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INTRODUCTION

The availability and importance of lichens as a forage utilized by deer (_Odocoileus_ spp.) has not been extensively studied. Cowan (1945) examined the forage of Columbian blacktailed deer (_Odocoileus hemionus columbianus_) on Vancouver Island, finding that certain arboreal lichens constituted a major percentage of the winter diet. The extent to which deer may utilize lichens in other habitat types has not yet been determined. However, the availability of arboreal lichens to woodland caribou (_Rangifer tarandus osborni_) in the interior range of British Columbia indicates many parallels to Cowan's (1945) deer study. Caribou, in contrast to deer, subsisted entirely during the winter months on arboreal lichens made available through windfalls (Edwards, Soos, & Ritcey, 1960).

The composition and availability of arboreal lichen communities has likewise received little surveilance. Szczawinski (1953) studied the arboreal composition on a Vancouver Island Douglas-fir stand. The distribution and range of ground and arboreal lichens native to Washington has been described by Howard (1950), and Cook (1956).

Since the availability of arboreal lichen loads to Cervids has only been treated by Edwards, Soos & Ritcey (1960) on woodland caribou, the objective of this study is to relate the arboreal and ground lichen community structure of several forest types at Ross Lake, Washington, and to determine their relative abundance and utilization by deer as a forage during winter months.

DESCRIPTION OF AREA

Ross Lake (Lat. 48° 80' N, Long. 121° 10'W) is located in the North Cascades of Washington, extending from the Canadian border (49th parallel) twenty-two miles to Ross Dam . The Ross Lake basin is enclosed on the west by the northern and southern Picket range, the highest peak being Mount Challenger, 8,236 feet. The eastern edge of the lake is bordered by the Cascade complex, the highest of which are Three Fools Peak, 7 7,960 feet, and Jack Mountain, 8,928 feet. Glacial systems are continuously feeding the Ross basin.

Major rivers feeding into Ross Lake are the Skagit, Ruby, Big Beaver, and Lightening Creeks (Figure C1). The smaller tributaries which drain the immediate peaks adjacent to the lakeshore follow steeper courses before entering the reservoir. The lake elevation at normal high water level is 1,602.5 feet (Ross Lake Report, 1972).

The climate of the Ross Lake basin is considered to have a maritime influence with variations occuring locally. Precipitation is greatest during the winter months with approximately 47 percent falling during the November to January period (Ross Lake Report, 1972). Yearly precipitation varies from 43.32 inches annually to 69.91 inches Snow accumulation at the time of the study (March) varied from 2 to 4 feet on the west side of the lake to 0 to 2 feet on the east and more southerly facing exposure of the lake.

The vegetation in the lake drainage has been described as the humid transition (Merriam, 1898; Piper, 1905), and the Tsuga heterophylla zone (Franklin & Dyrness, 1969). The eastern border of the lake contains small pockets of the arid transition zone (Merriam, 1898).

Conifer forests dominate the vegetation of the lake basin except in small patches where deciduous regeneration has resulted from an extensive fire which occurred in 1926. Here extensive stands of lodgepole pine (Pinus contorta), paper birch (Betula papyrifera), and alder (Alnus rubra) exist.

Climax and subclimax forests existing in the lake basin consist of a xerophytic rocky bluff habitat, and the mature coniferous forest ranging from a hydroseric to xeroseric condition (Klein, 1965). The rocky bluffs occur throughout the lakeshore, consisting primarily of a climax and stable community of lodgepole pine (Pinus contorta), and scattered individuals of Douglas-fir (Pseudotsuga menziesii). The major portion of the climax forest on the western shore of the lake is humid, and represented by the Big and Little Beaver drainages. Here vegetation consists primarily of Western hemlock (Tsuga heterophylla), western red cedar (Thuja plicata), western white pine (Pinus monticola), and Douglas-fir. The more exposed and southerly facing slopes which are found primarily on the east shore of the lake are mesic, Douglas-fir being the dominant species. Grand fir (Abies grandis) and Pacific silver fir (Abies amabilis) also occur in scattered areas. More xerophytic sites contained Ponderosa pine (Pinus ponderosa) but was extremely restricted to very local conditions.

METHODS

Four major vegetational types representative of the lake were chosen for the study: 1) Rocky outcrop type consisting of a stable lodgepole pine community, 2) Immature and mature Douglas-fir subclimax forest, 3) Climax hemlock forest facing a northeast exposure, and 4) a recently burned mixed hardwood-conifer subclimax forest.

Of the four areas sampled for lichen content, area three did not have a wintering deer population due to the deep annual snow accumulation along the entire Big Beaver drainage Areas one, two, and four had large winter pellet groupings, each area containing a substantial wintering deer population (Ross Lake Study, 1971).

Within each vegetational type, an average of eight sample trees were chosen for measuring the total arboreal lichen structure and composition. The trees sampled were chosen over a spectrum of heights and ages, giving a broader distribution of total lichen content for the forest type than sampling one age class. Each tree was sampled along its entire length for lichen content by climbing it. To measure branch lichen loads and distribution, one branch was selected from every fourth node from the base of the tree to the top of the crown. The distance between these nodes was recorded to obtain a height distribution of the lichen communities. The entire lichen load was removed from each branch by hand. The lengths of the branches, and the number of branches for each four node unit were also recorded so that an estimate of the entire branch load for the sample tree could be calculated. To measure the lichen volume on the bole, a sample was taken at DBH 3.5 feet and 6 feet in order to determine if deer were browsing on the lower portion of the bole (Table 2).

The lichen samples were separated in the lab according to species, and air dried at 70° F. The samples were weighed to a thousandth of a gram and total yields for each tree were calculated by summing the branch and bole lichen load.

The tree density of each vegetation type was calculated by the point-centered quarter method (Cottom & Curtis, 1956). Two transects perpendicular to the lake were made for each vegetational type. Plots were established for sampling by using a random numbers table, generating a plot randomly every fifty feet. The nearest tree in each quarter quadrant was measured from that point, a total of four distances being recorded. The sums of these distances are then computed to obtain a density relationship for the stand. Ages, and heights were additionally recorded to obtain a height frequency distribution for each stand.

Ground plots one foot square at 50 foot intervals were established along a transect line perpendicular to the lakeshore. Plant and lichen composition was recorded, the lichens being air dried at 70°F. The percentages of lichen composition by weight were determined
Arboreal lichens that had fallen from the crown were especially important in these plots, and an estimate of their percentage by weight was also recorded (Table 4).

Finally, to determine the amount of lichen falling from the crown over a unit period of time, wire baskets with a capturing surface area of 1 meter square were erected along three different transects in area two. There existed a bias in this sampling procedure since each basket had to be erected in a group of trees in order to suspend it, indicating they would give values only near tree crowns.

STUDY AREAS AND HABITAT DESCRIPTION

Of the four vegetational types sampled, area 4 was in a region not frequented by a winter population of deer (Ross Lake Study, 1972; see Table 1d for reference). Areas 1, 2, and 4 contained a moderate to dense population of wintering deer (Ross Lake Study, 1972), and high concentrations of pellets were evident in all three study areas. To determine if deer utilize lichens in their winter diet, it was desirable to quantify the entire relative abundance of arboreal lichens in the crown, and their availability on the forest floor.

AREA I

Area 1, Ruby Arm, had an even aged stand of mixed lodgepole pine (*Pinus contorta*) comprising 80 percent of the overstory, and Douglas-fir (*Pseudotsuga menziesii*) comprising 20 percent. Lodgepole pine is a common pioneer species over much of the area bordering Ross Lake, favoring xerophytic sites. It becomes a relatively stable climax species on rocky bluffs and may form nearly pure stands of up to 1200 stems per acre (Ross Lake Report, 1972). The stand density for Ruby Arm was found to be 647 stems per acre. Shrubs and herbs commonly associated with lodgepole were *Berberis nervosa*, *Gaultheria shallon*, *Pachystima myrsinites*, and *Arctostaphyllos uva-ursi*. The shrub layer was not extensive where the canopy was closed.

Rock outcroppings and open bluffs within the lodgepole stand support a large percentage of ground lichens. Mosses (*Polytrichum* spp.) form up to 60 percent of the vegetation, with lichen concentrations reaching 50 percent (Table 5). Common ground lichens found are *Stereocaulon tomentosum*, *Stereocaulon paschele*, *Cladonia rangiferina*, *C. fimbriata*, and *C. mitis*, all in association with the Polytrichum complex.

The foliose lichen Umbilicaria hyperborea is common with Cladonia rangiferina on talus and boulder slopes.

Under a closed canopy the understory contains scattered clumps of the lichens Peltigera membranea, and shrubs such as Berberis and Gaultheria.

The arboreal lichens seemed more abundant where the stand is open (i.e. on both rock outcroppings and along the lakeshore). At Ruby Arm there appears to be four species of fruticose lichens of the genus Alectoria and one species of the genus Usnea . Alectoria sarmentosa appears on the lower half of the tree crown and bole, favoring an exposed substratum (Szczawinski, 1953). The remaining three species of Alectoria are A. jubata, A. oregona, and A. fremontii, all dark green to greyish in color Since the latter three species are extremely difficult to separate in the field, they were lumped into the category of A. jubata. The latter group was generally found in the upper half of the crown (Table 1).

The major foliose lichens found were Parmelia and Cetraria, and Parmelia physodes. Under the Parmelia and Cetraria grouping were lumped the following indistinguisable species: Parmelia perlata, Parmelia entermorpha, Cetraria glauca, and Cetraria stensophylla. The Parmelia and Cetraria complex was found to be in greatest concentration on the lower portion of the crown and bole. Parmelia physodes was primarily confined to the upper branches and bole of all the trees sampled. A foliose lichen restricted to the upper crown is Cetraria juniperina, which is a distinct yellow in color.

AREA II

Area 2, Roland Point, had an even aged stand of both immature and mature Douglas-fir vegetational types. Both stand types represent 40-50 percent of the vegetational types in the Ross Lake basin (Ross Lake Report, 1972).

Both types were sampled for tree density and lichen loads.

The immature stand is characterized by a dominance of Douglas-fir which followed a major disturbance. The site was located at the lakes edge on a ridge bordering the southern tip of the point. Associated trees in the understory were vine maple (Acer circinatum), willow (Salix, spp.) and western hemlock. Stand volumes may reach as high as 1000 stems per acre for this vegetational type (Ross Lake Report, 1972) In the study area the stand was found to be 197 stems per acre (Table 3).

Common shrubs and herbs associated with the immature Douglas-fir types are Gaultheria ovafolia, Berberis nervosa, and Rosa gymnocarpa.

The mature stand of Douglas-fir contained in addition to the immature understory, grand fir, and in more hydric sites, western red cedar. Stand density was found to be 173 stems per acre.

On the more mesic site, large Douglas-fir dominates a generally more open stand with open crowns. This stand supported a greater diversity of shrubs than the immature or hydric climax vegetational types, and a high live crown ratios. Shrubs associated with the mesic or xerophytic sites are Rosa gymnocarpa, Amelanchier alnifolia, Holodiscus discolor, and Arctostaphylos uva-ursi.

The understory was extremely poor in both areas of ground lichens where there was a substantial overstory. Peltigera membranea occurred only sparingly . On the more open bluffs, a greater diversity of lichens were found. Species occurring were Stereocaulon tomentosum, S. paschele, Cladonia rangiferina, C. carosa, C. mitis, and Peltigera membrenea. All were in an association with the moss Polytrichum, and were in similar proportions as those found at Ruby Arm.

The epidendric lichen composition consisted of the same species as those found in the Ruby Arm locality. There were, however, greater concentrations of Alectoria sarmentosa on the peripheral stand bordering the lake in both the immature and mature stand. Alectoria jubata was found in the upper portions of the crown as in Area 1. Usnea barbata was identified in the stand in extremely low concentrations in comparison to that indicated on Vancouver Island by Szczawinski (1953). Foliose concentrations were larger on the hydric sites of the old growth stands.

AREA III

Area 3, Big Beaver Creek, is representative of a climax forest facing a north slope, typical of the western exposure of Ross Lake. Western hemlock dominates the overstory, and on more hydric conditions is associated with red cedar, Pacific silver fir, and grand fir. The stand sampled contained old growth Douglas-fir in the 400-500 year old age class and western white pine (Pinus monticola) as co-dominant. The stand density was found to be 233 stems per acre (Table 5). The crown canopy is closed beyond 50 meters from the lakeshore.

The understory consisted primarily of huckleberry (Vaccinium membraneum), pippssissiwa (Chimophila umbellata), Gaultheria ovafolium, and Berberis nervosa.

The few ground lichens occurring in the understory were Peltigera membranea, and Cladonia mitis. The larger percentage of the vegetation consisted of the mosses Polytrichum and Hylocobium.

Snow accumulation was up to three feet in the stand, and contained a large amount of branch debris with large lichen loads. A comparison of these loads will be undertaken in the discussion section.

The arboreal lichens in the stand were extremely rich and varied. One new species not found in other localities was Lobraria pulmonaria, a leafy foliose lichen confined to the lower portion of tree crowns . Alectoria sarmentosa and Alectoria jubata were both very dense in the lower portion of the crown, as well as the tops of snags. The Parmelia and Cetraria complex was not as abundant as that of Areas 2 and 3. To exemplify the lichen diversity of this area, one young western red cedar contained moderate loads of Alectoria and Lobraria (in comparison to the Douglas-fir and hemlock trees sampled in the same locality). The cedar sampled and those observed at Roland Point had no lichens, indicating that this area seemed to favor lichen growth on almost any substrate.

AREA IV

Area 4, Pumpkin mountain, is located on the western shore of the lake, north of Big Beaver Creek. It is characterized by young regeneration of hardwoods and conifers in the overstory, 30-40 years old. The locality was burned by fire in 1926, and fire subclimax species such as birch (Betula papyrifera) and Douglas-fir predominate. Birch and alder (Alnus rubra) are both dominant in the more hydric sites.

The understory consists primarily of Berberis nervosa, Polystichum munitum, and western hemlock.

Both ground and arboreal lichens were totally absent in this locality. There was some evidence of fungal invasion on Douglas-fir which had recently died (Polyporus spp.)

RESULTS

The potential abundance and availability of the ground lichen base as a resource for deer was measured and compared in each vegetation type. The total weight in kilograms per hectare for each sample area was derived.

The highest lichen concentration of the four vegetational types were on xerophytic rocky bluffs in areas 1 and 2. Lichen loads varied from 800-2300 kilograms per hectare for Cladonia rangiferina, 300-2700 kilograms per hectare for Stereocaulon spp., and 900 kilograms per hectare for Umbilicaria hyperborea. Moss (Polytrichum spp.) constituted up to 50 percent of the ground vegetation by weight.

As tree density increased, the amount of ground lichens as determined by weight decreased for Areas 1 and 2. In dense stands of either lodgepole or Douglas-fir, Peltigera membranea, Cladonia cariosa, and C. mitis appeared, and Stereocaulon spp. and Cladonia rangiferina became absent. Peltigera occurred in concentrations as high as 65 kilograms per hectare. Berberis nervosa and Gaultheria octopelada were also present in these plots. There was no evidence of deer browsing on the ground lichen flora in any of the vegetational types.

The arboreal lichen concentrations on the ground in each vegetational type were compared to determine if deer in fact forage on them, and, if they do, what species are preferred. The arboreal lichen load on the ground was found to be heaviest in area 3.

Alectoria sarmentosa occurred by weight as high as 143 kilograms per hectare in the deeper interior of the hemlock stand. Alectoria jubata was found to range between 10-35 kilograms per hectare on the lake edge (Area 3), and 3 kilograms per hectare in the interior portion of the hemlock stand. Alectoria jubata was found to range between 10-35 kilograms per hectare on the lakes edge (Area 3), and 3 kilograms per hectare in the interior portion of the hemlock stand. The available amounts of Alectoria sarmentosa at Roland Point did not exceed .403 kilograms per hectare, and for A. jubata, 10 kilograms per hectare. Alectoria of either species was not found in any of the sample plots at Ruby Arm.

Concentrations of Parmelia and Cetraria for Roland Point-b (Sample area-a refers to the mature Douglas-fir type in a xerophytic site, sample b area refers to the mature stand in the hydric site), and Big Beaver Creek were approximately equal (Table 1,), and somewhat reduced on Ruby Arm and Roland Point-a.

The lichen traps at Roland Point yielded a low percentage of arboreal lichen loads), in comparison to the yields found in the ground plots over the year. The average yield for the stand was .083 kilograms per hectare of Alectoria sarmentosa, and .0031 kilograms per hectare of Alectoria jubata over a four week interval. This constituted a very small fraction of the total yield in comparison to the amount of branches with heavy lichen loads which had fallen over the winter. It seems that high winds would produce massive lichen fallouts from broken branches. This, however, could not be quantified since the traps were not checked during an interval that had a major storm.

The total lichen yield for each tree species was estimated from the selected trees sampled in each forest type . The spectrum of trees sampled were chosen at different heights, representing a different age and height distribution.

The density (stems per hectare) of the trees for each vegetational type was calculated by the point center coordinate method (Cottam & Curtis 1956). A frequency distribution for heights was compiled, forming an analysis of the proportion of individual trees in height classes, P(h). The weights of the lichen species loads for each individual tree was plotted against the height distribution of the stand in each vegetational type. A regression line was fitted for three species of lichens in each stand using the sum of squares analysis (Snedecor, 1970). From the fitted lines, a weight distribution of lichens L(h) was calculated for each stand type. The mean lichen weights for a tree in a vegetation type was then determined by integrating P(h) and L(h), $\int_{h_o}^{h_n} P(h)L(h)dh$. The lichen loads in kilograms per hectare for each vegetational type was found by multiplying the number of stems per unit area times the mean lichen weight. The data are summarized in Table 3.

Roland Point (Area 2) contained the largest lichen loads per individual tree for the foliose lichen group _Parmelia_ and _Cetraria_. However, Ruby Arm yielded the largest load for the group in terms of kilograms per hectare. Generally _Parmelia_ and _Cetraria_ were substantially equal in abundance on trees in Areas 1 and 2, but reduced in abundance in Area 3, Big Beaver Creek. The weight distribution of _Lobraria pulmonaria_, a large lettuce-like foliose lichen which seems to displace _Parmelia_ and _Cetraria_ in wetter sites on old growth stands (Big Beaver Creek) approaches 300 kilograms per hectare.

Alectoria sarmentosa was found to be most abundant in Area 3. Big Beaver Creek yielded 314 kilograms per hectare of _A. sarmentosa_, whereas Ruby Arm and Roland Point (exposed bluff) contained only 18 kilograms per hectare in the crown, a very low proportion (Table 3). This was in agreement with the general observation that the A. sarmentosa yields were greatest in more open crowns, a possible function of light intensity. The weight distribution of A. jubata was in the same proportion as A sarmentosa, being most abundant in Area 3, and least abundant in Area 2 (Roland Point b) in the denser part of the stand. The total epiphytic load in the crown in terms of kilograms per hectare were highest at Ruby Arm, yielding 2,279 kilograms on a per hectare basis.

In order to determine if deer feed upon lichens, and the potential availability of these lichen loads on trees to deer, a measure of vertical distribution of lichen communities is necessitated. Lichen loads for both the bole and crown were calculated for each 10 foot section of the sample trees in all the vegetation types.

The abundance of lichen on the bark of trees was sampled at the 3.5 foot and the 7 foot level from the ground. Differences in the lichen densities at these points occurred for Areas 1 and 2 but not for 3. At the 3.5 foot level in Areas 1 and 2 (Table 2), there were low concentrations of Alectoria sarmentosa, A. jubata, and Usnea barbata. Parmelia and Cetraria, however, remained relatively constant for weights measured at 3.5 and 7 feet with the exception of tree number three measured at Roland Point. This indicated a possible preference by deer for Alectoria and Usnea since at the seven foot section, A. sarmentosa, A. jubata, and U. barbata were in greater concentrations. An index of the ratio of the seven foot section divided by the 3.5 foot section (Table 2) indicated that Alectoria yielded an index as high as 230 in Area 2 (Areas 1 and 2 were both relatively high) and Area 3 yielded a very low index of .743.

DISCUSSION

ECOLOGY OF LICHENS

Several relationships may be formulated from the previously mentioned data on lichen distribution and abundance. In the unpublished thesis on corticulous lichens on Vancouver Island, Szczawinski (1953) concluded that in a Douglas-fir forest, Alectoria spp. and Usnea spp. were generally most abundant in open, drier sites, where A. fremontii was especially confined to the xeric habitat. In the more dense forest types, Alectoria was generally confined to the tops of the dominant overstory. Edwards, Soos and Ritcey (1960) found that Alectoria sarmentosa was dominant in the lower third of the crowns, favoring the open branches in dense forest. A. jubata occurred primarily in the upper crown, higher than most other lichen species.

In the Ross Lake basin, the areas sampled indicate that A. sarmentosa also occurs in exposed areas as suggested by their heavier density observed adjacent to the lake. A. sarmentosa occurred in greatest concentrations on the most exposed portion of the bole, the side facing the most light during the major portion of the suns arc. In contrast, the denser stands of trees (Roland Point-b, Ruby Arm) contained A. sarmentosa only on the larger dominant trees and snags on the upper crown levels. In Big Beaver Creek the lichen loads on trees adjacent to the lake shore were comparable to that of the mesic site of Douglas-fir on Roland Point. The frequency of Alectoria in exposed places in the Ross Lake area is in general agreement with Szczawinski (1953) hypothesis that Alectoria sarmentosa occurs in more exposed localities, but is in conflict with Edwards, Soos, and Ritcey (1960) conclusion that Alectoria favors sheltered localities.

The darker Alectoria group (A. jubata) was found to frequent the upper third of the crown, (Figures 52-5[illegible]) again in all three areas seeming to favor exposure to light. Another factor may be that it is only able to survive where it has less competition from other lichen species. The exception to this occurred in Area 3, Big Beaver Valley where it was found primarily on the lower third of the crown with A. sarmentosa.

The Parmelia and Cetraria group was fairly constant in abundance under varying conditions of light intensity in each vegetation type. Comparable lichen loads occurred on both exposed and sheltered sites. (Table [illegible]) There was a substantial deviation in density in Area 3 which had a high concentration of Lobraria pulmonaria. There seemed to be evidence of competition between the Parmelia and Cetraria group and Lobraria in that the latter grew faster, as one young cedar sampled contained heavy loads of Lobraria, but little of Parmelia and Cetraria.

The parameters which seem to affect the abundance of lichens are stand density, exposure, moisture, temperature, age of the stand, and the availability of a spore source. The lichen loads in the first three vegetational types exemplified this variability. In dense stands of lodgepole pine (1600 stems per hectare) which have open crowns, a large epidendric lichen load occurred. Areas 2 and 3 supported comparable loads with lesser stocking densities (Big Beaver-576 stems per hectare; Roland Point-197 stems per hectare). Where the stand has a closed crown, only the Alectoria and Usnea group seems to be reduced.

The amount of exposure to a sufficient light source seemed to influence Alectoria sarmentosa, A. jubata, and Cetraria juniperina. In contrast, Parmelia and Cetraria were abundant in all sites, even the lower portions of the bole in the deeper forest stands where little available light filtered through to the ground.

The effects of humidity and temperature on lichens were exemplified in differences found in the Roland Point and Big Beaver areas. Trees aged (hemlock and Douglas-fir) on the lakeshore for both areas were comparably equal, yet contained greater lichen loads of both foliose and fruticose species. Alectoria (kilograms per hectare) in the crown was found to 1.5 times the highest Alectoria loads of Areas 1 and 2. The abundance of foliose lichens such as Clasonia, Lobraria, Parmelia and Cetraria occurred in the crown.

The growth rate of lichens directly influences its abundance in a habitat. Growth of the algal-fungal thallus is accelerated under optimal conditions of sufficient humidity, temperature, and light conditions to survive (Pegau, 1968). Pegau (1968) found that the growth rate of both fruticose and foliose lichens in southeastern Alaska was far greater than similar species found in the interior of Alaska. The interior experiences greater temperature extremes and less available moisture than the humid coast, indicating slower growth rates would be expected. Growth rates for Alectoria in the coastal islands reached up to 13 cm per year (Pegau, 1968).

The Ross Lake area lichen growth rates also seemed to be rapid. The abundance of Alectoria in the understory where favorable conditions occurred was high. The mesic sites of Area 2 and 3,where exposed, contained large lichen loads on very young understory. Many trees which were under 40 years old contained huge colonies of A. sarmentosa, and A. jubata. In the deeper stand farther away from the lake where there were few lichens in the overstory, the understory was void of any Alectoria. This indicates that where colonies are able to start, the growth rates are comparatively high. The ability to colonize seems to be dependent upon the availability of parental fragments of the thallus which can start new colonies when they fall from the overstory into a new substratum. This again was evident at Ross Lake where large lichen loads were found in the younger understory where conditions for growth were optimal and availability from the overstory was high.

In contrast, Area 4, Pumpkin Mountain, was also of the 40 year age class but did not contain any lichens in the stand. This was partly the result of poor availability of spores, and a lack of availability due to rapid growth from fragmentation. Again the abundance of lichens seems to be a function of availability of spores, fragmentation, exposure, humidity, temperature and density.

THE AVAILABILITY TO AND USE BY DEER OF ALECTORIA AND USNEA

The potential use of ground and arboreal lichens by deer as winter forage has received little attention. However, deer during winter have been observed utilizing lichens in their diet where availability of other forbs is extremely low. A quantitative study on the use of ground lichens by deer is described by Cowan's research (1945) on Vancouver Island, Britis Columbia. Cladonia spp. was identified in the stomach content analysis on blacktailed deer to occur as a small percentage by volume (.6%) of other forbs. The poor utilization of Cladonia by deer in this area may be attributed to either poor availability and abundance of ground lichens on the forest floor, or their unpalatability.

The consumption of ground lichens by deer in the Ross Lake area could not be determined without stomach analysis. However, potential ground lichen loads were high along rocky outcroppings where heavy concentrations of wintering deer occurred. There were no observations made of deer eating any lichens in this locality.

The observation of deer eating arboreal lichens has been described by Cowan (1945). He found that blacktailed deer wintering on a Douglas-fir stand in southeastern Vancouver Island consumed a large percentage of fruticose arboreal lichens in their diet. In his analysis of stomach contents of deer, Usnea barbata (also found in the Ross Lake are) comprised about 36 percent of the forage eaten through the months of January to March. In the fall Usnea was found to be only 4 percent of the forage consumed by deer. Douglas-fir comprised the other major percentages of the diet (46%) (Cowan, 1945). He concluded that blacktailed deer actively sought Usnea: "The second largest single food source is the arboreal lichens. The high consumption of these lichens (by deer) is apparently characteristic wherever they are available" (Cowan, 1945: page 128).

Edwards, Soos, and Ritcey (1960) found that woodland caribou actively sought Alectoria sarmentosa and A. jubata. Older growth stands of Douglas-fir and spruce yielded a large enough amount of windfall with heavy lichen loads to support a wintering population of caribou through the winter stress periods. Availability ran as high as 343 kilograms per acre (Edwards, Soos, and Ritcey, 1960).

There is substantial evidence that deer in the Ross Lake area also utilize the lichen resource during the winter stress periods, when favorable browse is not available. Deer normally seek out preferred forage such as Vaccinium, Amelanchier, Pseudotsuga, Acer, and Alnus, (Klein, 1965; Cowan, 1945). When this forage is not available during the winter when deep snow conditions occur, blacktailed and mule deer seem to utilize Alectoria and Usnea where it occurs. This is plausible since there was evidence leading to the fact that where deer occur, there is a paucity of Alectoria on both the ground and lower boles of the trees where deer could reach to browse.

The availability of lichens on standing trees occurs primarily on lower branches and the bole where deer can reach when browsing. A browse line in which Alectoria did not occur below 3.5 feet above the ground was found in Areas 1 and 2, both inhabited by wintering deer populations. The index of the 7 foot samples divided by the 3.5 foot section (Table 2,

as previously mentioned, indicated that Alectoria above 3.5 feet occurred 384 times the amount below 3.5 feet. On larger trees the browse line was higher on the uphill side of the tree. Deer feeding upon the bark could then be the primary reason for this occurrence.

Other conditions such as snow influencing the Alectoria level is discussed by Taylor (1922). He found a scarcity of Usnea barbata on the entire lower level of the tree boles (below 5 feet), concluding that the primary cause was abrasion from the accumulated snow. However, Edwards, Soos, and Ritcey (1960) found the opposite to be the case in Wells Grey of British Columbia. Alpine trees entirely under snow contained the largest Alectoria loads of his study areas. Alectoria occurred to the base of the trees. At Ross Lake this also was the case since there were many trees with heavy Alectoria loads at the base, but only where they were protected by branches in which deer could not reach to browse. The influence of deer seemed very significant when wintering areas were compared to non-wintering areas. In Area 3, where a large snow depth occurs but where deer are absent during the winter, a large volume of Alectoria occurs at the base of each tree. The index of the 7 foot section divided by the 3.5 foot section was again very low (Table 2, , indicating that deer were the primary cause of the browse line of Alectoria. This also indicates that deer do not eat lichens when other preferred browse species are available since deer inhabit the area (Area 3) in the fall and late summer (Ross Lake Report, 1972).

The availability of standing lichen loads from fallen trees represents only a variable and frequently small fraction of the lichen loads available to deer. This is due to the rare occurrence of wind storms capable of knocking trees down, and the relatively young age of the stand (Older trees are blown down with less resistance). Trees examined in the Big Beaver Creek area which were felled by winds were full of both fruticose and foliose lichens. Trees in Areas 1 and 2 which were recently felled also had comparatively the same lichen loads as those trees standing that were sampled, but contained only a trace of the fruticose lichens such as Alectoria sarmentosa and A. jubata. Parmelia and Cetraria however, were abundant. Again this seems to indicate that deer are consuming the fruticose lichens wherever they are wintering.

Fallen branches and lichen debris provide a third portion of the lichen availability to deer during the winter months, although the lichen traps captured only a small fraction of the total yield predicted. Arboreal lichen densities of Alectoria on the ground were again high in the Big Beaver Creek drainage, Area 3 (Table 1, Figure 18), but extremely low in Areas 1 and 2 where deer were wintering. The difference may be attributed primarily to deer since the total epidendric loads in each vegetational type were relatively equal (Area 2 and 3 were almost equal). This is also substantiated by the fact that Parmelia and Cetraria were almost equal in abundance on the ground for Areas 2 and 3, indicating deer prefer Alectoria.

The abundance of epidendric lichens near the lakeshore may provide a major potential food source for wintering deer. However, deer do not seem to actively seek a wintering range with lichens, but rather select for areas with little snow accumulation and high quality forage. Area 4 a recently burned young stand had no lichen colonies, however supported a substantial population of wintering deer (Ross Lake Report, 1971).

The nutritional importance of lichens in the diet of deer has not been studied. Since the overall nutritional requirements of deer, as well as the quality and quantity of the range forage show considerable variation throughout the year, the use of lichens during poor range conditions is important in the annual cycle of deer nutrition. Nutritional requirements during the winter are usually in excess of available forage in quantity and quality. This is apparent in the gradual loss of body weight by deer during this time period (Klein, 1965). The reduction of food availability is associated with growth retardation in young deer, and in weight loss in adults (Cowan, 1945; Klein, 1965). This implies that the physiological requirements of deer during the winter is high in order to maintain a body temperature, metabolize, and in the case of pregnant females to support a fetus.

The nutritional quality of lichens in the diet of caribou is discussed by Courtwright, (1959), Kelsall (1969), Palmer (1944), and Klein (1965). Lichens are low in protein (5%), but high in carbohydrates (35%). Their benefit to deer seem to parallel that of caribou in that they contain sufficient amounts of carbohydrates to allow a somewhat retarded maintenance of basic physiological functions. Their low protein value, however, indicates that deer would not utilize them during periods when more nutritious forage is available. In order to concretely determine the extent to which deer may eat lichens a more formal analysis involving a greater sampling of vegetation types and sample trees, and stomach analysis would be needed.

SUMMARY

Deer at Ross Lake appear to eat only specific epidendric lichens for winter forage: the genera Alectoria and Usnea. The evidence for the use of Usnea by blacktailed deer is cited by Cowan (1945) on Vancouver Island, however, at Ross Lake the lichen appeared in too low a concentration to be measured.

The use of Alectoria by deer is indicated in the differential quantities found on the ground in areas wintered by deer as compared to the area sampled which is not wintered by deer. In the former areas, a very small proportion of Alectoria was found on the ground. In contrast there were very large proportions in the vegetation type where there were no wintering deer. Other genera of foliose arboreal lichens such as Parmelia and Cetraria were relatively equal in abundance on the ground in all the vegetation types with or without wintering deer populations with the exception of Area 4. This indicated that only Alectoria was sparse where deer were wintering.

The abundance of lichens in the crown for both fruticose and foliose genera approached equality for the areas with and without wintering deer, indicating the differences on the ground were not the result of any possible differences in source from the crown. It seems conclusive that since Alectoria was scarce on the ground only where deer were wintering, that deer utilize it in their winter diet.

Secondly, a browse line occurred in the habitats sampled where deer were wintering. Where deer could not reach above four feet to browse on lichens on the tree boles, the only significant difference in abundance of any of the lichen genera was found in Alectoria. Below 4.5 feet, Alectoria was extremely sparse, where deer wintered. A browse line was not evident where deer were not wintering. Again other species of foliose lichens such as the Parmelia and Cetraria group were relatively abundant on deer winter ranges, on both the lower section of the bole below 3.5 feet, as well as the 7 foot level above. This indicated that deer seem to have a special preference for Alectoria but none of the foliose group. From this evidence it seems conclusive that deer in fact eat Alectoria during the winter months.

No evidence of deer utilizing ground lichens in their diet could be found in the areas sampled by direct observation or by evidence of grazing damage.

The lichen community structure varied according to the age of the vegetation stand, moisture availability, temperature, exposure, and competition. Each species of lichen generally had varying degrees of tolerance for these parameters. The total epidendric lichen community was greater in abundance in the exposed humid sections of Area 3. In the genus Alectoria, A. jubata was usually found in the higher exposed portions of the crown. However, trees in the lakeshore of Area 3, located in a more humid microclimate, contained heavy Alectoria loads in the lower portion of the crown as well.

The most favorable habitat for Alectoria sarmentosa was in the exposed conditions of the immediate lakeshore. In contrast, Parmelia and Cetraria were abundant in both exposed and humid vegetational types, indicating a large tolerance of varying moisture regimes. Lobraria was confined primarily to the lower boles of Area 3, a humid and sheltered exposure.

The abundance of epidendric lichens near the lakeshore may provide a major potential food source for wintering deer. Deer, however, do not seem to winter in areas primarily for the purpose of eating lichens. This is indicated by the large wintering deer population in Area 4, a recently burned stand 40 years old, depauperate in lichen colonies.

Finally, in order to determine and substantiate the utilization of epidendric lichens by deer, more research should be oriented towards stomach analysis.

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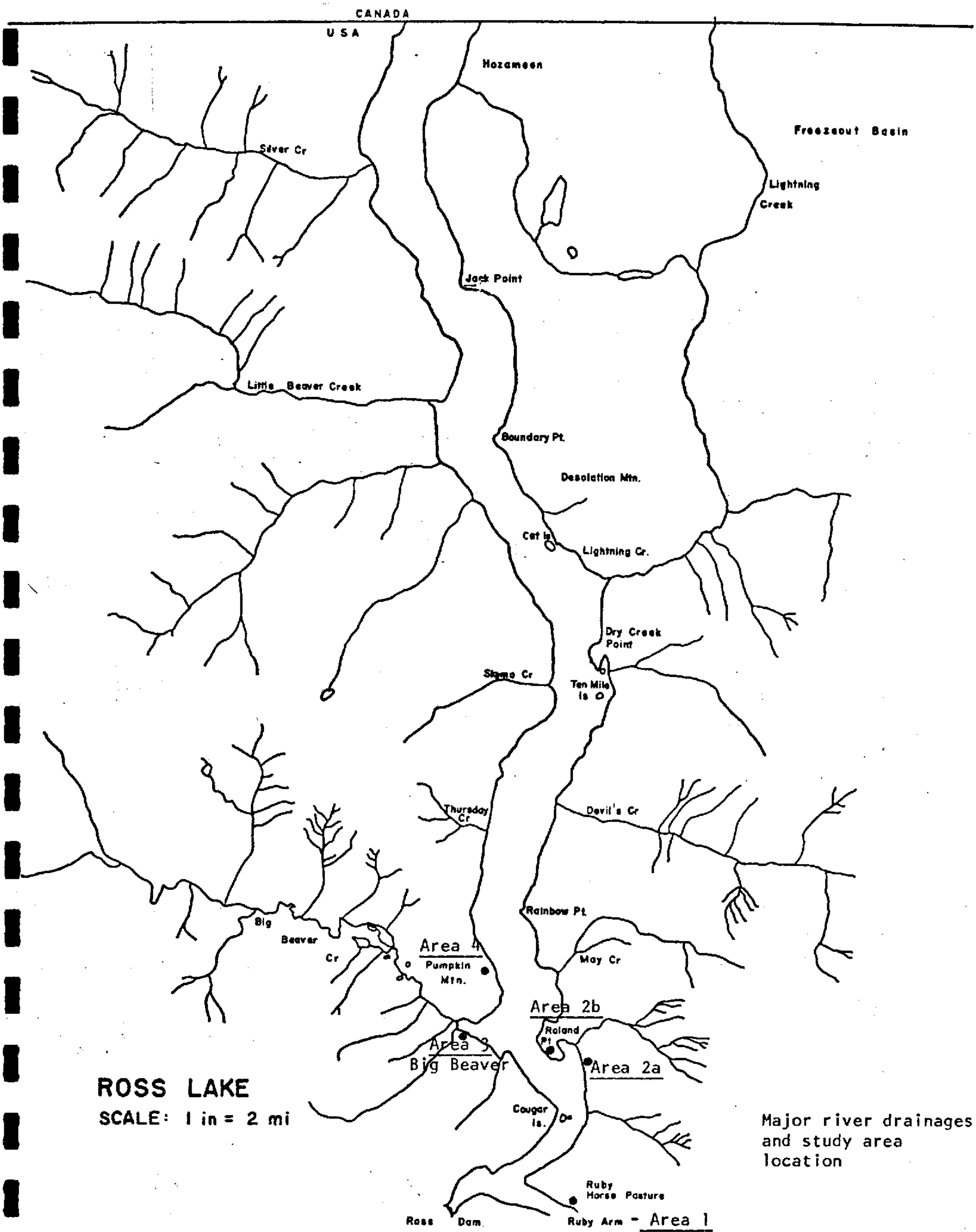

Major river drainages and study area location

FIGURE C-1

TABLE 1

SUMMARY

ARBOREAL-GROUND LICHEN WEIGHTS

ARBOREAL LICHEN DENSITIES ON THE GROUND -- KG/HECTARE

Locality	Species	Kg/Hectare on ground	Kg/Hectare on forest stand	Arboreal Wt/ground Wt Index	Deer Concentration per acre: Max	Min.
Ruby Arm					.361	.254
	Parmelia cetraria	9.993	998.31	99.90		
	Alectoria sarmentosa	0.0	218.51	218.00		
	Alectoria jubata	0.0	63.39	63.39		
Roland Point - 1					.122	.070
	Parmelia cetraria	2.150	602.63	280.29		
	Alectoria sarmentosa	0.0	17.95	17.95		
	Alectoria jubata	0.0	29.24	29.24		
Roland Point - 2					.122	.070
	Parmelia cetraria	38.002	557.21	14.66		
	Alectoria sarmentosa	0.430	165.50	384.88		
	Alectoria jubata	10.208	67.76	6.64		
Big Beaver Creek					.000	.000
	Parmelia cetraria	37.110	192.08	5.18		
	Alectoria sarmentosa	143.393	314.98	2.19		
	Alectoria jubata	33.715	211.97	6.39		
Pumpkin Mountain	---	------	------	----	.205	.127

TABLE 2

MEAN LICHEN WEIGHTS FOR BOLE

BARK SAMPLE *3.5, 6 FOOT SECTION

Bark Sample	Parmelia physodes (gms)	Parmelia cetraria (gms)	Alectoria sarmentosa (gms)	Alectoria jubata (gms)	Index Alectoria S. 6-7'/3.5'	Deer Concentration/acre Max.	Min.
Ruby Arm						.361	.254
DBH	0.341	2.818	0.097	0.031			
6-7'	0.280	3.056	1.849	0.011			
Index	0.821	1.084	19.061	0.355			
Roland Point -- 1						.122	.070
DBH	0.725	0.225	0.005	0.038			
6-7'	1.913	1.875	1.145	0.268			
Index	2.62	8.33	229.00	7.053			
Roland Point -- 2						.122	.070
DBH	0.092	0.608	0.354	0.018			
6-7'	0.136	0.756	3.980	0.165			
Index	1.47	1.243	11.240	9.166			
Big Beaver Creek						.000	.000
DBH	0.005	0.140	0.993	0.270			
6-7'	0.008	0.293	0.738	0.000			
Index	0.145	2.093	0.743	0.000			

TABLE 3

SUMMARY

LICHEN LOADS FOR FOREST TYPES 1-4

Locality	(gms) Mean Lichen Weight (Form 1b)	Stems/ Acre	Stems/ Hectare	Lichen kg/acre	Lichen kg/Hectare
Ruby Arm		647.83	1600.78		
Parmelia cetraria	623.64			404.01	998.31
Alectoria sarmentosa	136.50			88.43	218.51
Alectoria jubata	39.60			25.65	63.39
Roland Point--1		197.27	482.44		
Parmelia cetraria	1249.12			246.14	602.63
Alectoria sarmentosa	37.21			7.34	17.95
Alectoria jubata	48.52			9.57	29.24
Roland Point--2		173.17	427.91		
Parmelia cetraria	1302.16			225.50	557.21
Alectoria sarmentosa	386.76			66.98	165.50
Alectoria jubata	158.34			27.42	67.76
Big Beaver Creek		233.10	576.00		
Parmelia cetraria	333.48			77.73	192.08
Alectoria sarmentosa	546.84			127.47	314.98
Alectoria jubata	368.00			85.78	211.97

TABLE 4

ARBOREAL LICHEN DENSITIES

GROUND PLOTS (KMS/HECTARES)

Plot No.	Parmelia cetraria	Parmelia physodes	Neophromopsis Californicus	Alectoria sarmentosa	Alectoria jubata
	Ruby Arm--Ground Plot #1				
1	45.13	10.75			
4	54.80				
5		24.72			
	Roland Point -- Ground Plot #1				
4	4.30	3.22			
5		15.04			
6	6.45				
7		3.22			
10	10.75				
	Roland Point -- Ground Plot #2				
1	220.29	4.30	8.60		5.37
2	31.16	19.34			7.52
3					13.97
4	20.42				
6	2.15				
7	144.00			2.15	70.92
8		7.52			4.30
11		4.30		2.15	
	Big Beaver Creek -- Ground Plot #1				
1		17.19		1055.26	127.88
2	46.21	58.03		609.30	120.35
3				102.09	1.08
4	12.89			32.23	3.22
5	13.97			95.64	13.97
6	6.45				
7	184.83	12.90		42.98	
8	36.54	26.87		9.67	3.22

TABLE 5

GROUND PLOTS

% COMPOSITION, MOSSES, LICHENS, SHRUBS, AND LITTER

Location	Plot No.	Lichens	Mosses	Shrubs	Litter
Ruby Arm	1	25.0	5.0	70.0	
	2	52.0	46.0	2.0	
	3	67.0	12.0		21.0
	4	10.0	28.0	62.0	
	5	7.0	37.0	56.0	
	6	46.0	15.0		39.0
	7	23.0	18.0		59.0
	8	19.0	32.0	49.0	
	9	48.0	22.0	9.0	21.0
	10	62.0	19.0	8.0	11.0
Roland Point	1	47.0	42.0		11.0
	2	3.0	31.0	18.0	48.0
	3	20.0	35.0	45.0	
	4	2.0	24.0	72.0	
	5		10.0		90.0
	6	7.0	4.0	69.0	20.0
	7			40.0	60.0
	8		2.0	48.0	50.0
	9		16.0	32.0	52.0
	10	10.0	12.0	65.0	13.0
Roland Point	1	30.0	17.0	33.0	15.0
	2	17.0	14.0	65.0	4.0
	3	6.0	19.0	75.0	
	4	5.0	12.0	81.0	2.0
	5	1.5	22.0	66.5	
	6	7.0	11.0	75.0	7.0
	7	2.0	9.0	75.0	14.0
	8	3.0	3.0	78.0	12.0
	9	0.0	0.0	87.0	13.0
	10	0.0	4.0	87.0	9.0
	11	3.0	1.0	89.0	7.0
Big Beaver Creek					
	1	2.0	35.0	62.0	1.0
	2	1.0	17.0	79.0	3.0
	3	3.0	26.0	81.0	
	4	6.0	18.0	76.0	
	5	0.0	29.0	60.0	11.0
	6	5.0	14.0	81.0	
	7	1.0	9.0	77.0	13.0
	8	0.0	17.0	80.0	3.0

APPENDIX D: CLIMATOLOGICAL STUDIES

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INTRODUCTION

In any geographical region, the climate of a valley is dependent upon its orientation, the amount of radiation and precipitation it receives, the depth of soil in various portions of the valley, and whether it is flooded or not flooded. These main factors interact to form certain temperature, humidity, wind speed, and evaporation regimes within valleys. The two most important factors are the amount of radiation received by the valley and the rainfall distribution.

In addition to the above factors, the climate within the valley is also determined by the air circulation. The air circulation is composed of two types of winds: (1) the up- and down-slope winds; and (2) the up- and down-valley winds. These winds are similar in origin but differ in direction of flow and time of occurrence. Generally speaking, the up-slope and up-valley winds are caused by differential solar heating between the tops of the slopes and the head of the valley with respect to the base of the valley. The heated air over the slopes and the head of the valley rises and is replaced by descending air in the middle of the valley which rises up the slope from the valley. In the late afternoon and early evening, the upper portions of the slopes and head of the valley cool off more rapidly than the base of the valley. The mechanism of cooling is long-wave radiation exchange with the cold sky. The air in contact with the cold surfaces becomes cool, consequently more dense, and slides down the slopes of the valley. This air is then replaced by air which rises from the center of the valley. The onset of these winds is dependent upon the aspect of the valley, the steepness of slopes, and vegetation cover. Generally speaking, for an idealized valley in this particular latitude in the summertime, the up-slope winds start shortly after sunrise; the up-valley winds start at approximately 9 a.m.; the up-slope winds continue to early afternoon. So from about 9 a.m. until 1 p.m., both up-slope and up-valley winds are occurring. From about 1 p.m. to 4 p.m., just up-valley winds occur. At about 4 p.m. down-slope winds begin, and at about 6 p.m. the up-valley winds cease. About 9 p.m. the down-valley winds start. Thus, there is a complex wind circulation pattern existing in each valley.

The effects of these circulations upon the climate of the valley may be drastically different for flooded and nonflooded valleys. For example, the up-slope wind would originate over the water surface in a flooded valley and would carry with it the characteristics of the water surface. In the autumn or winter portion of the year, the air in contact with the water surface would be warmer and more moist than the air existing in a nonflooded valley. This relatively warm, moist air would flow up the side slopes and up the valley, possibly changing vegetation and snowpack distributions. At night the cold, descending air from the side slopes would glide out over the flooded portion of the valley and be forced to rise in the middle of the valley. The rising air would carry with it the characteristics of the water and if lifted sufficiently, would form a cloud in the middle of the valley. This cloud then would move as the valley winds forced it and could cause different environments in sections of the valley.

A different contrast could occur in late spring. A nonflooded valley would heat up more quickly than a flooded valley due to the reservoir heat capacity. Thus, the up-slope winds from a nonflooded valley would be warmer and drier than from a flooded valley. This could possibly enhance snow melt and the evaporation demand of the side slopes.

Data contrasting the environments of flooded and nonflooded valleys are generally nonexistent. Therefore, certain questions pertaining to vegetation cover and changes in animal habitat locations may be answered more readily with the use of climatic data from flooded and nonflooded valleys.

In addition, the climate of specific areas of the valley is largely dependent upon the slope and aspect of those areas and the interaction of these slopes with solar radiation. The intensity of radiation per unit area enjoyed by a particular surface is a function of the angle with which the sun's rays strike the surface and of the number of hours of daylight. The amount of energy absorbed by the surface is used to heat the surface, to heat the air, and to evaporate water, evaporation being the largest heat sink. If water is not available for evaporation, then the energy will go into heating the air and heating the surface. For example, if two sites have similar slopes and aspects but have different soil depths, the site with the shallower soil will be warmer and drier than the site with the deeper soil due to the fact that the shallow soil does not have as large a water-holding reservoir for evaporation as the deeper soil.

The question as to whether one environment is different from another environment 100 feet higher may be partially answered by comparing the amount of radiation received by the two sites in question. Direct beam potential radiation incident upon various slopes and aspects can be calculated with the aid of a computer program, and thus, different sites may be compared theoretically.

OBJECTIVES

The objectives of the climatological studies were to: (1) contrast the climates of the flooded and nonflooded valleys, (2) determine the magnitude and location of the thermal belt in flooded and nonflooded valleys, and (3) compute direct beam potential insolation for selected locations around Ross Lake.

DIRECT BEAM POTENTIAL INSOLATION

Methods

The amount of direct beam potential insolation striking various surfaces around Ross Lake was computed by combining two programs. The first program, described by Buffo, Fritschen, and Murphy (1971), computed the direct beam potential insolation incident upon slopes of different aspects by hourly increments for eleven selected days of the year. The second program written by Ann Westhagen computed the local horizon for each grid point around the lake. For a particular day, the direct beam potential for a specific slope and aspect was accumulated for the period when the sun's elevation at a given azimuth exceeded the local horizon. The results consisted of a daily total which was a function of the slope and aspect, the day of year, and the local horizon of that grid point. The daily totals for many grid points were then plotted and isopotential lines drawn.

The local horizon program was written to accomodate two grid sizes: the large grid size provided data for the local horizon calculations; the small grid contained the points for which the local horizon was being calculated. In this study, the large grid was ten miles wide, east to west, and twenty miles long, north to south, and consisted of a grid point at half-mile intervals. There were several small grids each containing 1/8-mile grid point intervals.

Results

A sample of the isolines of potential insolation on March 8 is shown in Figure 1 for the grid section with topography shown in Figure 2. If other factors such as soil depth and texture, precipitation, and wind circulation are similar, then the areas of greatest potential insolation (total for the year) labeled H would be the warmest and driest, and conversely, the areas receiving minimum potential insolation labeled L would be the coolest and most humid. The vegetation associated with the warm dry sites should be pines, grasses, and droughty type shrubs, and the vegetation associated with the cool humid climate should be denser with more undergrowth as characteristic of westerly Cascade slopes.

Maps of potential insolation are being prepared for selected areas. The areas were selected because of animal populations and vegetation information. The animal populations and vegetation information will be correlated with the potential insolation data. With these correlations unsurveyed areas of similar habitat can be selected from potential insolation maps.

FLOODED AND NONFLOODED VALLEY TRANSECT

Methods

Since data comparing the environments of flooded and nonflooded valleys are generally nonexistent, a valley adjacent to the Ross Lake

Reservoir was sought for comparison with the Ross Lake Valley. The basic criteria for selection was that the valley chosen have similar aspects and side slope to those of the Ross Lake Valley. Generally speaking, Ross Lake is oriented north and south; the second valley for comparison was the Lightening Creek drainage. East and west transects were established in both valleys. The approximate locations of stations on the transects are shown in Figures 3, 4, and 5.

The original plan was to establish an instrument shelter housing a hygrothermograph at 2000, 3000, 4000, 5000, and 6000 foot elevations on all four transects. Due to the ruggedness of the area and the inability to flag the transects or to construct paths along them, these locations were not realized prior to September 1971. Since the stations at higher elevations would be almost impossible to service during the winter months with heavy snowfall, it was decided to maintain stations at lower elevations during the winter on the east and west sides of the lake and in the Lightning Creek drainage in addition to the higher elevations on East and West Desolation. A description of each site location is given in Table 1.

WEST DESOLATION

Aspect	Slope Percent	Horizontal Slope, Left* Percent	Horizontal Slope, Right* Percent	Elevation Feet
W	80	0	0	1620
W	0	-5	0	2000
WSW	65	-5	+5	3180
NW	70	-10	+5	4320
WSW	80	-25	-30	5160
WSW	60	-10	+5	6000
Summit	0	0	0	6085
		EAST DESOLATION		
SE	60	-5	0	2900
SE	50	0	0	3900
SE	80	-10	-5	4000
NE	30	+20	-10	4900
E	10	-30	-20	4960
E	85	-25	-10	6000
		SKAGIT		
Flat	Flat	Flat	Flat	2040
WSW	70	+5	-5	2760
WNW	70	+70	-5	2800
W	50	-20	-5	4000
W	50	-20	-20	5160
W	30	-10	-5	6000
		LITTLE BEAVER		
NNE	80	0	0	1620
ENE	75	0	-5	2020
NE	75	-20	-10	3000
NE	85	-10	+5	3980
N	20	+20	0	5000
Ridge	70	+10	+30	6100

*Direction facing downslope

Table 1. Aspect, slope, horizontal slope left and right, and elevation of sites on West Desolation, East Desolation, Skagit, and Little Beaver transects.

West Desolation transect is on the east side of Ross Lake while Little Beaver transect is on the west side. East Desolation and Skagit are on the west and east sides of Lightning Creek, respectively. The stations at 6000 feet on East and West Desolation and the Summit were in operation but were discontinued due to heavy snowfall.

For safety reasons after snowfall on the higher elevations, two people were used to service the stations. Each of the four transects requires more than an 8-hour day to service. Thus, each station is visited only once a month on weekends.

Results

The length of record to date from each of the stations in the transects is given in Table 2. During the summer months, the stations were established and were operated with weekly charts. In October the 31-day clock movement was installed at each station.

Numerous installations have been attacked by bears. In particular, the West Desolation 3180 feet and the East Desolation 2800 and 4900 feet stations have been damaged repeatedly. The 2800 foot station on East Desolation was finally destroyed on November 4, 1971.

When weekly charts were utilized, data were read at 2-hour intervals from the charts. When monthly charts were utilized, data were read twice a day from the charts. Because the plotting program was not written to operate on missing data, missing data were formulated by averaging the values from the preceding and following periods.

The temperature and humidity values taken from the hygrothermograph charts were punched on computer cards and a program was written to convert the temperature-relative humidity data into vapor pressure, an indication of the quantity of water vapor existing in the air. These parameters, temperature, relative humidity, and vapor pressure, were plotted with the CALCOMP plotter to illustrate (1) variations of the parameters during the course of the month and (2) variations of the parameters with elevation. Samples of plot type 2 are shown in Figures 6 and 7.

Table 2. Date of start (S) and date of end (E) of 7 day (7) and 30 day (30) clocks at each location on four slopes at Ross Lake and Lightning Creek, 1971 and 1972.

			WEST DESOLATION (West Slope)				
Date	1620	2000	3180	4320	5160	6000	6085
1971							
1 Aug		S 7	S 7	S 7	S 7	S 7	
22 Sep						E 7	S 7
24 Sep	S 7						
1 Oct	E 7	E 7	E 7	E 7	E 7		E 7
1 Oct	S 30	S 30	S 30	S 30	S 30		S 30
21 Oct							E 30
31 Oct				E 30	E 30		
30 Nov	E 30						
2 Dec		E 30			E 30		
5 Dec			E 30				
1972							
7 Jan			E 30				
30 Jan	S 30	S 30	S 30				
22 Apr					S 30		
5 May	E 30	E 30	E 30				
6 May					E 30		
6 May			S 30		S 30		S 30
5 Jun			E 30				E 30
14 Jun							S 7
21 Jun					E 30		
22 Jun			S 7		S 7		
1 Jul		S 7					
2 Jul	S 7						
14 Jul				S 7			
2 Aug			E 7				
3 Aug					E 7		
5 Aug	E 7	E 7		E 7			E 7
24 Aug	S 7	S 7		S 7	S 7		S 7
23 Sep			S 7				
14 Oct	E 7	E 7	E 7	E 7	E 7		E 7

Table 2. (Continued)

EAST DESOLATION (East Slope)

Date	2900	3900	4000	4900	4960	6000
1971						
10 Sep			S 7	S 7		S 7
20 Sep						E 7
24 Sep	S 7					
1 Oct	E 7		E 7	E 7		
1 Oct	S 30		S 30	S 30		
17 Oct	E 30					
27 Oct				E 30		
30 Oct	S 30					
2 Nov	E 30					
27 Nov			E 30	E 30		
1972						
4 Mar	S 30					
9 May	E 30					
20 Jun	S 7					
12 Jul		S 7			S 7	
2 Aug	E 7					
4 Aug					E 7	
5 Aug		E 7				
23 Aug		S 7			S 7	
7 Sep	S 7					
30 Sep		E 7				
9 Oct	E 7				E 7	

SKAGIT (West Slope)

Date	2049	2760	2800	4000	5120	6000
1971						
12 Sep	S 7		S 7			
22 Sep						
24 Sep						
1 Oct	E 7		E 7			
1 Oct	S 30		S 30			
27 Nov			E 30			
1972						
29 Jan	S 30					
8 Mar			S 30			
9 May	E 30		E 30			
20 Jun	S 7					
27 Jun		S 7				
9 Jul	E 7					
10 Jul				S 7		
27 Jul					S 7	S 7
29 Jul				E 7		
6 Aug		E 7			E 7	E 7
22 Aug		S 7		S 7	S 7	S 7
23 Aug	S 7					
12 Sep						
12 Oct		E 7		E 7	E 7	
18 Oct	E 7					E 7

Table 2. (Continued)

LITTLE BEAVER (East Slope)

Date	1620	2020	3000	3980	5000	6100
1971						
25 Sep	S 7	S 7	S 7			
1 Oct	E 7	E 7	E 7			
1 Oct	S 30	S 30	S 30			
12 Nov			E 30			
13 Nov						
26 Dec	E 30					
29 Dec			E 30			
1972						
30 Jan	S 30					
18 Mar			S 30			
6 May		E 30	E 30			
10 May	E 30					
28 Jun	S 7	S 7	S 7			
4 Aug	E 7					
5 Aug		E 7	E 7			
25 Aug	S 7	S 7	S 7	S 7	S 7	S 7
8 Oct	E 7	E 7				
17 Oct			E 7			
18 Oct				E 7	E 7	E 7

On West Desolation on 3 August 1971, the maximum temperature at the 2000-foot elevation occurred at 1800 (Figure 6) and was 27°C while the minimum occurred at 0800 and was 12°C. An apparent thermal belt appears at 4000 feet with a maximum temperature of 21°C occurring at 1400 while the minimum temperature at this elevation occurred at 0700 and was 7°C. These data illustrate the influence of the lake on the time and magnitude of maximum temperature at lower elevations.

The above facts were not as noticeable on 31 August (Figure 9) after the passage of several frontal systems. The thermal belt at 4000 feet is not as pronounced. The maximum temperatures at lower and upper elevations occurred at 1400 while the minimum temperatures occurred at all elevations at 0700.

Similar plots were prepared for other times of the year and for relative humidity and vapor pressure. These diagrams (Figures 6 to 55 suggest that a zone of uniform temperatures and vapor pressures exist at the 4000 foot level on all transects. There is a slight suggestion that this zone may move down the slopes in the winter months and up in the summer months. However, there are inadequate high elevation winter data to verify this point. The diurnal patterns of isolines appear to be similar for all transects sampled if one ignores the absolute magnitude of the parameters.

Direct comparisons of temperature and relative humidity on similar aspects and elevations were made using linear regression and correlation. Data collected during the spring, summer, fall, and winter were chosen for analyses. Data for two- to three-week periods were analyzed. The results of 5000 data points are summarized in Tables 3, 4, 5, and 6.

Relative humidity data collected in 1971 is not considered reliable because the instrument pens appeared to stick at higher relative humidities. The July 1972 relative humidity data (Table 3) appear to be valid and suggest that the relative humidity on the west facing Skagit slope is more humid than the West Desolation slope by 6% on the average. The correlation coefficients are very high indicating a good relationship and the standard error from regression is also small. The 2000-foot analyses suggest that Skagit is more humid than West Desolation by 12% and the range of relative humidity is greater on West Desolation. The 3000-foot analyses also indicate greater humidity on the Skagit slope; however, the range is greater at 3000 feet on Skagit and the correlation coefficient is not as good. The 4000- and 5000-foot analyses indicate similar ranges on both slopes and greater relative humidity on Skagit.

Table 3. Correlation parameters for relative humidity on West Desolation (X) versus Skagit (Y).

Height	Date	n	$\bar{x}$	$\bar{y}$	A	m	Std Error	r
				Maximum Relative Humidity (%)				
2000	Nov 71	30	91.77	86.55	81.38	0.005	0.005	0.1862
2000	Mar 72	31	89.61	84.94	80.91	4.493	2.830	0.2827
				Minimum Relative Humidity (%)				
2000	Nov 71	30	88.27	86.00	87.04	-0.001	0.005	-0.0045
2000	Mar 72	31	79.71	69.00	18.04	0.639	0.116	0.7149
				2-Hour Relative Humidity (%)				
2000,3000 4000	Sep 71	473	76.18	79.41	21.92	0.755	0.005	0.5457
2000	Sep 71	180	72.38	82.86	25.97	0.786	0.010	0.5085
3000	Sep 71	150	77.15	81.21	-15.90	1.259	0.007	0.8318
4000	Sep 71	143	79.93	73.17	-6.88	1.002	0.006	0.8351
2000,3000 4000,5000	Jul 72	500	60.25	68.89	4.09	1.076	0.005	0.7027
2000	Jul 72	172	61.37	73.66	-21.88	1.557	0.009	0.8096
3000	Jul 72	85	59.95	62.79	24.39	0.640	0.128	0.4808
4000	Jul 72	164	61.95	73.27	15.32	0.935	0.008	0.6739
5000	Jul 72	100	52.08	54.10	0.649	1.026	0.005	0.9097
				2-Hour Relative Humidity (%)				
2000,3000	Sep 72	188	74.13	69.09	14.65	0.707	0.006	0.624
2000	Sep 72	112	79.69	79.51	48.91	0.384	0.004	0.610
3000	Sep 72	76	65.95	48.79	52.48	-0.005	0.001	-0.504
2000,3000 4000	Oct 72	174	72.21	78.30	3.78	1.032	0.008	0.7613
2000	Oct 72	67	75.42	89.37	44.42	0.596	0.008	0.6931
3000	Oct 72	67	67.56	73.21	-4.57	1.151	0.008	0.8678
4000	Oct 75	40	74.60	68.28	-10.59	1.057	0.010	0.8687

n = Sample size
$\bar{x}$ = Mean of X
$\bar{y}$ = Mean of Y
A = Line intercept
m = Line slope
Std. Error = Standard error from regression
r = Correlation coefficient

Table 4. Correlation parameters for relative humidity on Little Beaver (X) versus East Desolation (Y).

Height	Date	n	$\bar{x}$	$\bar{y}$	A	m	Std Error	r
				2-Hour Relative Humidity (%)				
2000	Sep 71	66	74.85	81.39	63.21	0.243	0.301	0.1004
2000,3000	Jul 72	289	59.42	68.76	5.393	1.066	0.007	0.6907
2000	Jul 72	174	62.48	73.81	3.465	1.126	0.009	0.6692
3000	Jul 72	115	54.80	61.13	13.652	0.866	0.009	0.6869
2000,3000 4000	Sep 72	485	75.38	81.53	52.06	0.391	0.004	0.4154
2000	Sep 72	192	70.28	83.18	54.35	0.410	0.006	0.4137
3000	Sep 72	192	78.83	78.98	25.18	0.674	0.007	0.5902
4000	Sep 72	101	76.60	83.23	51.05	0.420	0.005	0.6109
2000,3000	Oct 72	178	68.31	80.83	54.09	0.391	0.007	0.3781
2000	Oct 72	91	66.73	89.87	78.81	0.165	0.005	0.3414
3000	Oct 72	87	69.95	71.38	16.08	0.790	0.007	0.7564

Table 5. Correlation parameters for temperature on West Desolation (X) versus Skagit (Y).

Height	Date	n	$\overline{x}$	$\overline{y}$	A	m	Std Error	r
				2-Hour Temperature (°F)				
2000,3000	Sep 71	268	40.67	39.68	14.416	0.621	0.003	0.7413
2000	Sep 71	192	43.15	39.57	4.939	0.802	0.003	0.8544
3000	Sep 71	76	34.41	39.96	10.943	0.843	0.007	0.8077
				Maximum Temperature (°F)				
2000,3000	Mar 72	39	22.44	23.28	7.805	0.690	0.113	0.7082
2000	Mar 72	31	34.39	30.68	8.256	0.652	0.007	0.8738
3000	Mar 72	8	33.00	38.00	16.688	0.646	0.252	0.7227
				Minimum Temperature (°F)				
2000,3000	Mar 72	39	34.10	32.18	11.367	0.610	0.105	0.6895
2000	Mar 72	31	22.13	21.97	10.875	0.501	0.007	0.8091
3000	Mar 72	8	23.62	28.38	11.522	0.713	0.124	0.9197
				2-Hour Temperature (°F)				
2000,3000 4000,5000 6000	Jul 72	500	59.23	57.75	-3.648	1.037	0.003	0.8188
2000	Jul 72	172	59.27	58.09	-9.183	1.135	0.007	0.7580
3000	Jul 72	91	58.74	55.68	1.245	0.927	0.008	0.7698
4000	Jul 72	166	59.94	58.27	-1.492	0.997	0.004	0.8732
5000	Jul 72	81	58.68	59.37	-9.404	1.172	0.004	0.9658
6000	Jul 72	103	59.91	57.54	16.21	0.690	0.007	0.7020
2000,3000 4000,6000	Sep 72	386	37.68	36.40	3.604	0.870	0.002	0.8685
2000	Sep 72	108	41.05	38.24	-2.149	0.984	0.007	0.7954
3000	Sep 72	91	33.34	31.37	-0.002	0.942	0.003	0.9654
4000	Sep 72	163	37.98	38.67	2.122	0.962	0.002	0.9754
6000	Sep 72	23	34.65	31.65	12.336	0.557	0.181	0.5586
2000,3000 4000	Oct 72	213	43.89	42.44	-3.516	1.047	0.002	0.9121
2000	Oct 72	67	44.92	41.64	-19.30	1.357	0.009	0.8903
3000	Oct 72	67	40.67	38.18	-2.25	0.994	0.004	0.9512
4000	Oct 72	79	45.72	46.77	4.91	0.916	0.003	0.9538

Table 6. Correlation parameters for temperature on Little Beaver (X) versus East Desolation (Y).

Height	Date	n	$\overline{x}$	$\overline{y}$	A	m	Std Error	r
				2-Hour Temperature (°F)				
2000,3000	Sep 71	131	36.95	37.37	16.08	0.576	0.004	0.7591
2000	Sep 71	66	40.22	38.18	7.09	0.773	0.005	0.8868
3000	Sep 71	65	33.63	36.55	2.87	1.001	0.008	0.8491
2000,3000	Jul 72	199	60.77	60.77	-26.691	1.455	0.007	0.8395
2000	Jul 72	120	61.63	59.58	-40.715	1.627	0.008	0.8776
3000	Jul 72	79	59.46	62.58	-17.815	1.352	0.008	0.8838
2000,3000 4000	Sep 72	394	36.07	40.09	15.49	0.682	0.004	0.6393
2000	Sep 72	192	39.03	40.39	-3.00	1.112	0.004	0.8787
3000	Sep 72	101	37.93	37.51	-11.58	1.294	0.005	0.9182
4000	Sep 72	101	28.54	42.11	9.08	1.157	0.004	0.9362
2000,3000 4000	Oct 72	254	42.66	47.17	14.80	0.759	0.008	0.5097
2000	Oct 72	78	43.28	41.64	-17.03	1.356	0.008	0.8980
3000	Oct 72	87	45.37	46.30	-7.19	1.177	0.009	0.8268
4000	Oct 72	89	39.58	33.07	8.31	1.130	0.007	0.8725

Similar trends were noted during October of 1972. During this period, the average relative humidity on Skagit was 6% greater than the relative humidity on East Desolation. The slopes of the regression lines were near 1.0 except at 2000 feet, indicating that the range in relative humidity was similar for both slopes. The slope of the regression line at 2000 feet suggests that the range in relative humidity was about 1.7 times greater than the range in relative humidity on Skagit.

Comparison of the east facing slopes (Table 4) illustrates that the relative humidity on East Desolation was about 9% greater than the relative humidity on Little Beaver. The range in relative humidity appears to be about twice as great on Little Beaver than on East Desolation.

The temperature comparisons of West Desolation and Skagit (Table 5) suggest consistently warmer temperatures (about 5°F) on West Desolation. This fact could account for the lower relative humidity on West Desolation. All of the correlation coefficients are high. In general, the regression coefficients are less than 1.0 with the exceptions of 2000 and 5000 feet, July 1972, and 2000 feet on October 1972. This indicates a greater diurnal temperature range on West Desolation, although the values approximate 1.0 during July and September 1972. During March 1972, a much larger range was noted on West Desolation.

Comparison of the east facing slopes is given in Table 6. The average temperatures on East Desolation appear to be about 9°F warmer than on Little Beaver. Data from July 1972 suggest warmer temperatures at 2000 feet on Little Beaver and at 3000 feet on East Desolation. Similar results were noted during July 1971 and October 1972.

The data suggest greater diurnal temperature range on East Desolation than on Little Beaver. This is in contrast to the west facing slopes. The opposite would be true if the 4000-foot level was ignored.

Summary and Conclusions

The data presented here are very preliminary. However, these data suggest that: (1) the humidity is about 8% greater on Skagit than on West Desolation; (2) the relative humidity on East Desolation is 9% greater than on Little Beaver; (3) the temperatures were consistently warmer on West Desolation than on Skagit; (4) the diurnal temperature range appeared to be greater on West Desolation than on Skagit; (5) the average temperature on East Desolation was 9°F warmer than on Little Beaver: the opposite would be true if the 4000-foot data were omitted; and (6) the temperature range appeared to be greater on Little Beaver than East Desolation. Thus, it appears that the temperatures on the west slope of the lake basin are warmer and have a greater diurnal range than those found in the Lightning Creek drainage. Similar results were noted at the 2000 and 3000-foot levels on the east facing slopes. This fact could be due to the presence of the water body (Ross Lake) or to the greater width of the Ross Lake basin which would permit more hours of sunlight.

LITERATURE CITED

Buffo, John, L. J. Fritschen, and J. L. Murphy. 1973. Direct solar radiation on various slopes from 0 to 60 degrees North Latitude. In press. Pacific Northwest Forest and Range Experiment Station Research Paper.

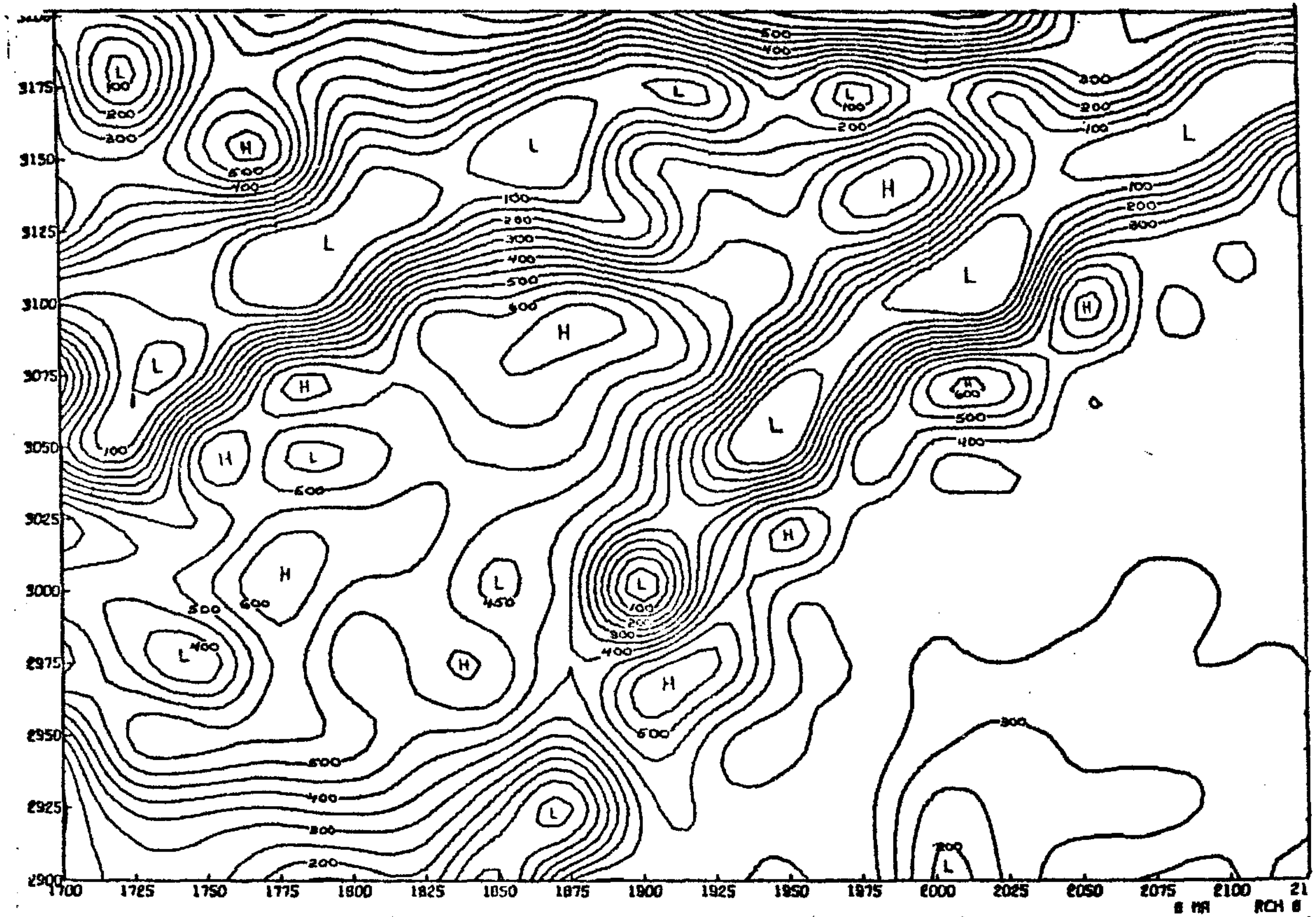

Figure 1. Isolines of potential insolation (cal day^{-1}) on March 8 computed for the grid section on the west side of Ross Lake. The topography of the section is shown in Figure 2.

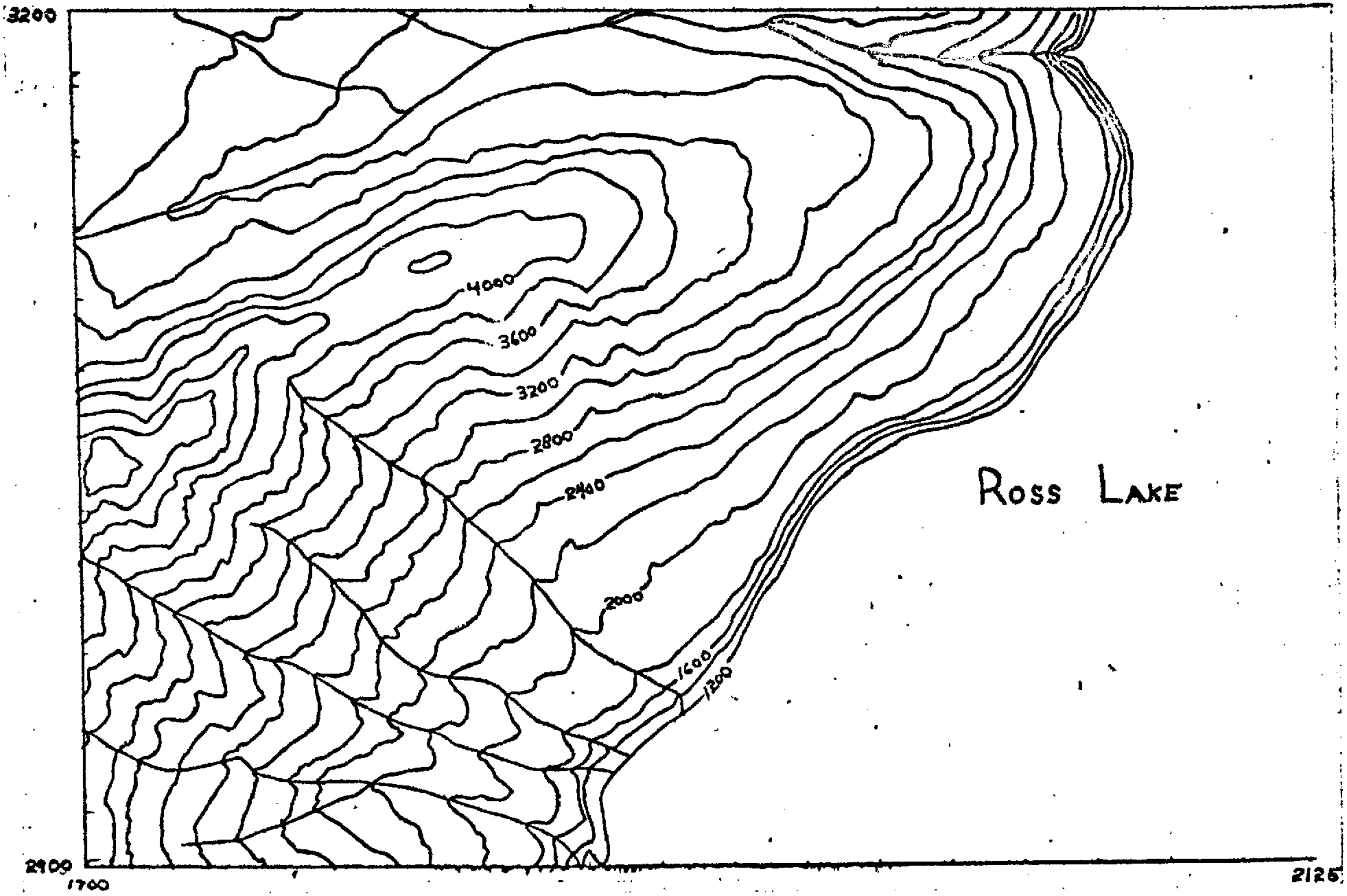

Figure 2. Topography of the grid section located on the west side of Ross Lake. Refer to Figure 1 for potential insolation.

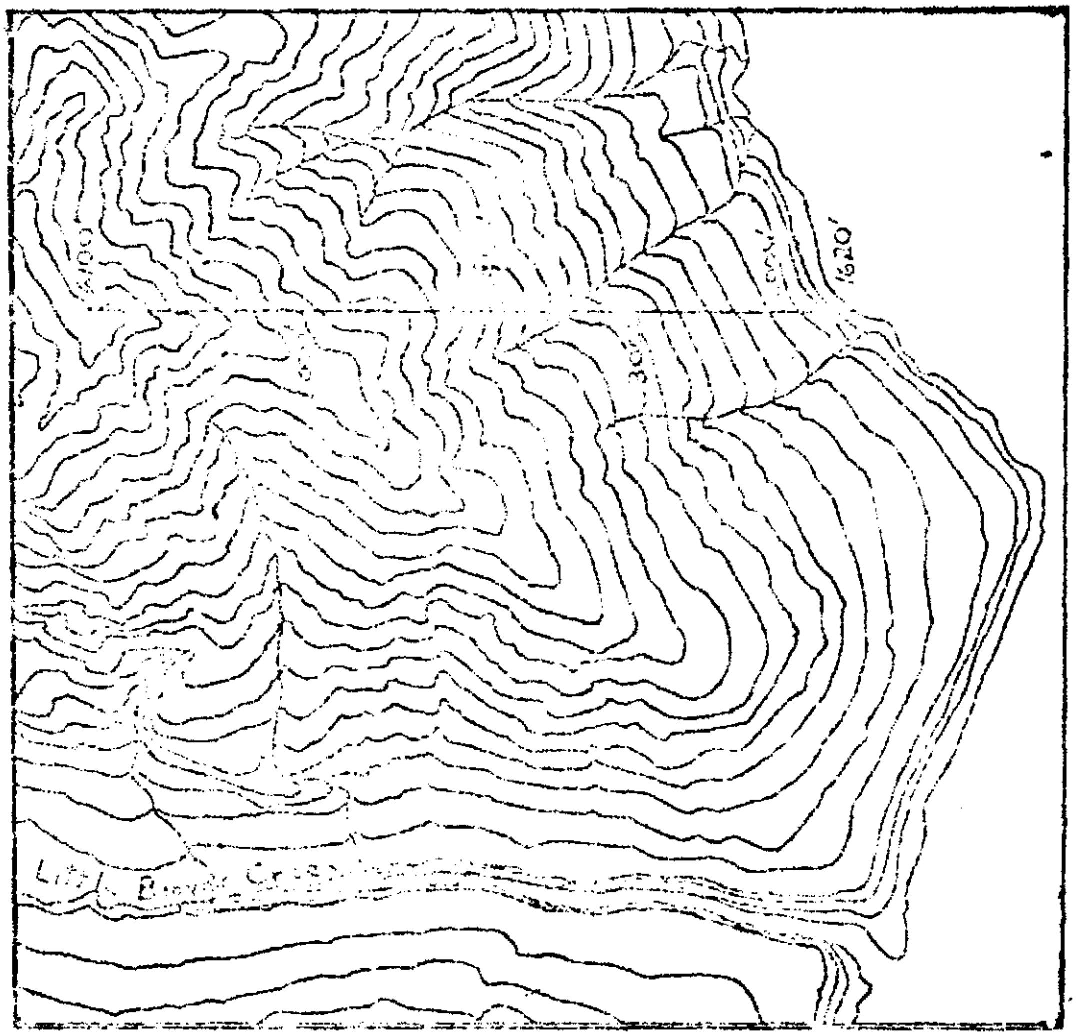

Figure 3. Location of stations on the Little Beaver transect.

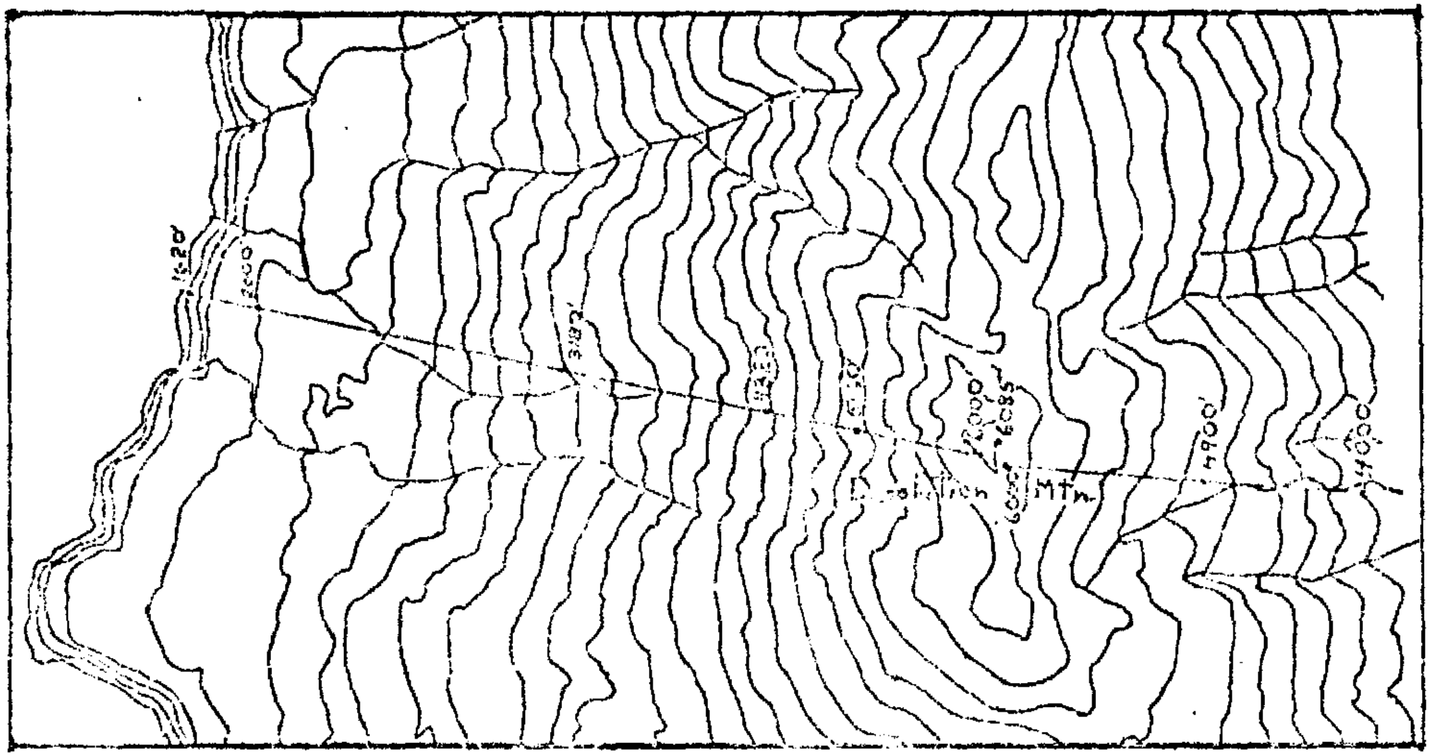

Figure 4. Location of stations on the West and East Desolation transects.

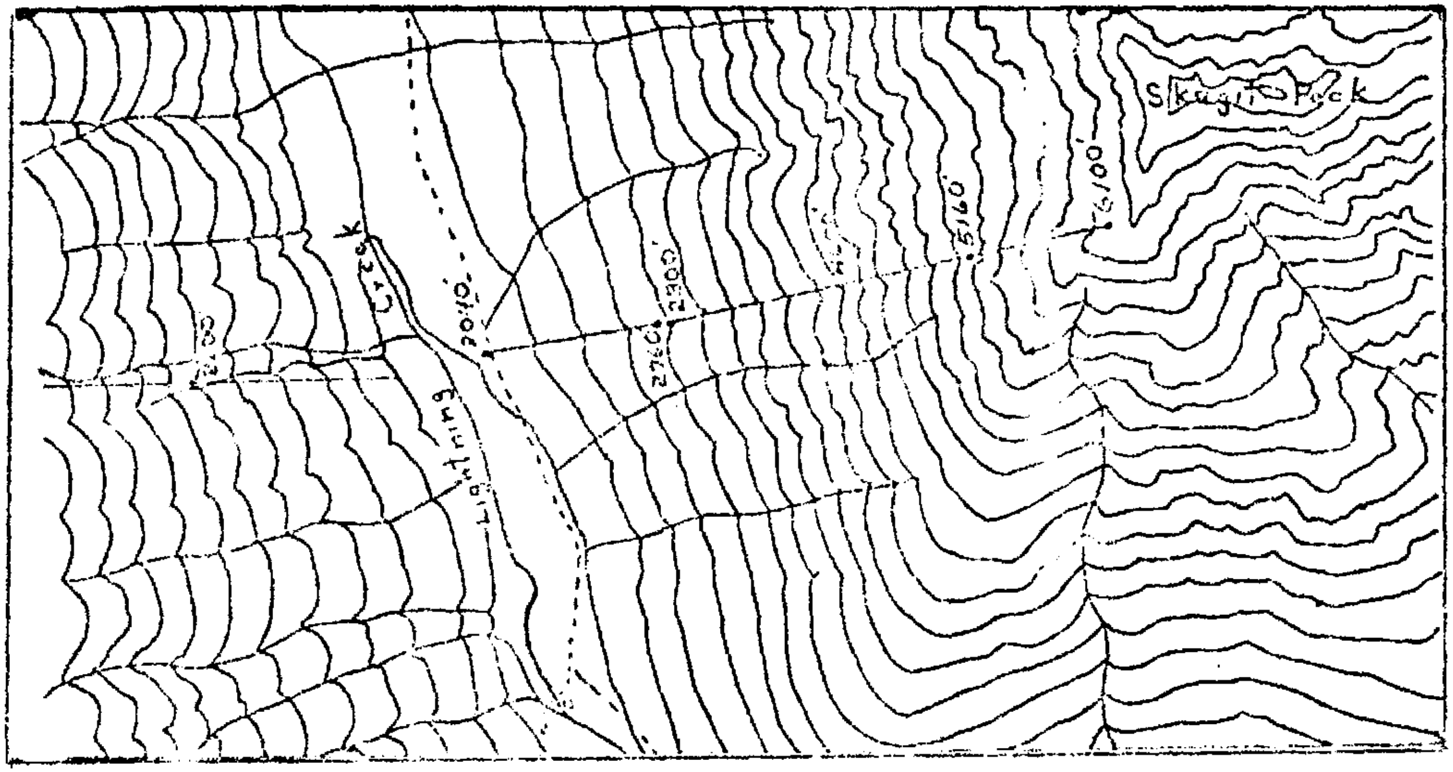

Figure 5. Location of stations on the East Desolation and Skagit transects.

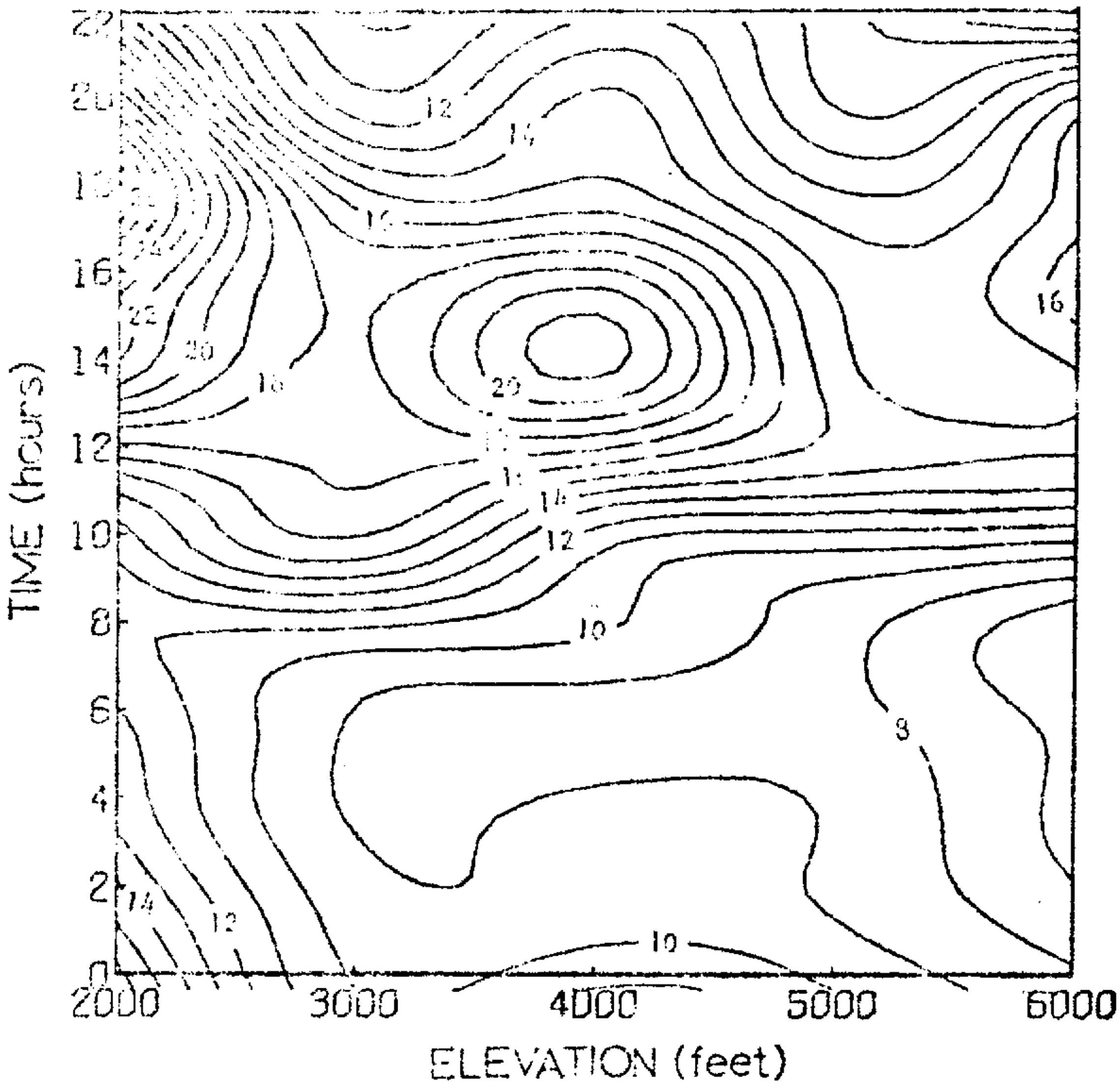

Figure 6. Isotherms (°C) on 3 August 1971 on West Desolation.

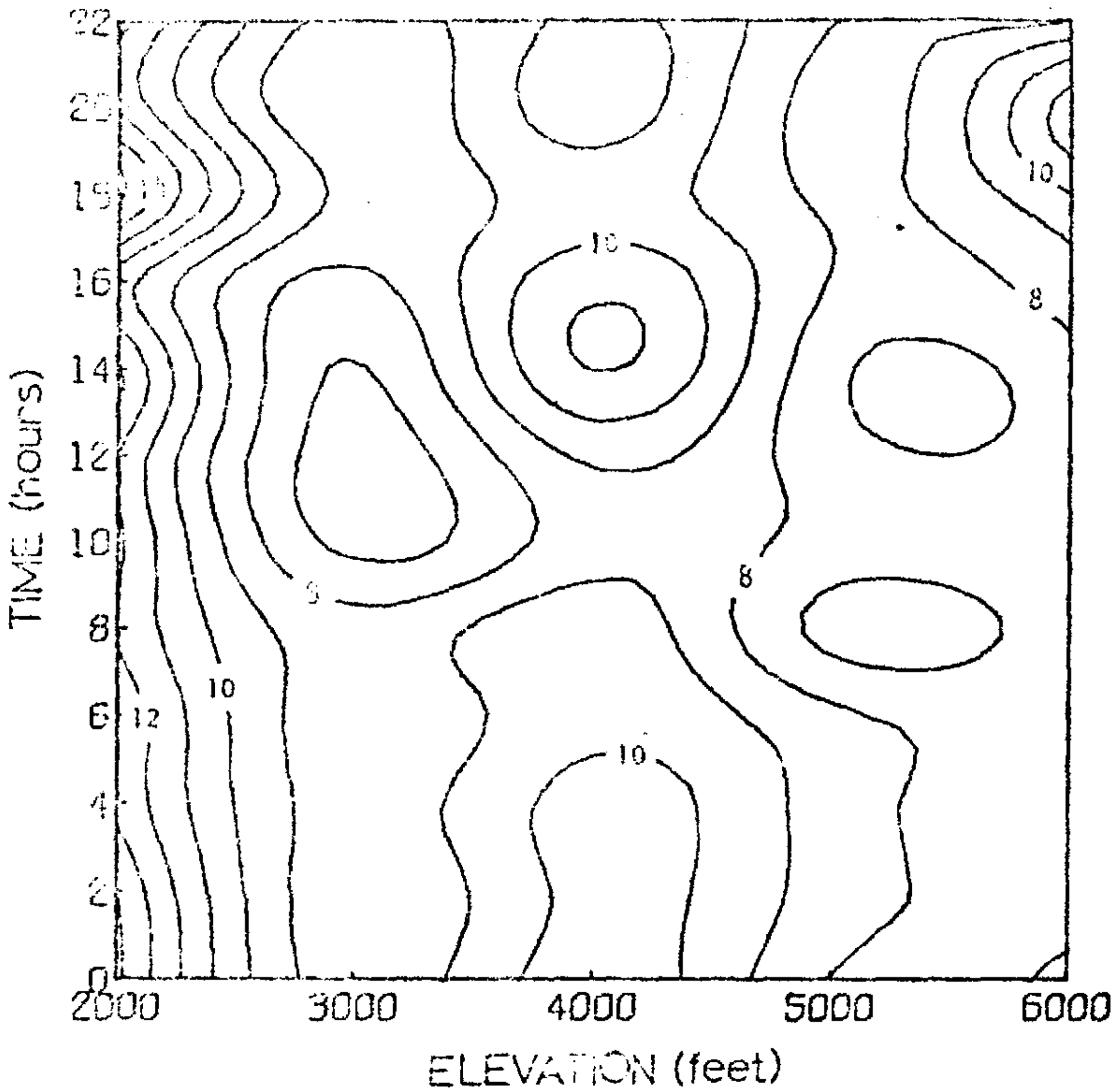

Figure 7. Vapor pressure (mb) on 3 August 1971 on West Desolation.

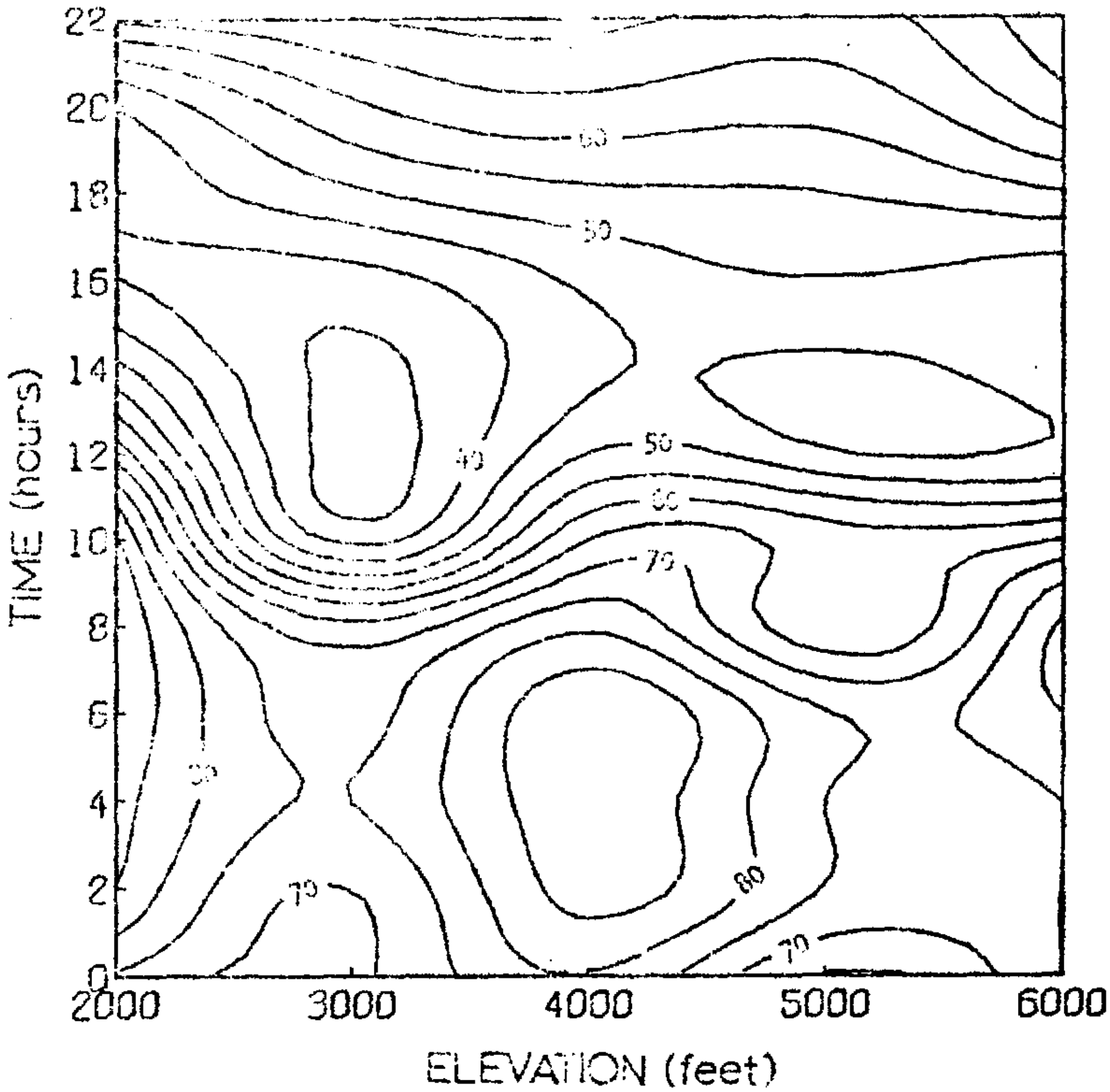

Figure 8. Relative humidity (%) on 3 August 1971 on West Desolation.

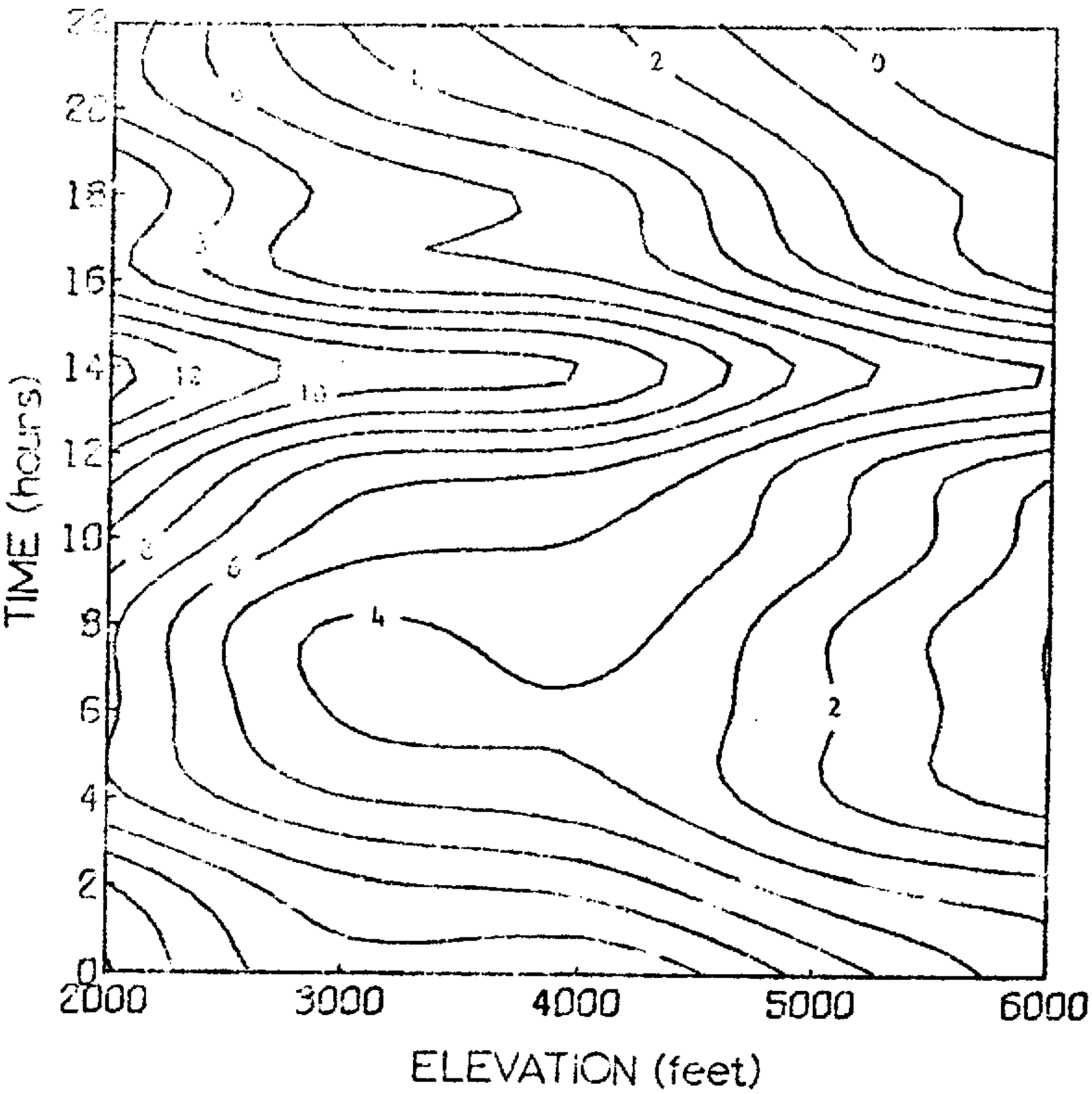

Figure 9. Isotherms (°C) on 31 August 1971 on West Desolation.

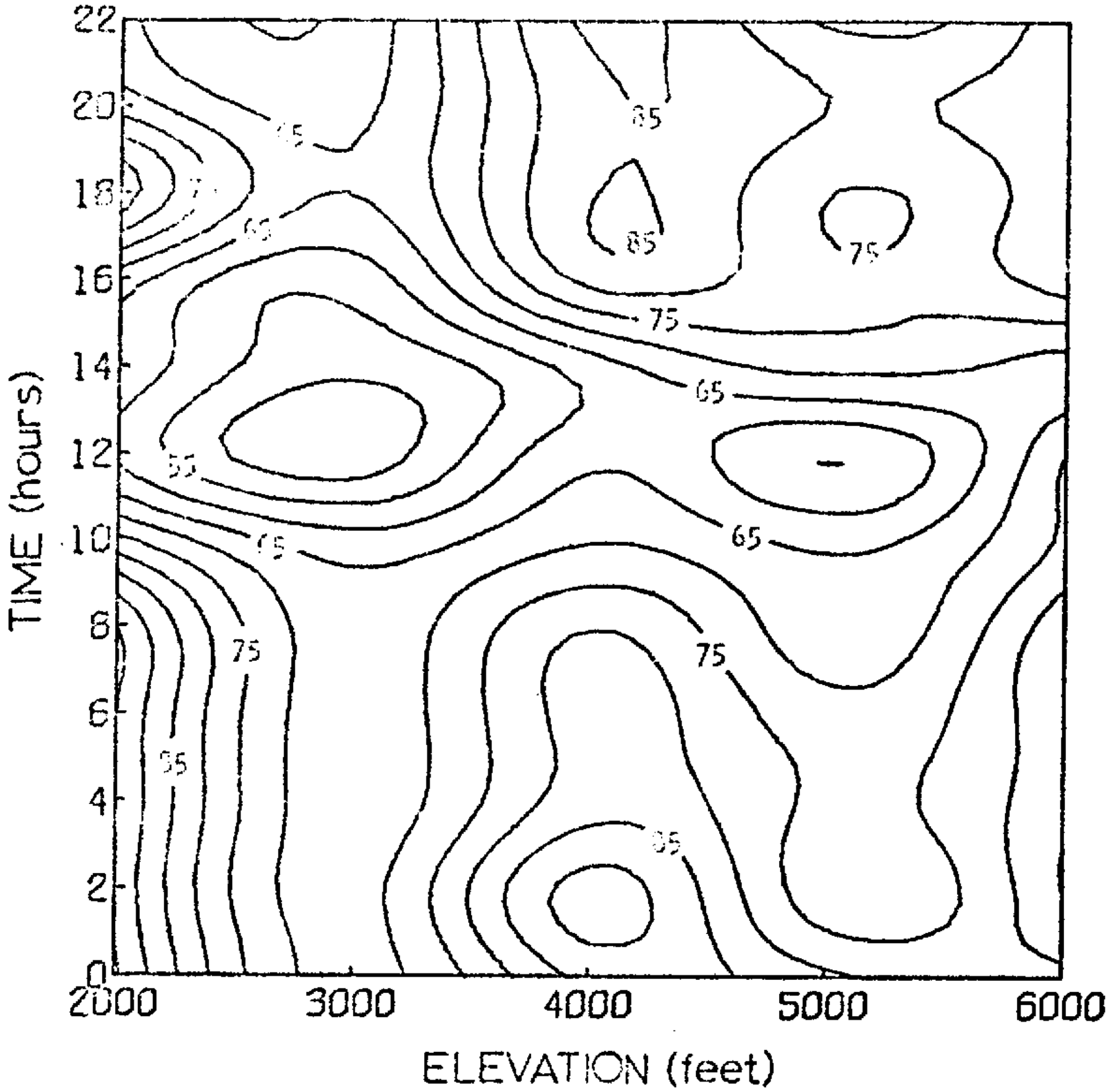

Figure 10. Relative humidity (%) on 31 August 1971 on West Desolation.

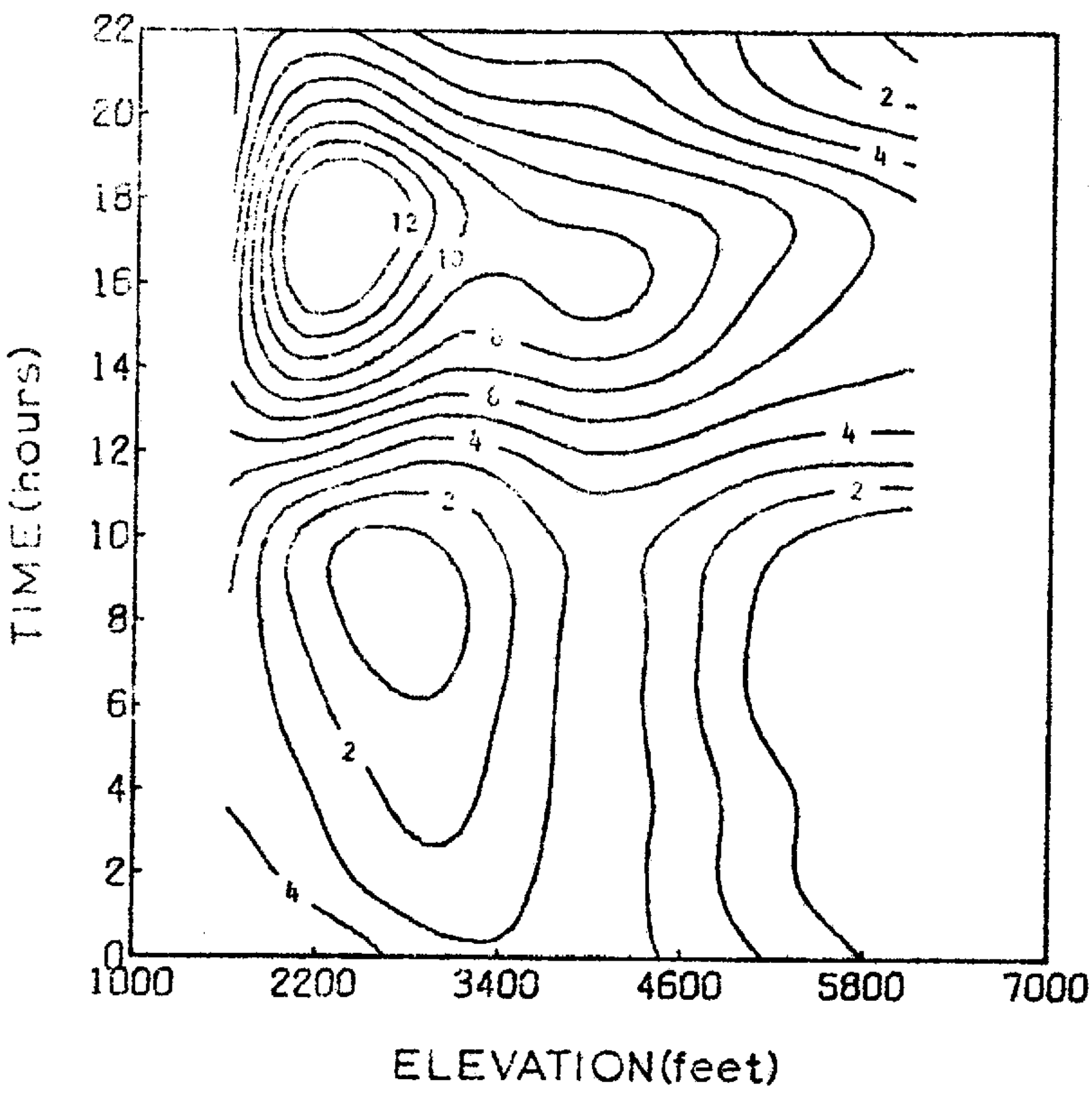

Figure 11. Isotherms (°C) from 15-30 September 1971 on West Desolation.

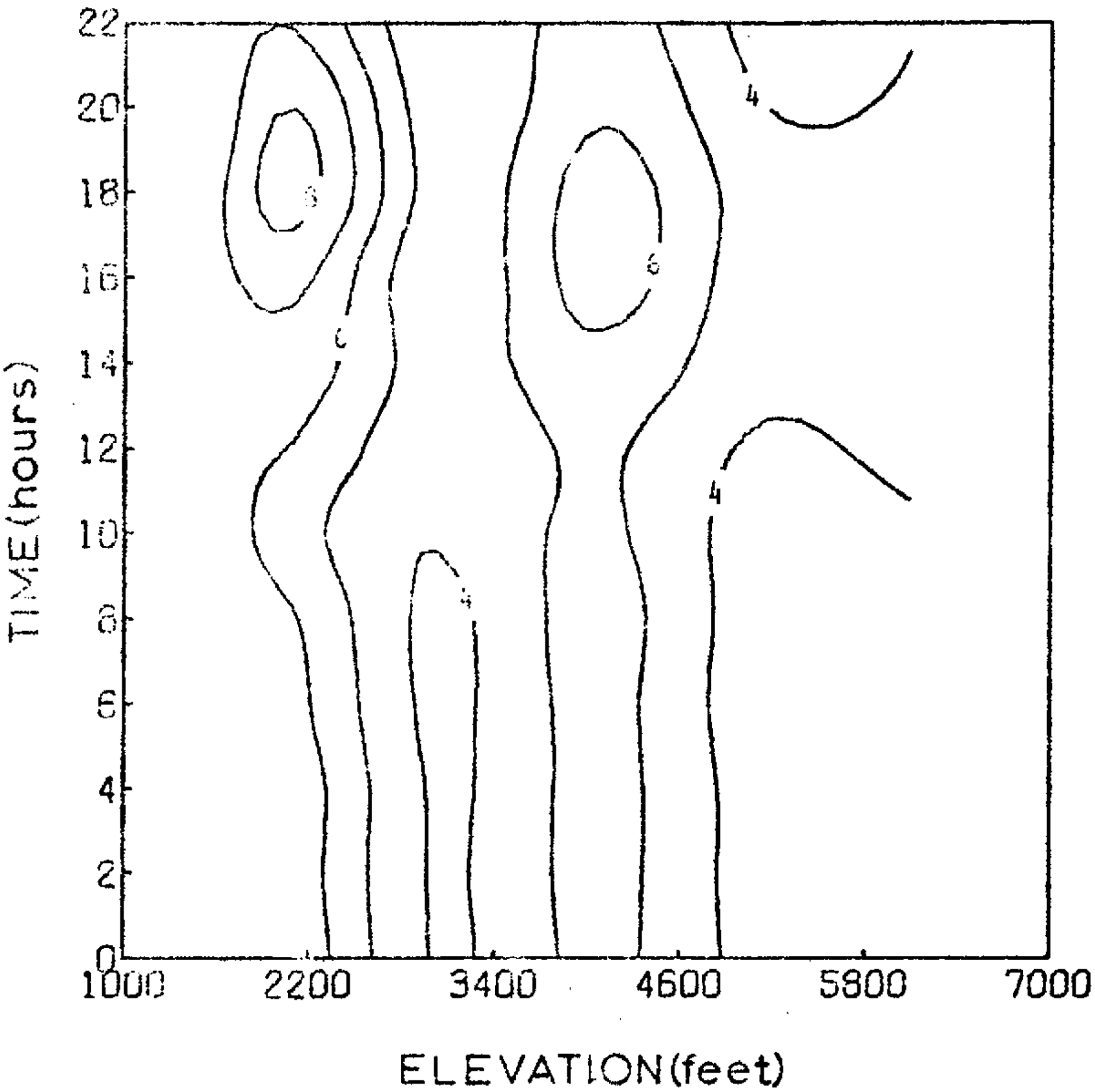

Figure 12. Vapor pressure (mb) from 15-30 September 1971 on West Desolation.

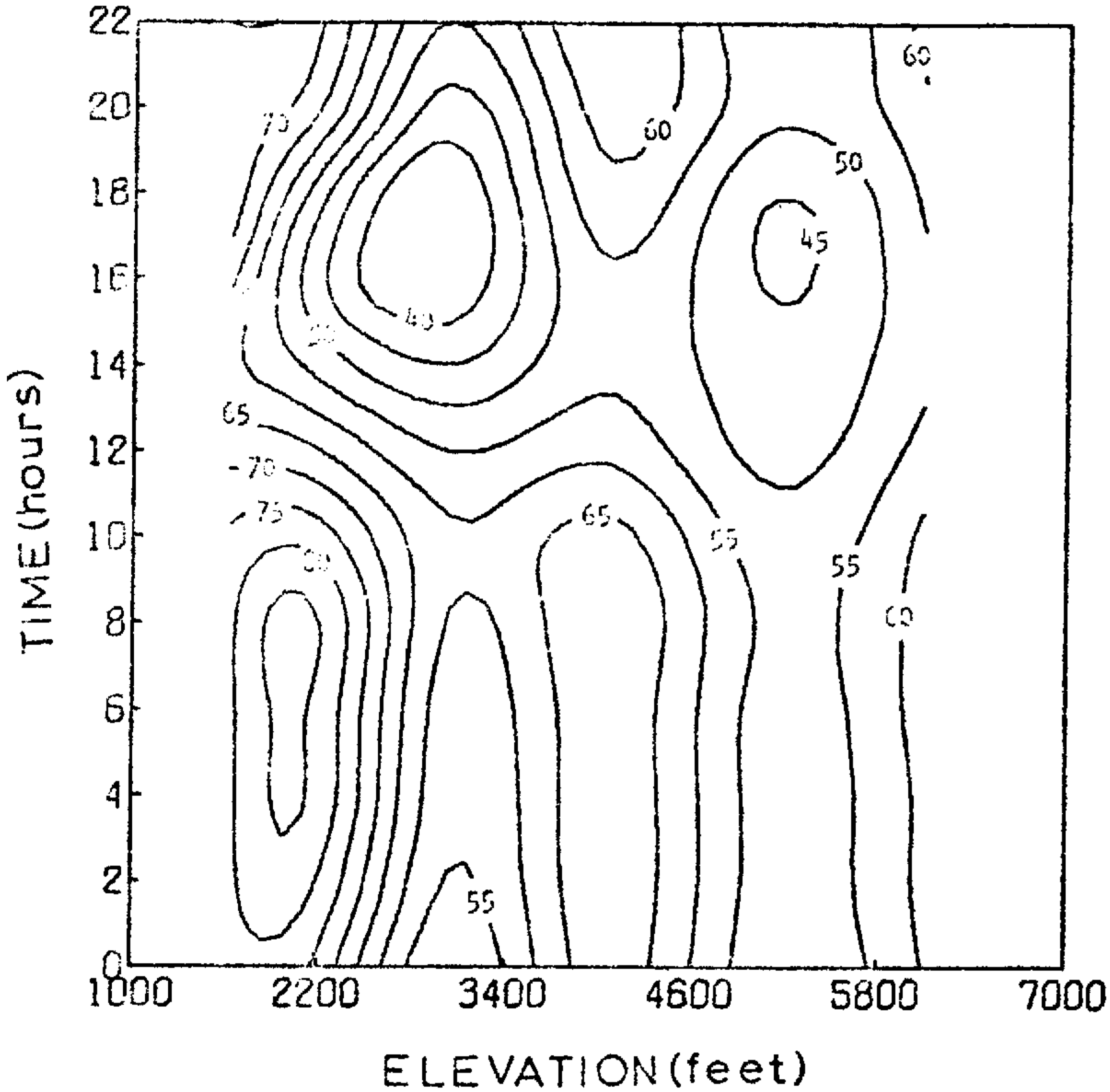

Figure 13. Relative humidity (%) from 15-30 September 1971 on West Desolation.

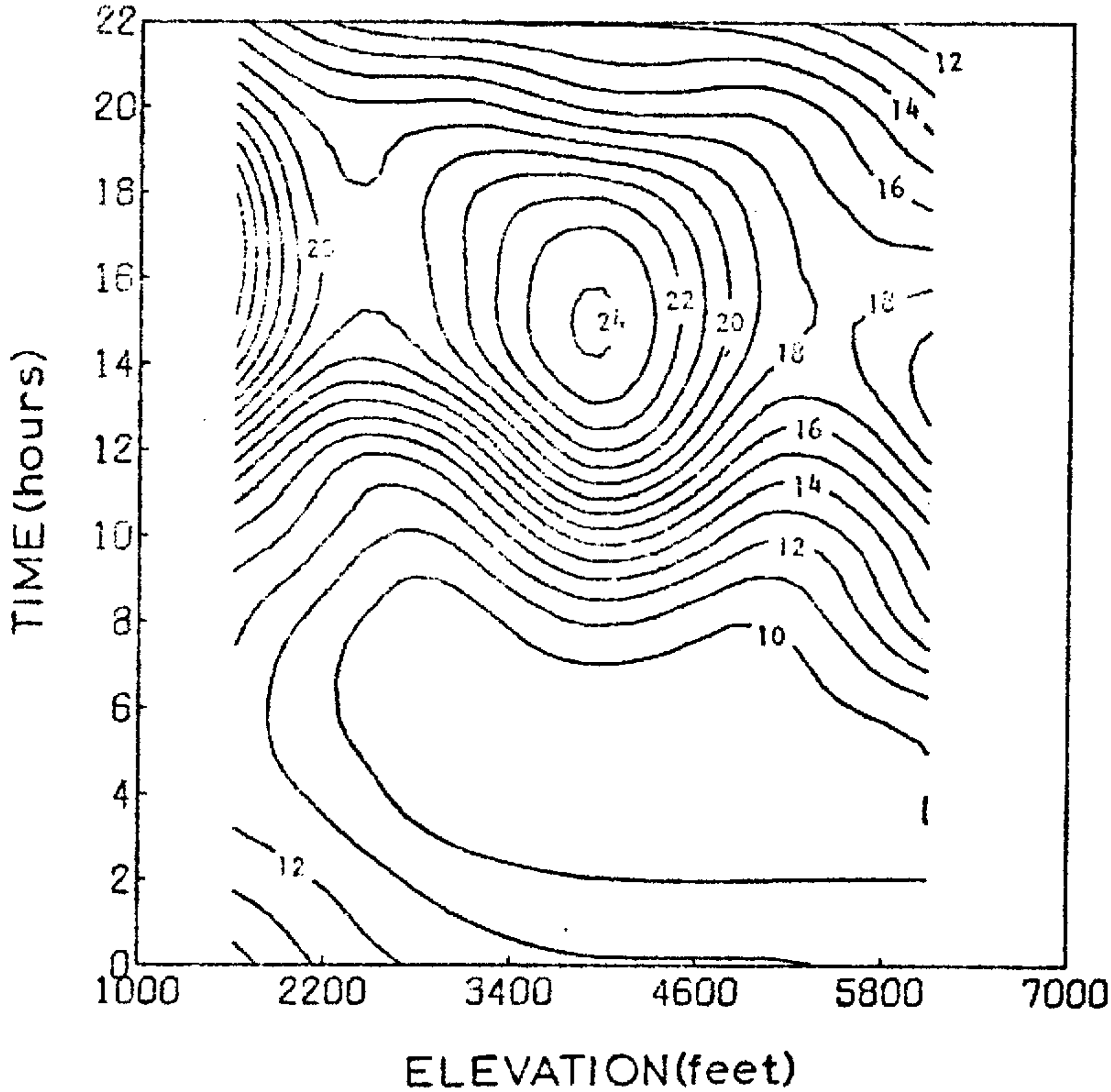

Figure 14. Isotherms (°C) from 22 July - 5 August 1972 on West Desolation.

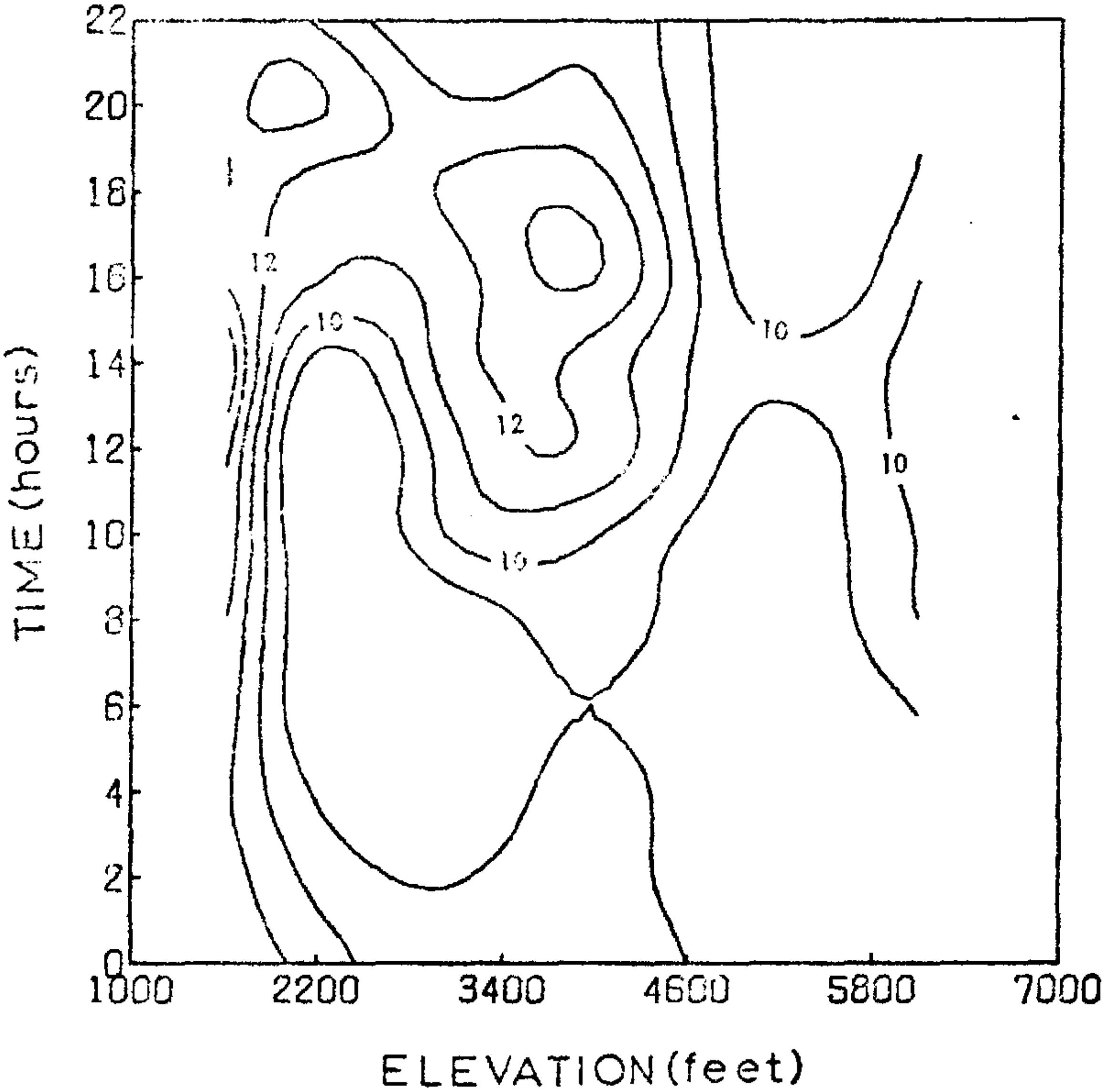

Figure 15. Vapor pressure (mb) from 22 July - 5 August 1972 on West Desolation.

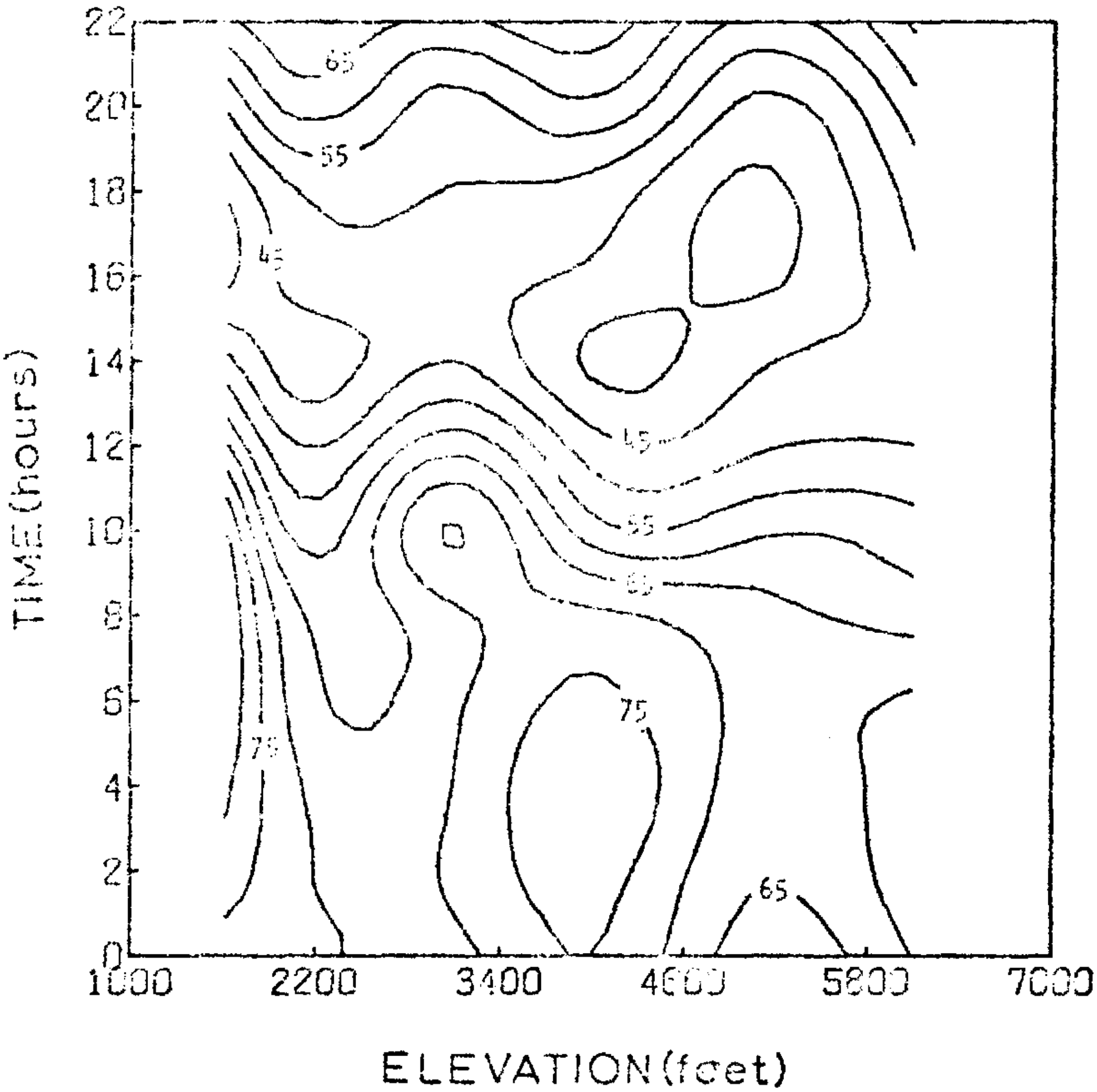

Figure 16. Relative humidity (%) from 22 July - 5 August 1972 on West Desolation.

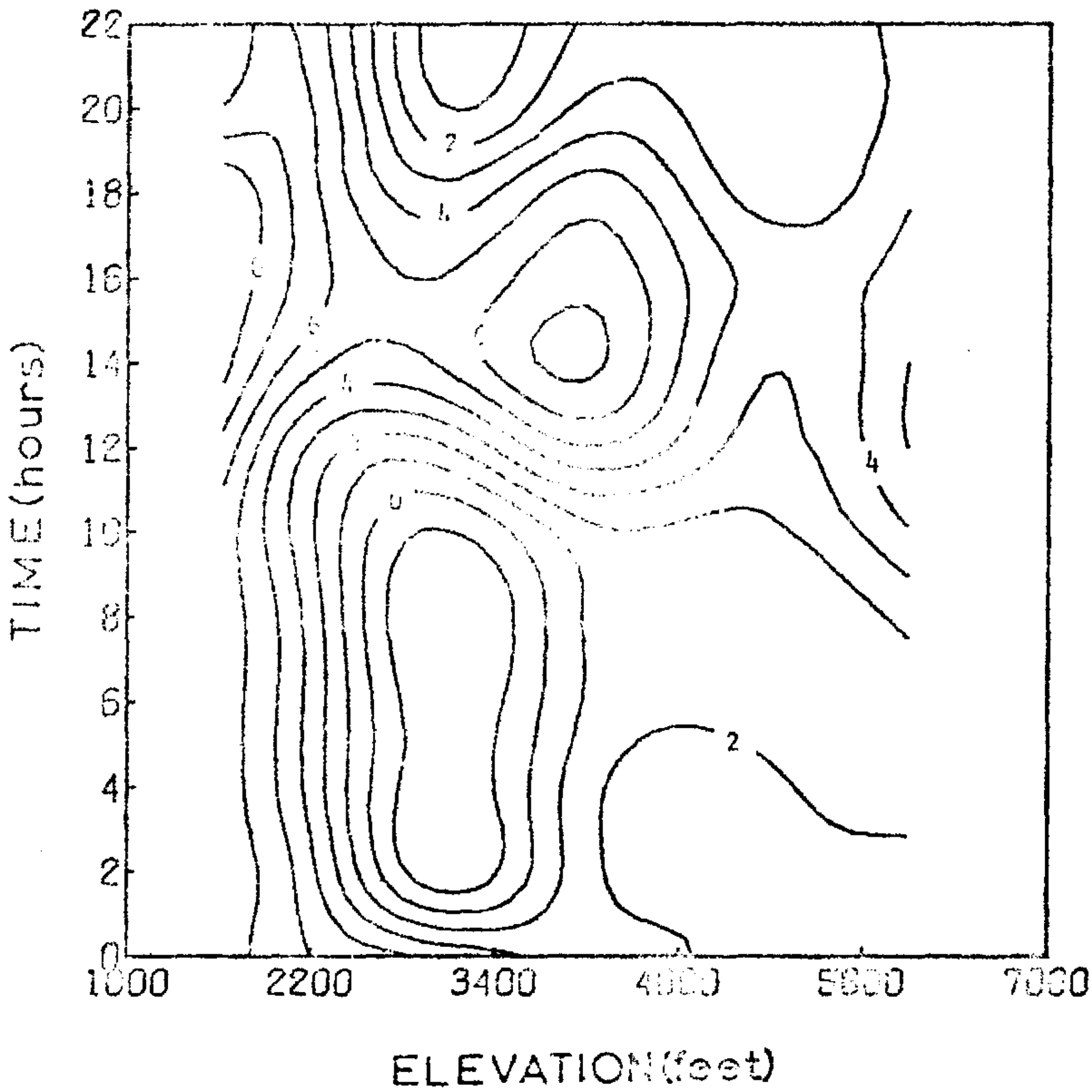

Figure 17. Isotherms (°C) from 15-30 September 1972 on West Desolation.

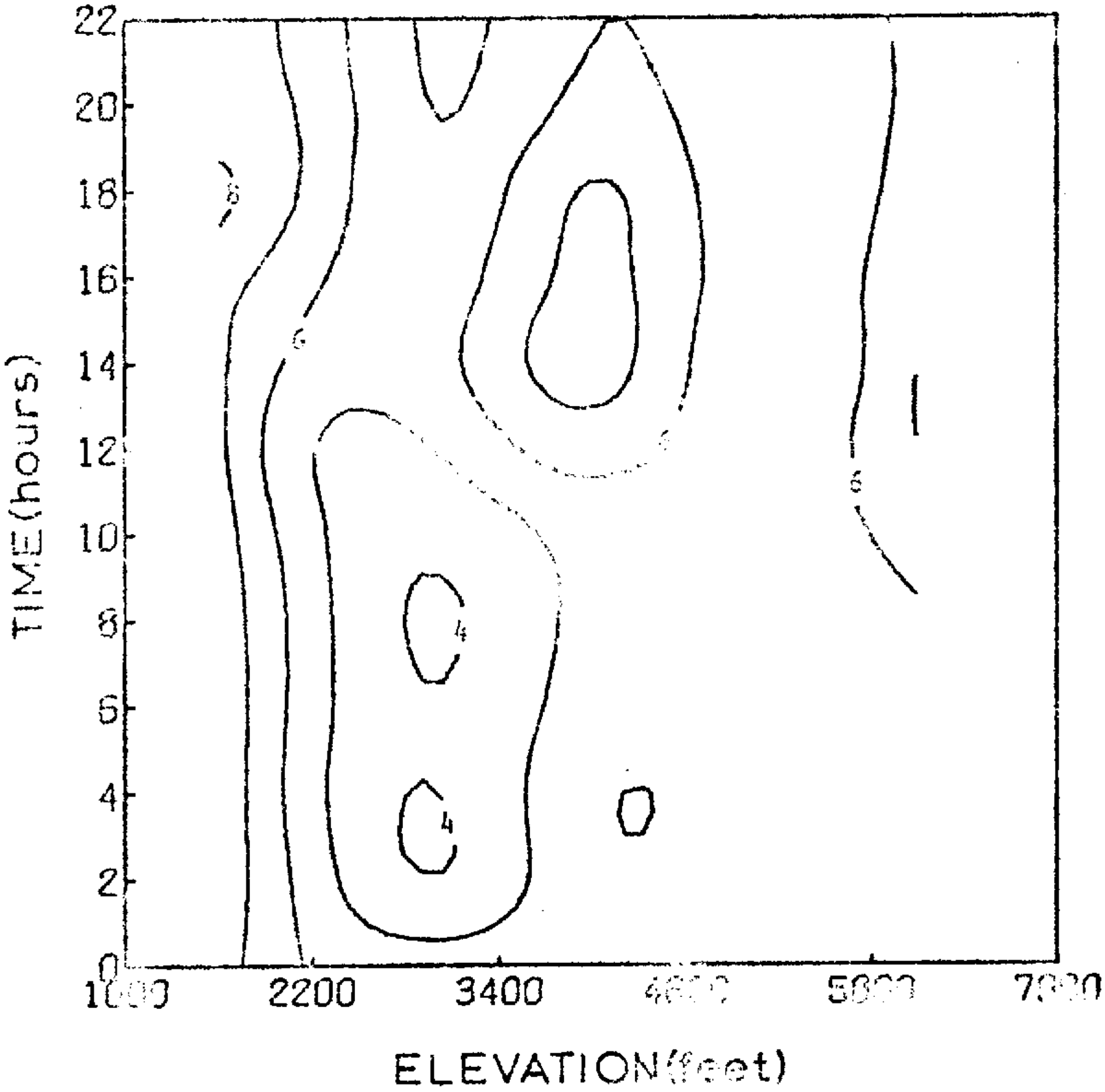

Figure 18. Vapor pressure (mb) from 15-30 September 1972 on West Desolation.

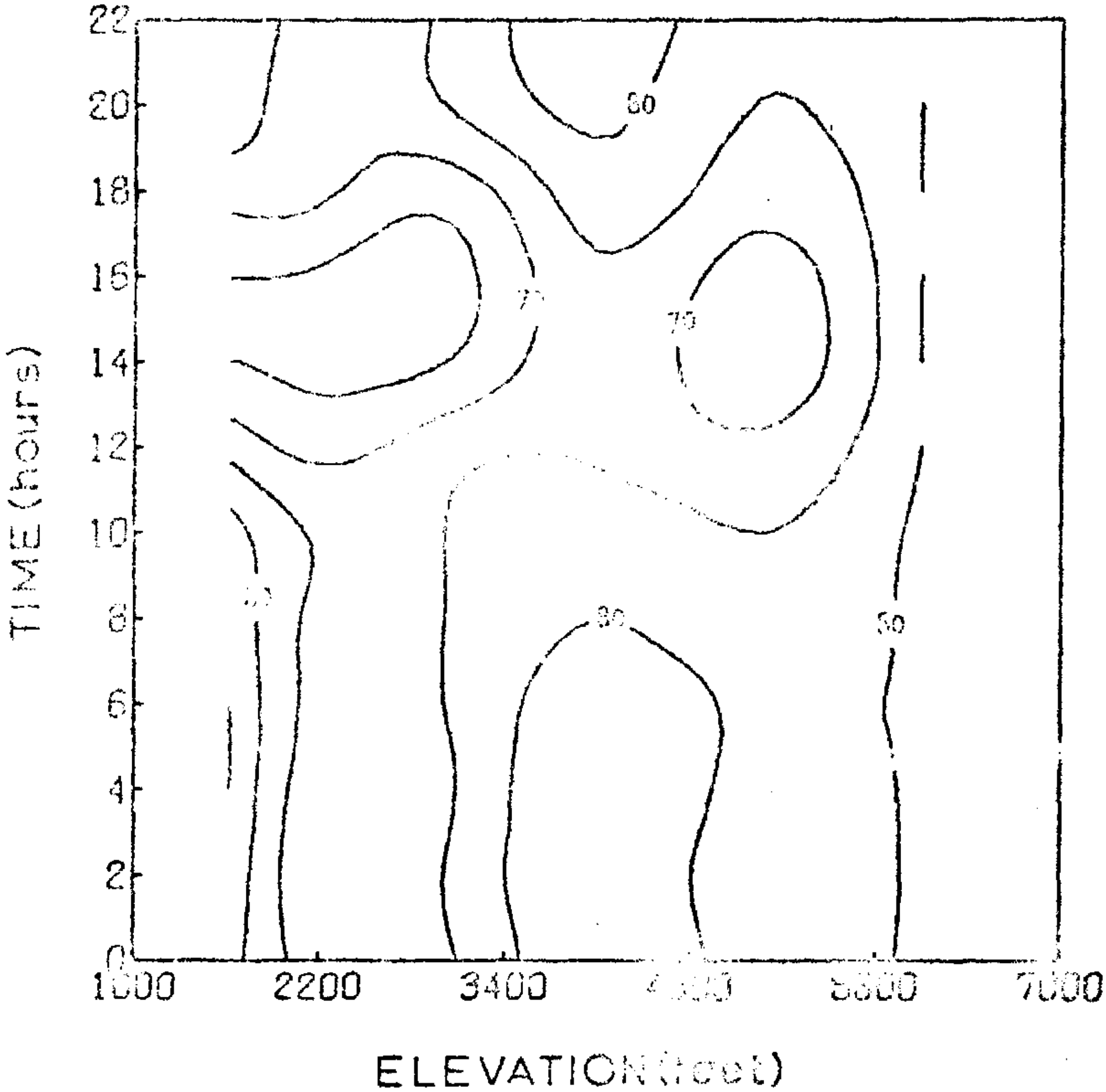

Figure 19. Relative humidity (%) from 15-30 September 1972 on West Desolation.

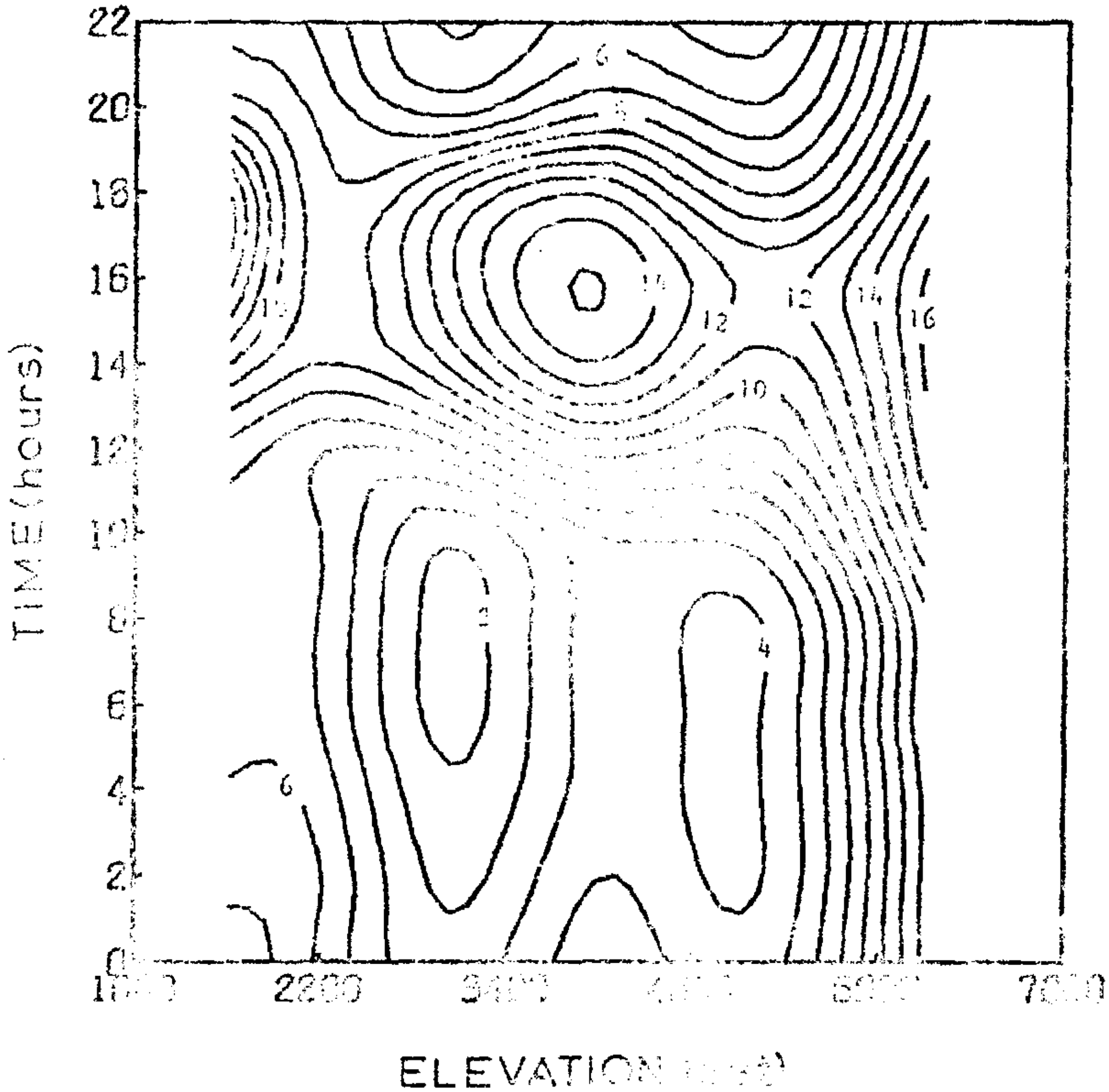

Figure 20. Isotherms (°C) from 1-8 October 1972 on West Desolation.

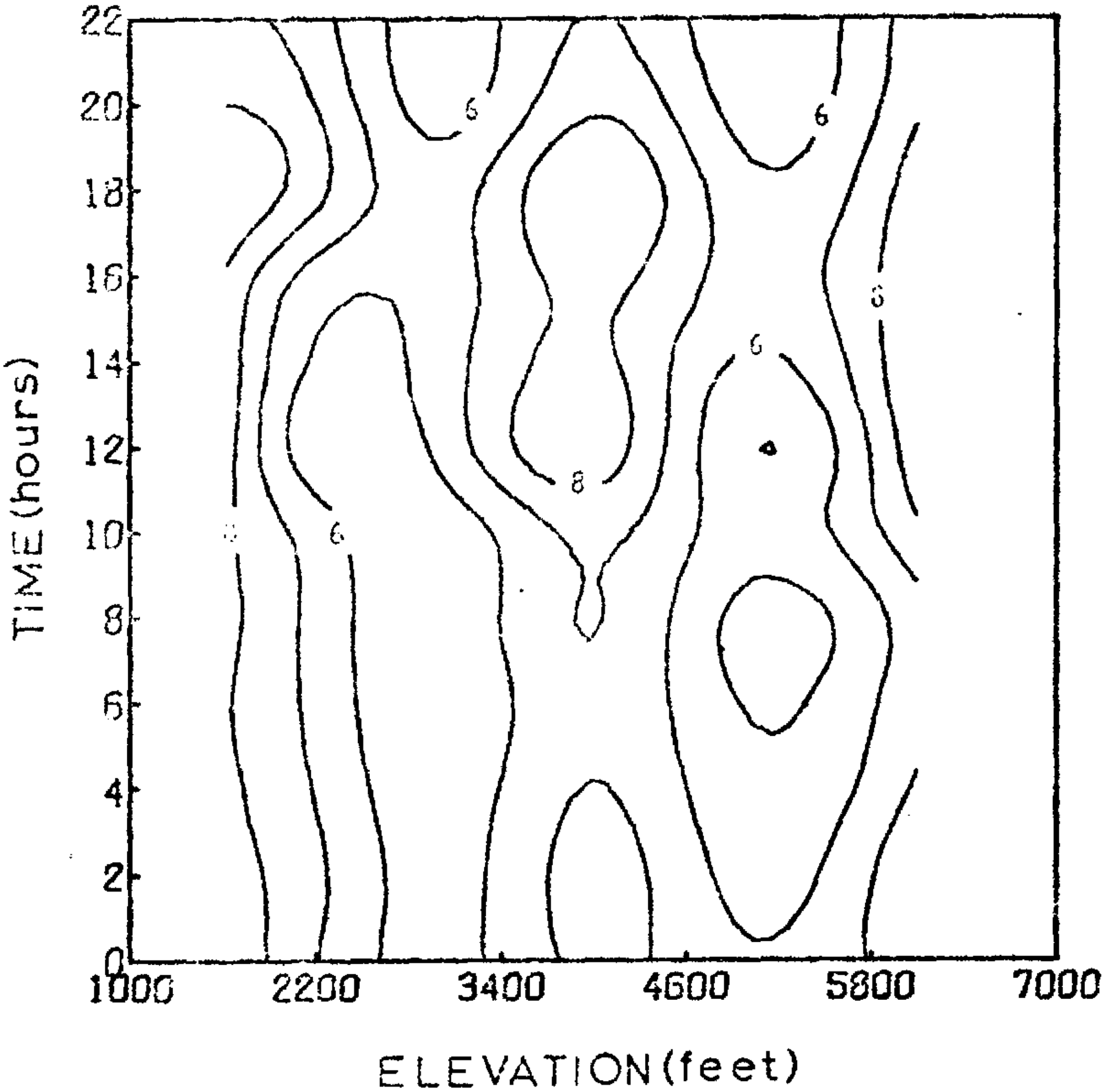

Figure 21. Vapor pressure (mb) from 1-8 October 1972 on West Desolation.

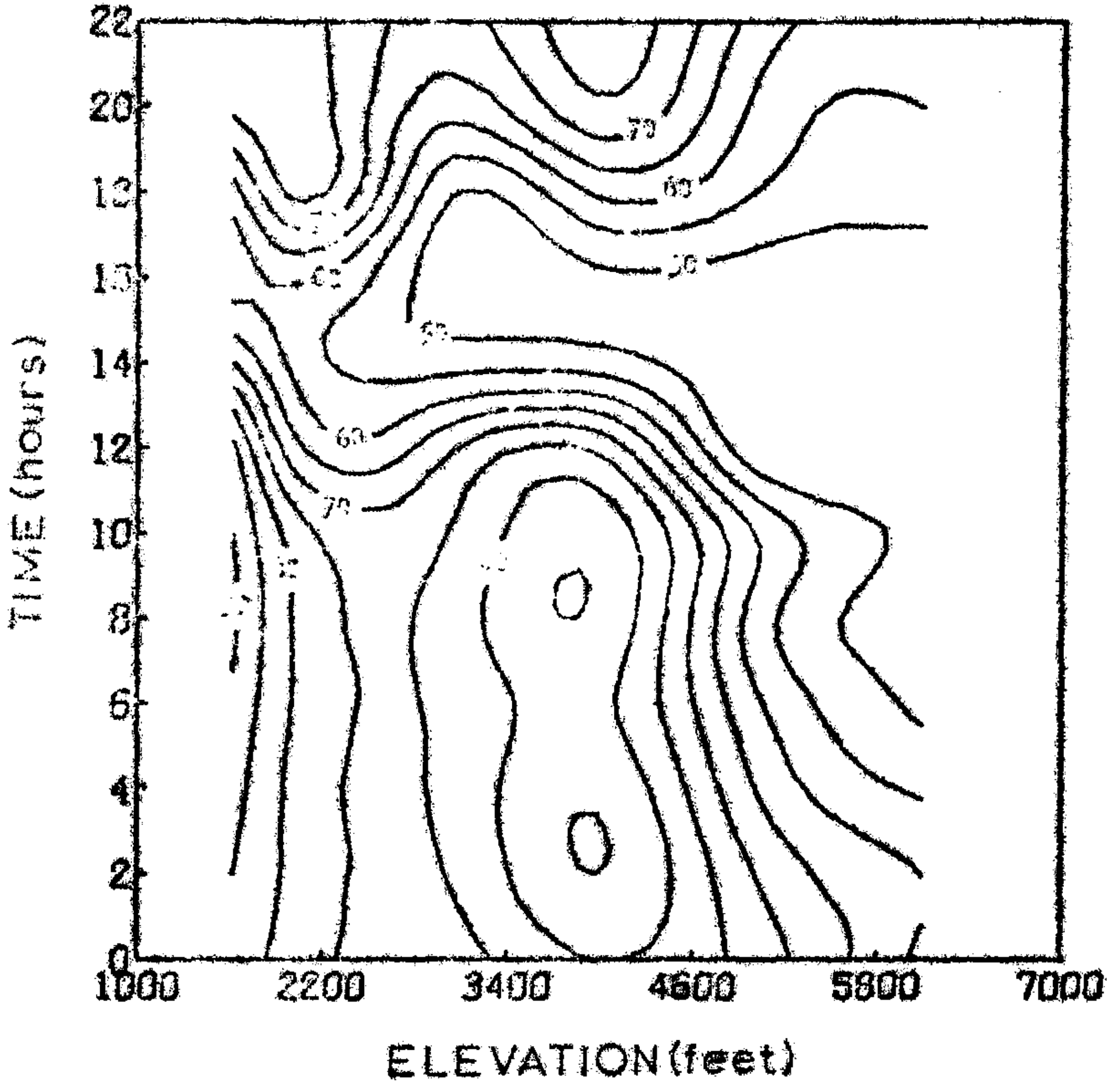

Figure 22. Relative humidity (%) from 1-8 October 1972 on West Desolation.

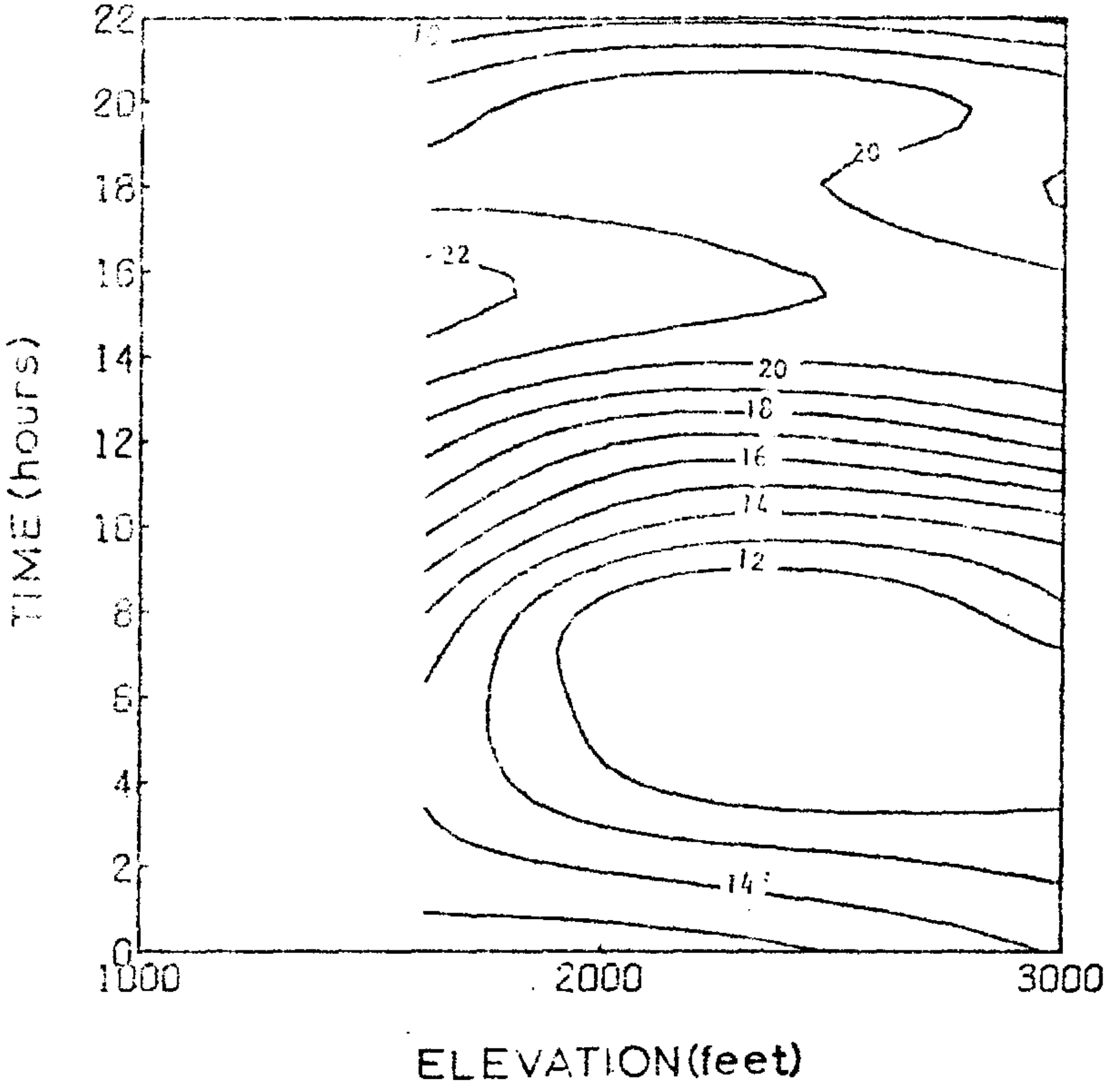

Figure 23. Isotherms (°C) from 22 July - 5 August 1972 on Little Beaver.

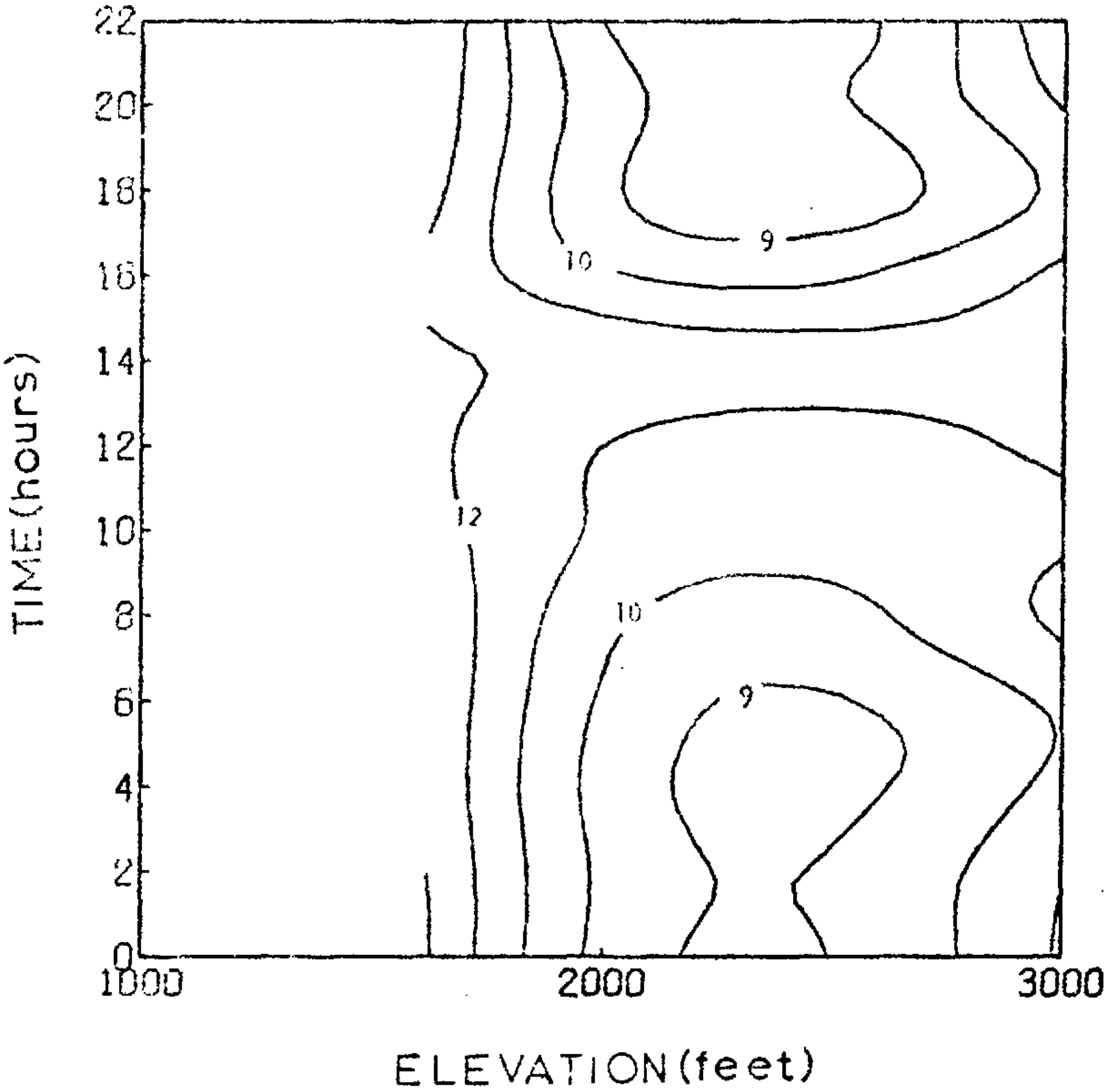

Figure 24. Vapor pressure (mb) from 22 July - 5 August 1972 on Little Beaver.

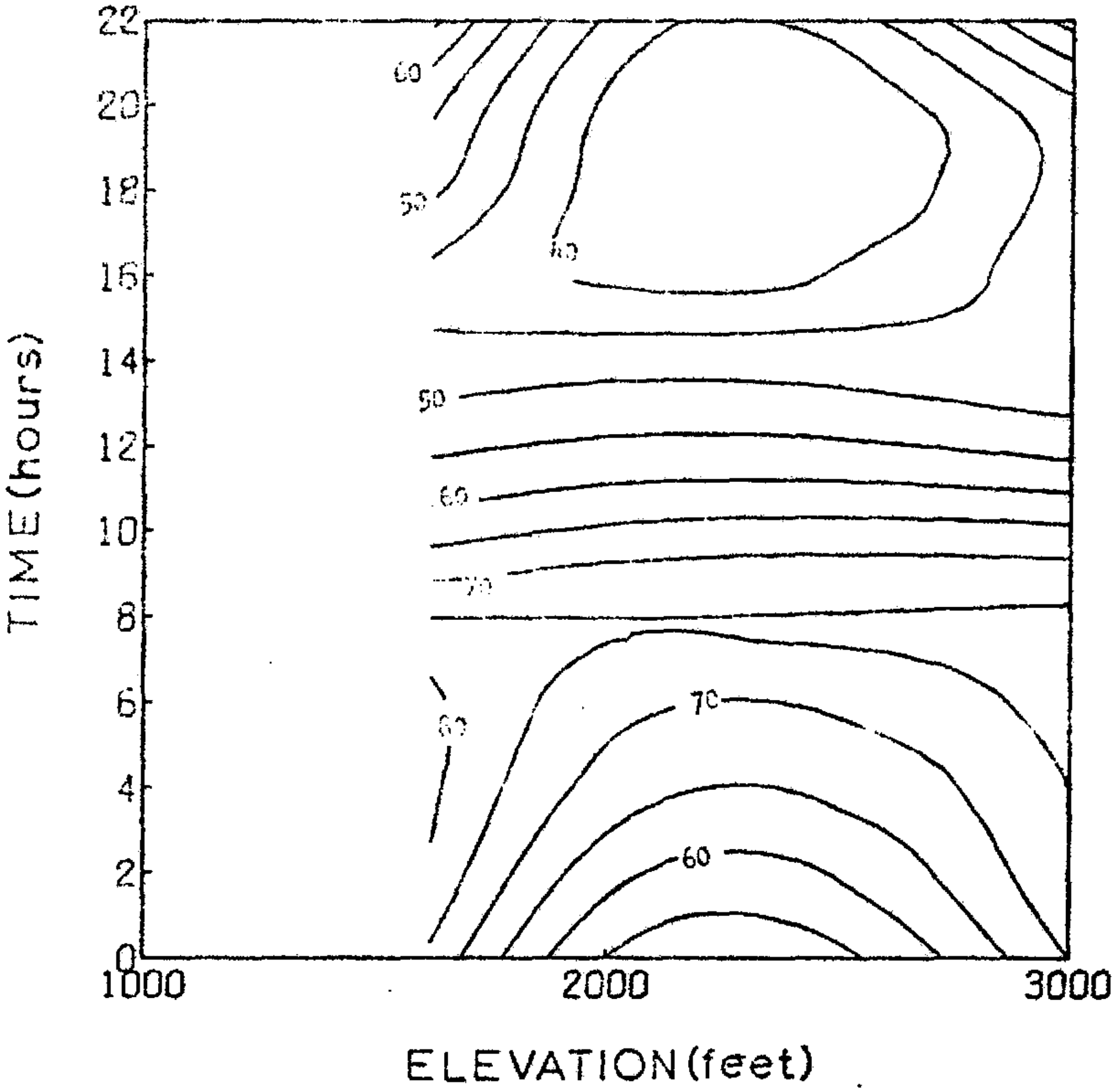

Figure 25. Relative humidity (%) from 22 July - 5 August 1972 on Little Beaver.

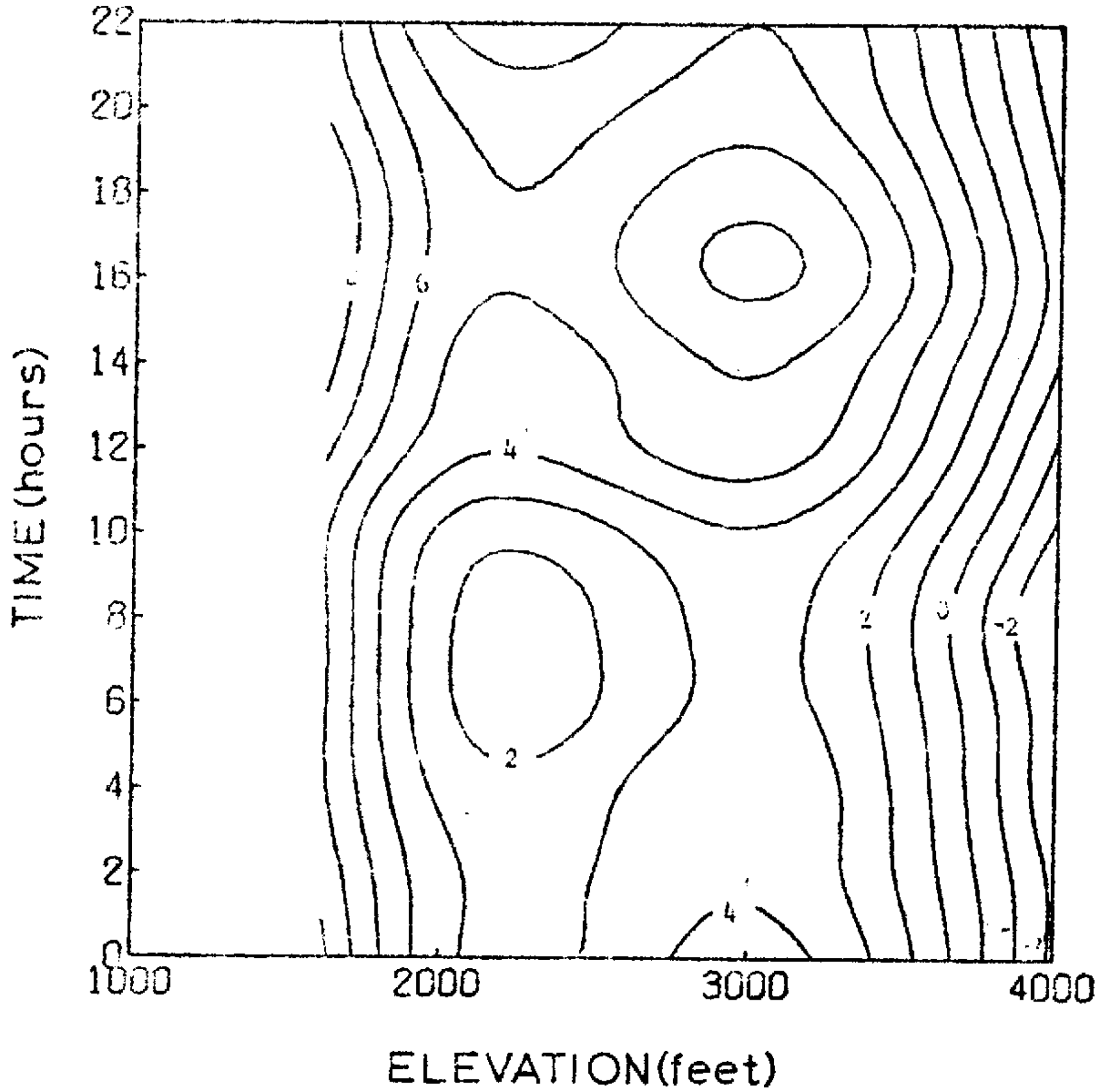

Figure 26. Isotherms (°C) from 15-30 September 1972 on Little Beaver.

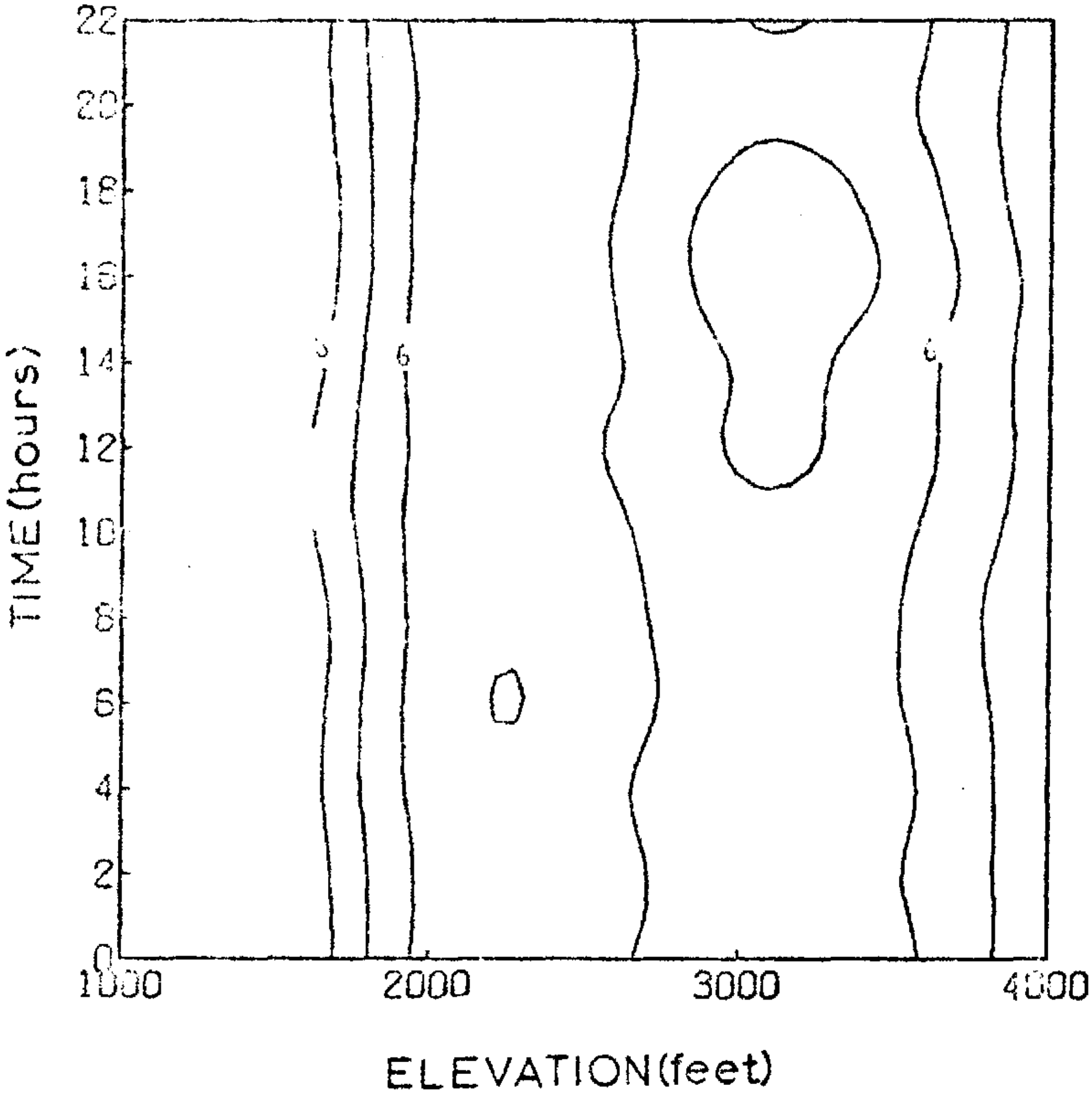

Figure 27. Vapor pressure (mb) from 15-30 September 1972 on Little Beaver.

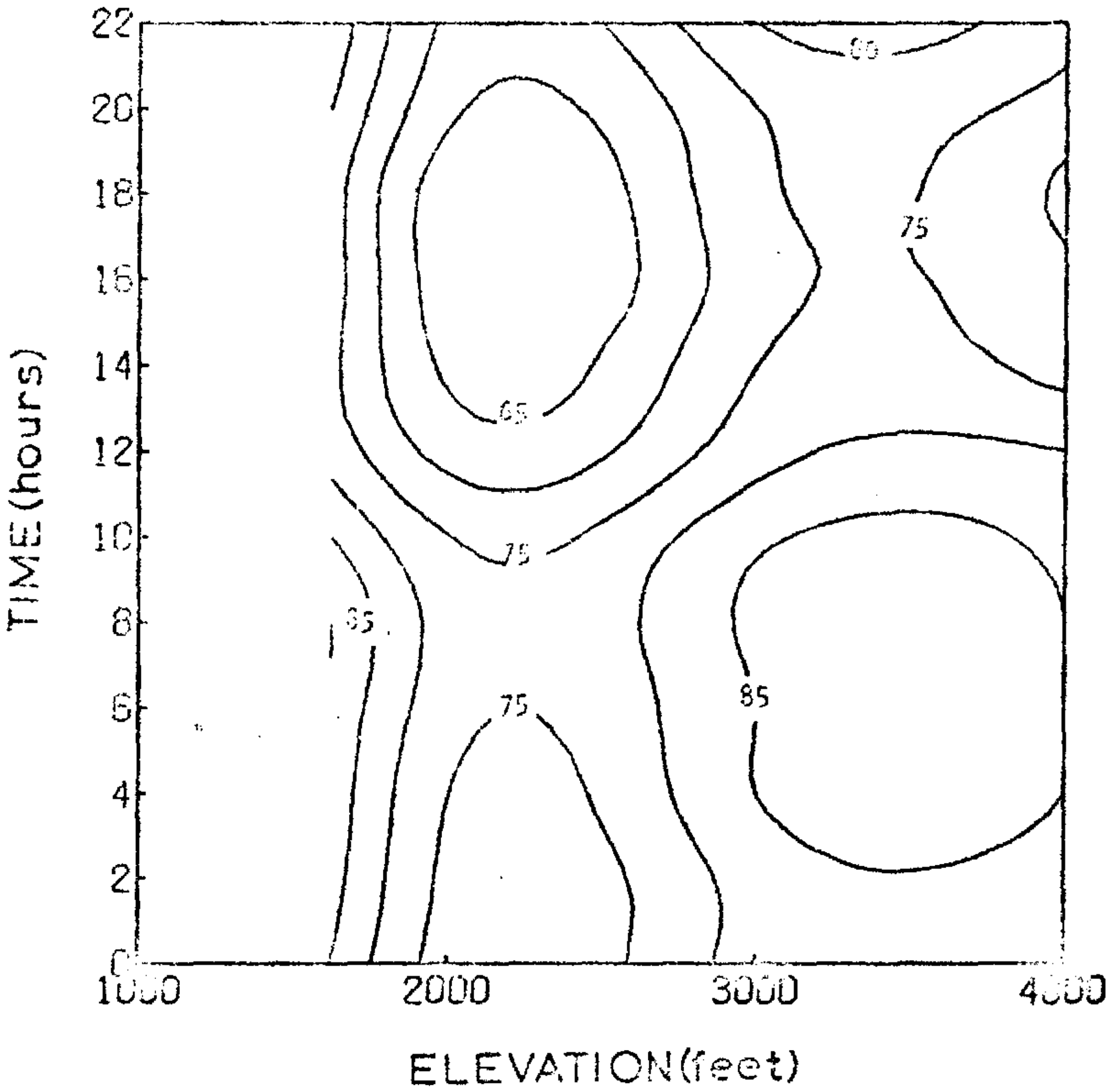

Figure 28 Relative humidity (%) from 15-30 September 1972 on Little Beaver.

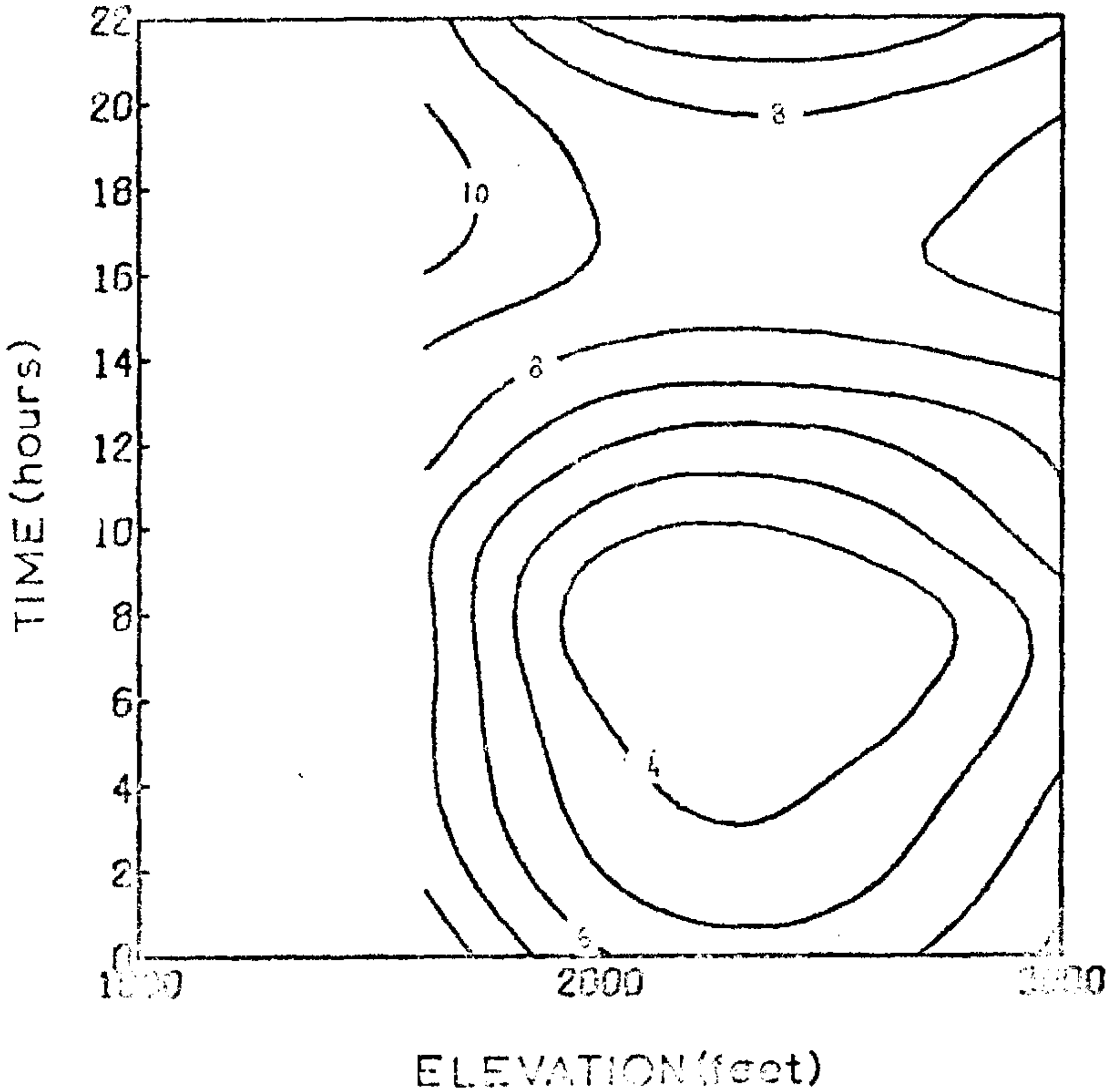

Figure 29. Isotherms (°C) from 1-3 October 1972 on Little Beaver.

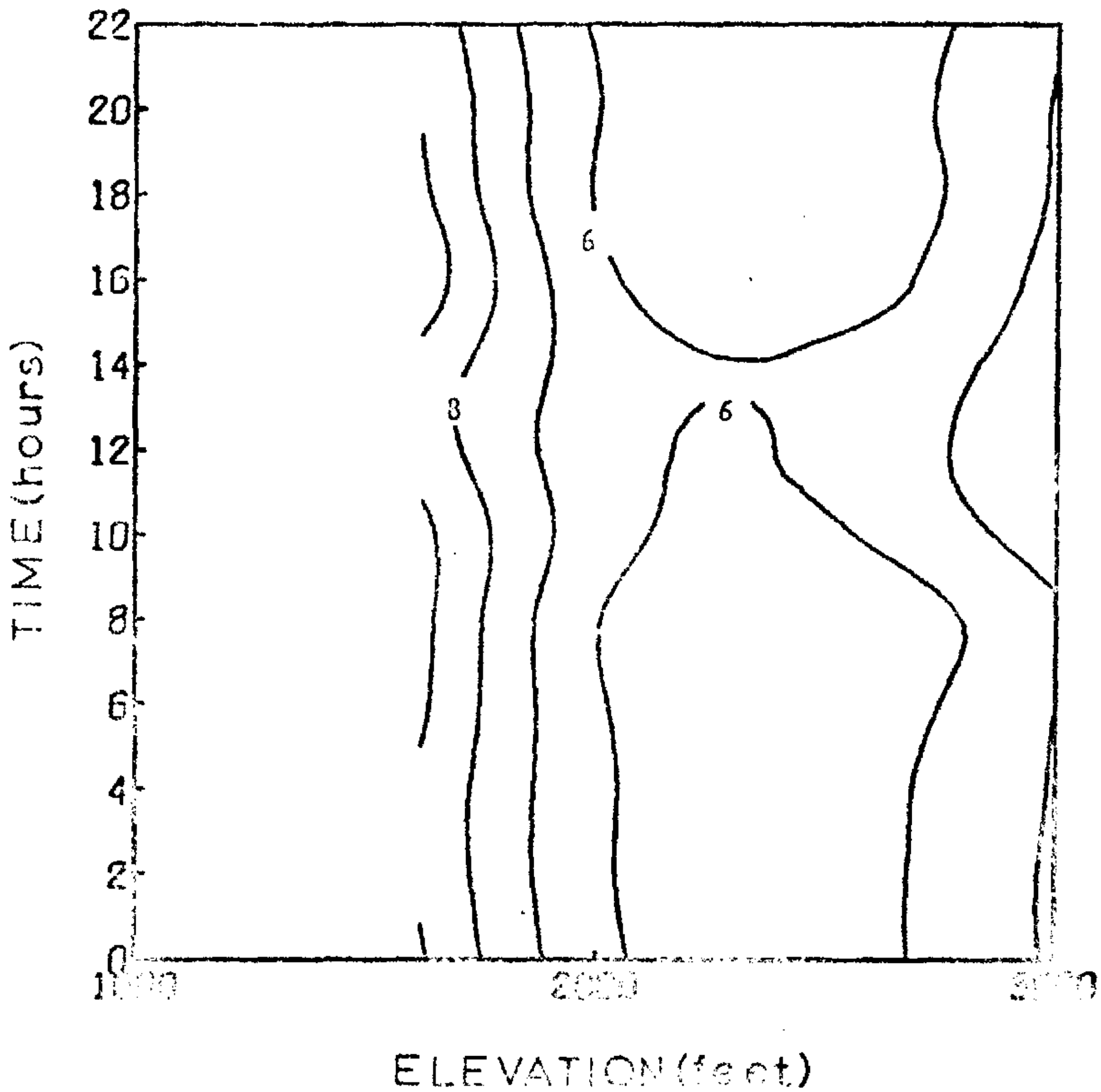

Figure 30. Vapor pressure (mb) from 1-8 October 1972 on Little Beaver.

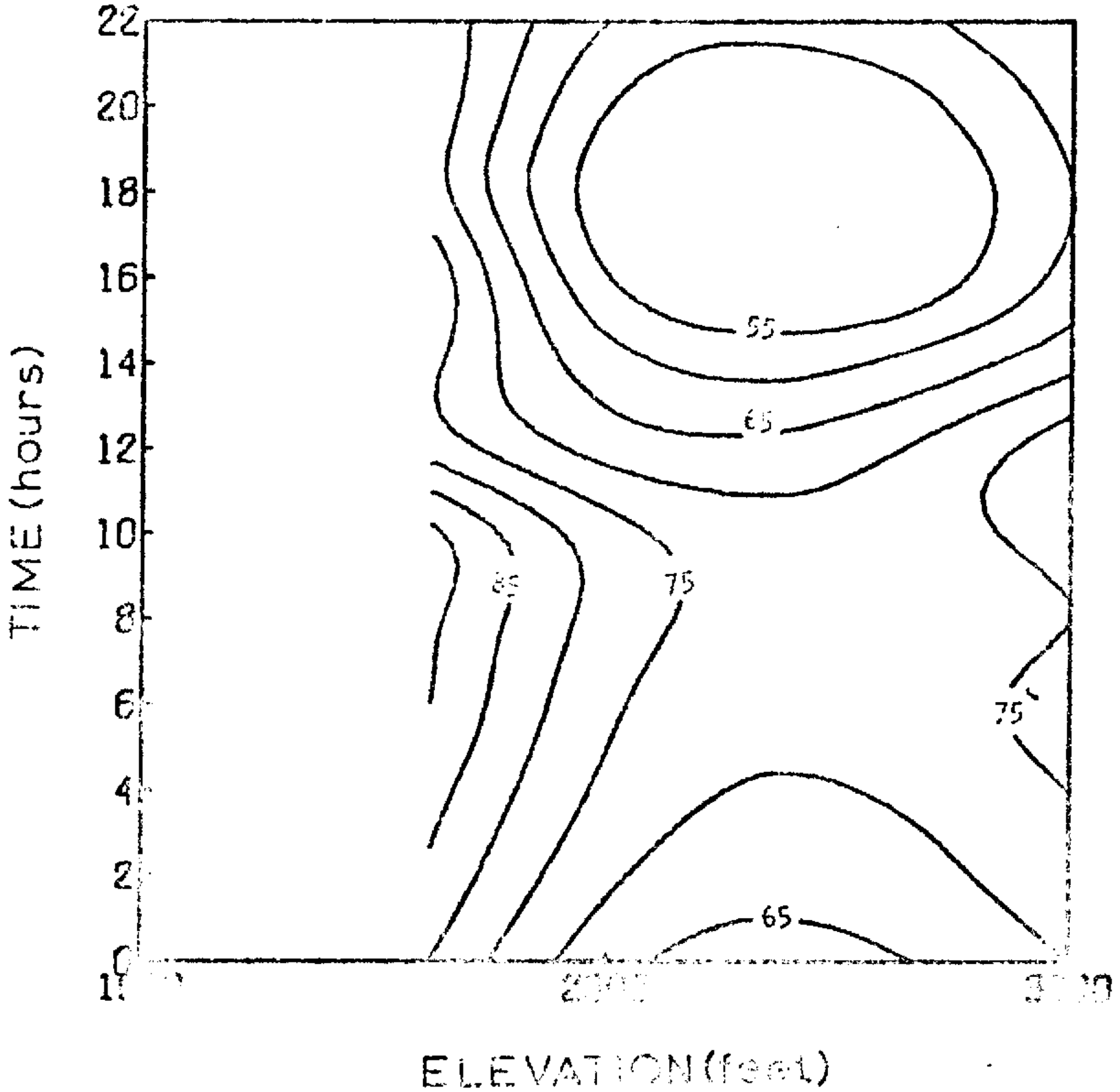

Figure 31. Relative humidity (%) from 1-8 October 1972 on Little Beaver.

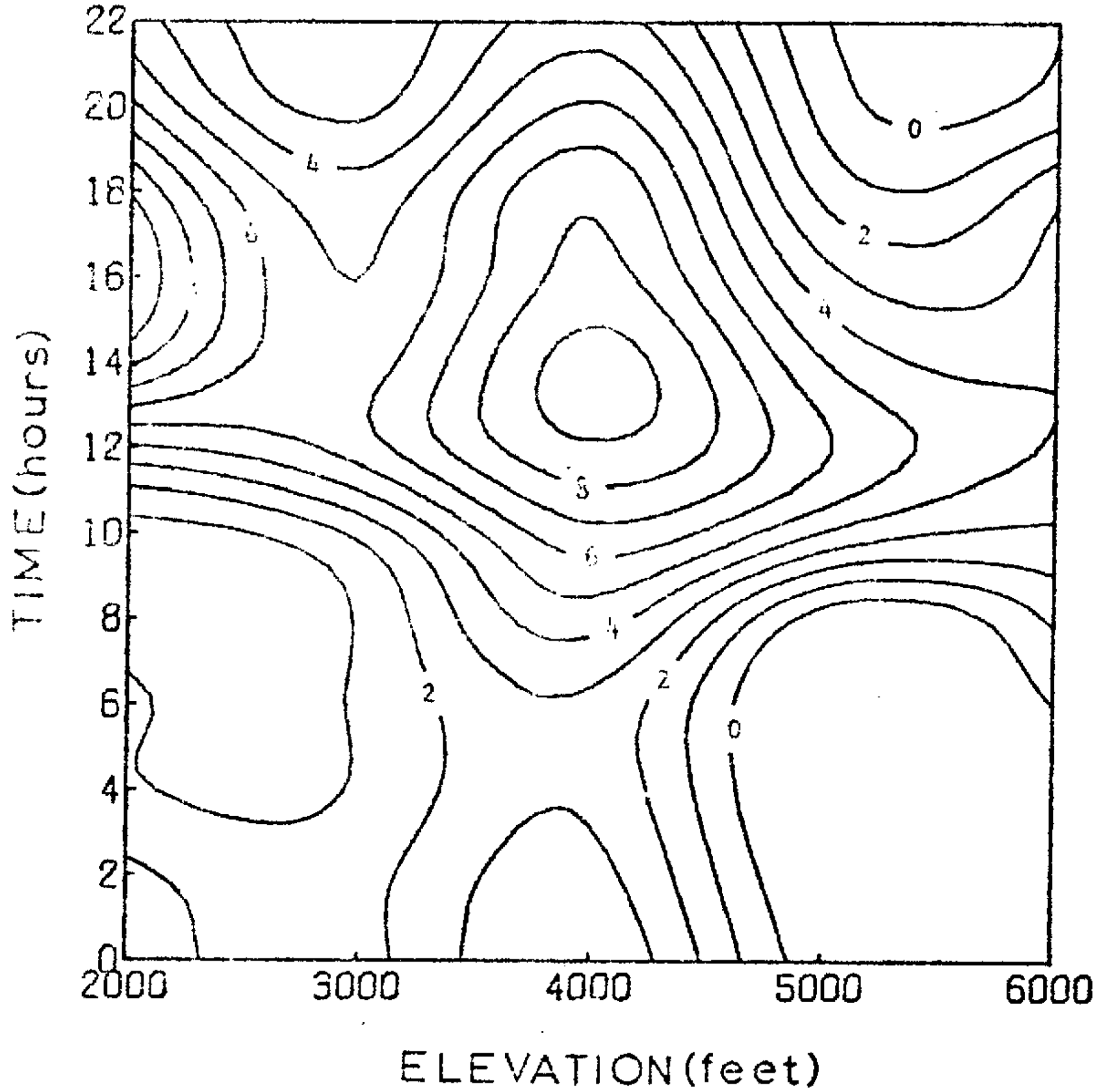

Figure 32. Isotherms (°C) from 15-30 September 1971 on East Desolation.

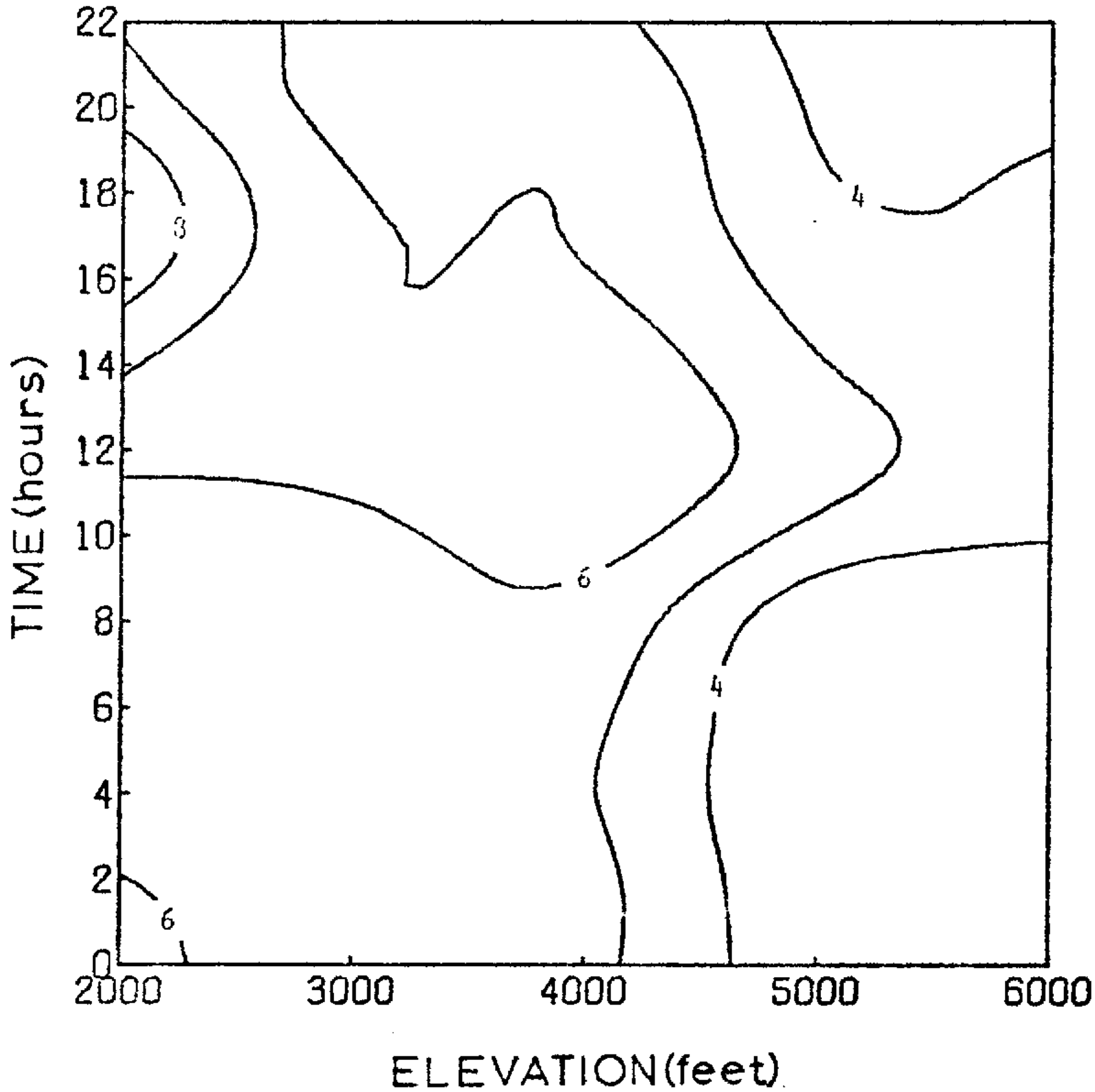

Figure 33. Vapor pressure (mb) from 15-30 September 1971 on East Desolation.

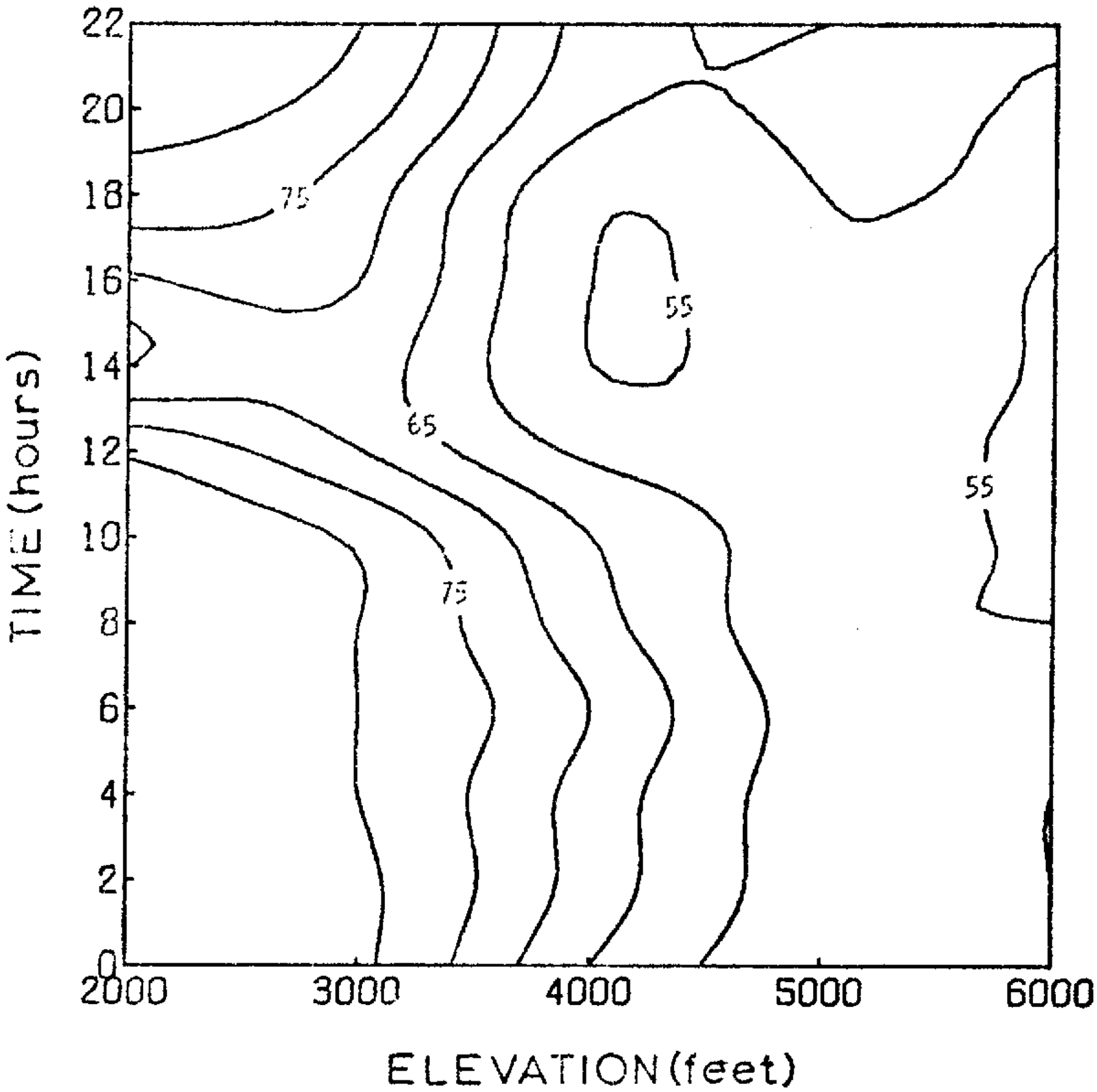

Figure 34. Relative humidity (%) from 15-30 September 1971 on East Desolation.

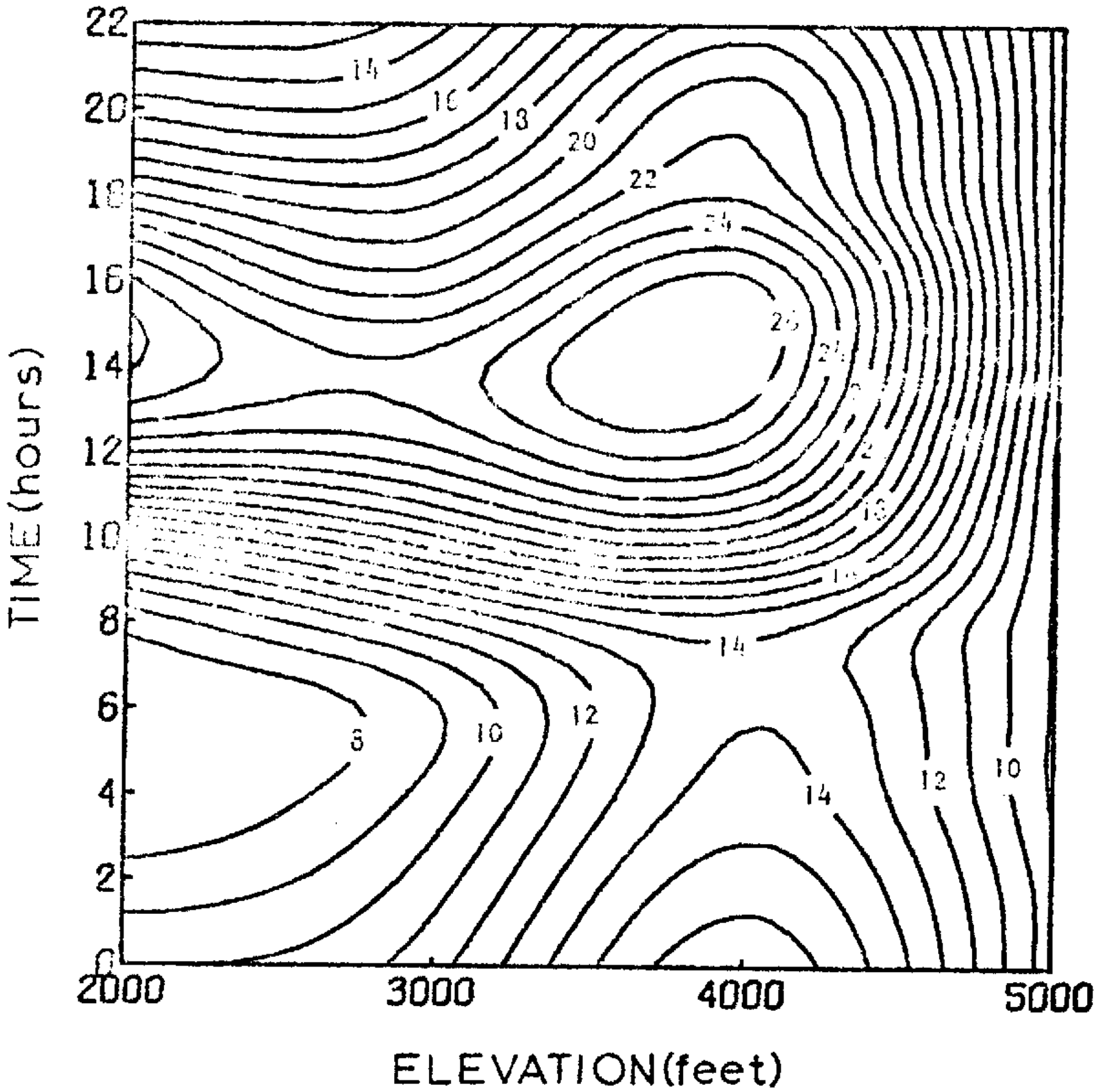

Figure 35. Isotherms (°C) from 22 July - 5 August 1972 on East Desolation.

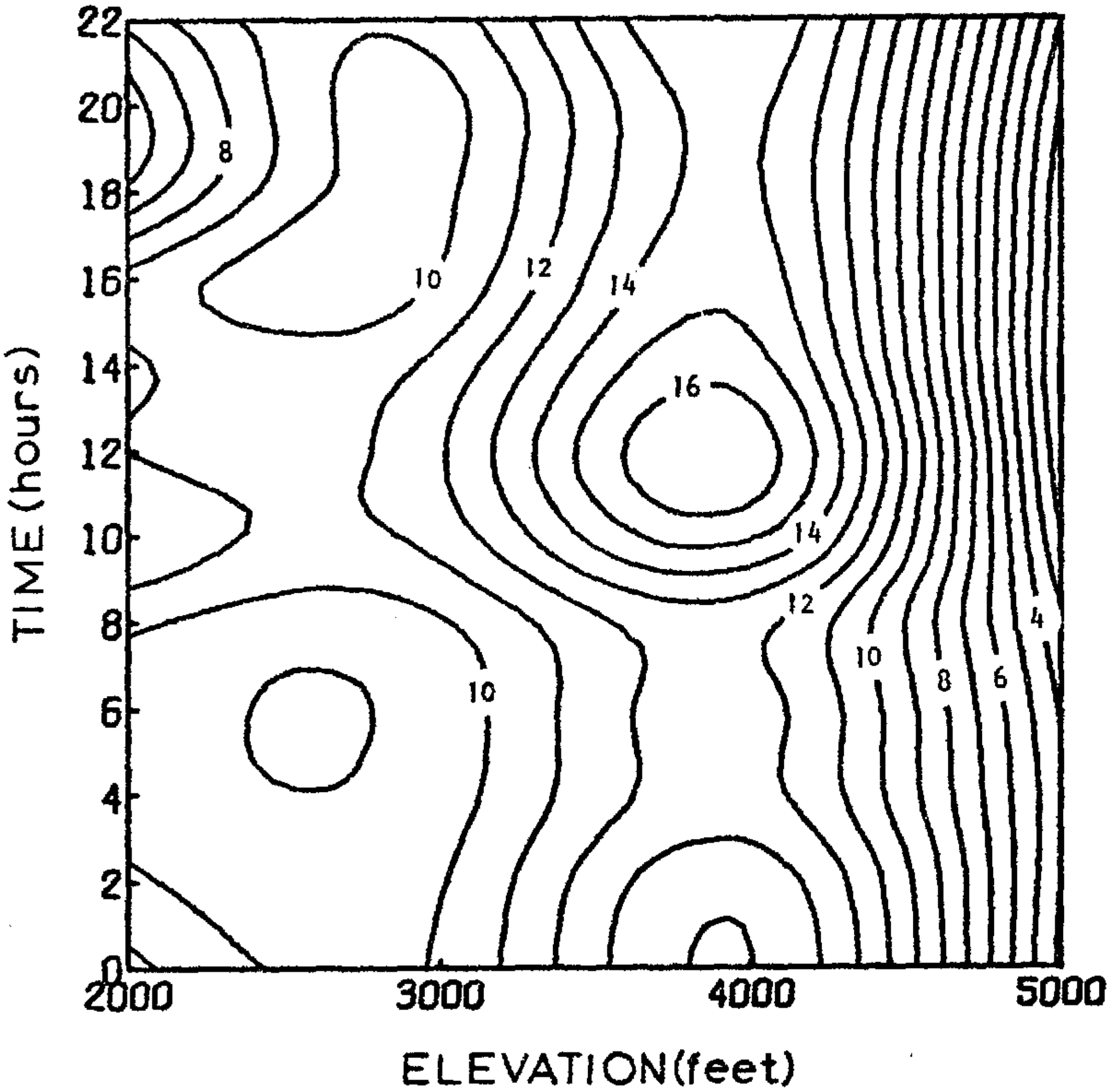

Figure 36. Vapor pressure (mb) from 22 July - 5 August 1972 on East Desolation.

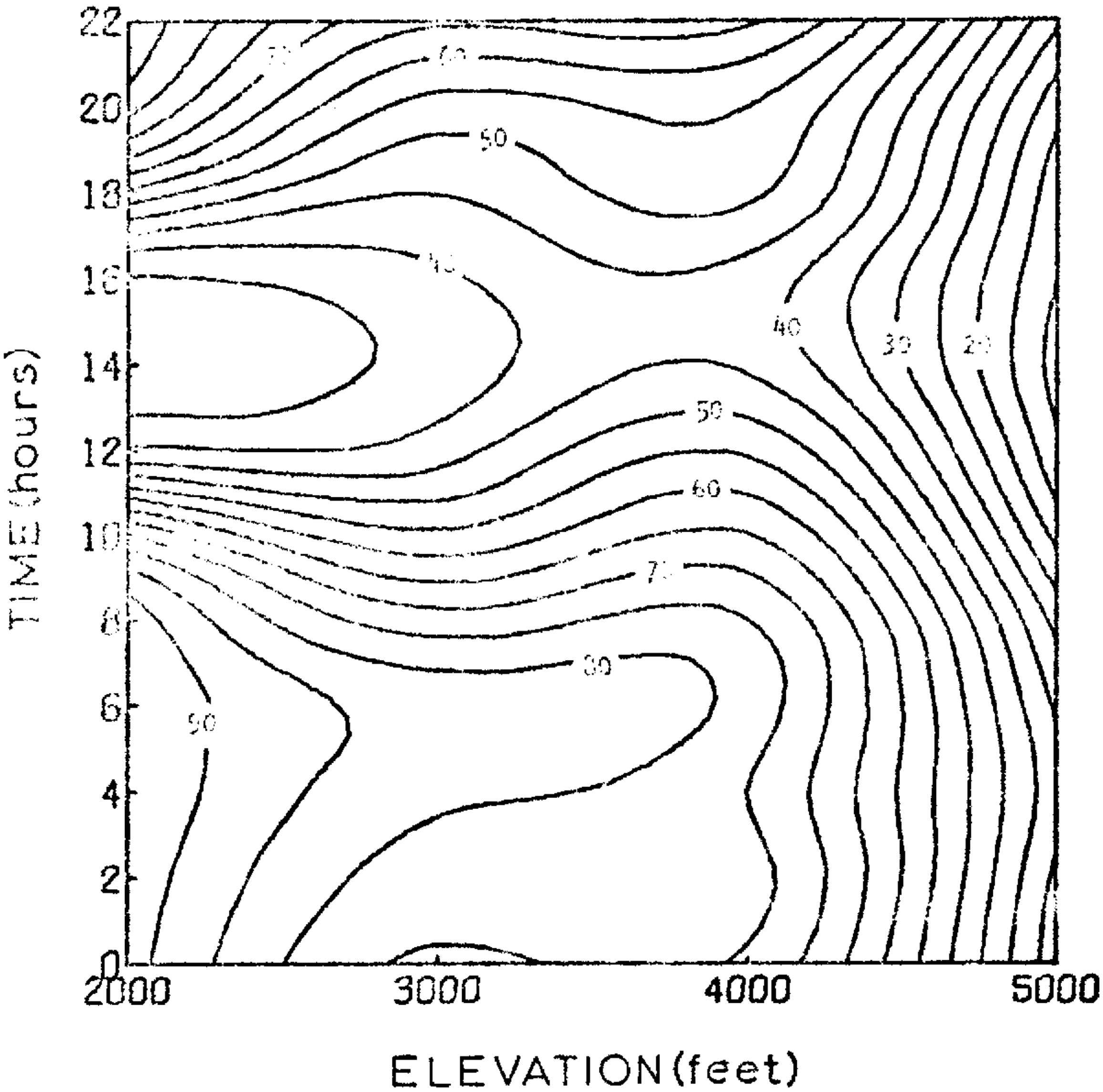

Figure 37. Relative humidity (%) from 22 July - 5 August 1972 on East Desolation.

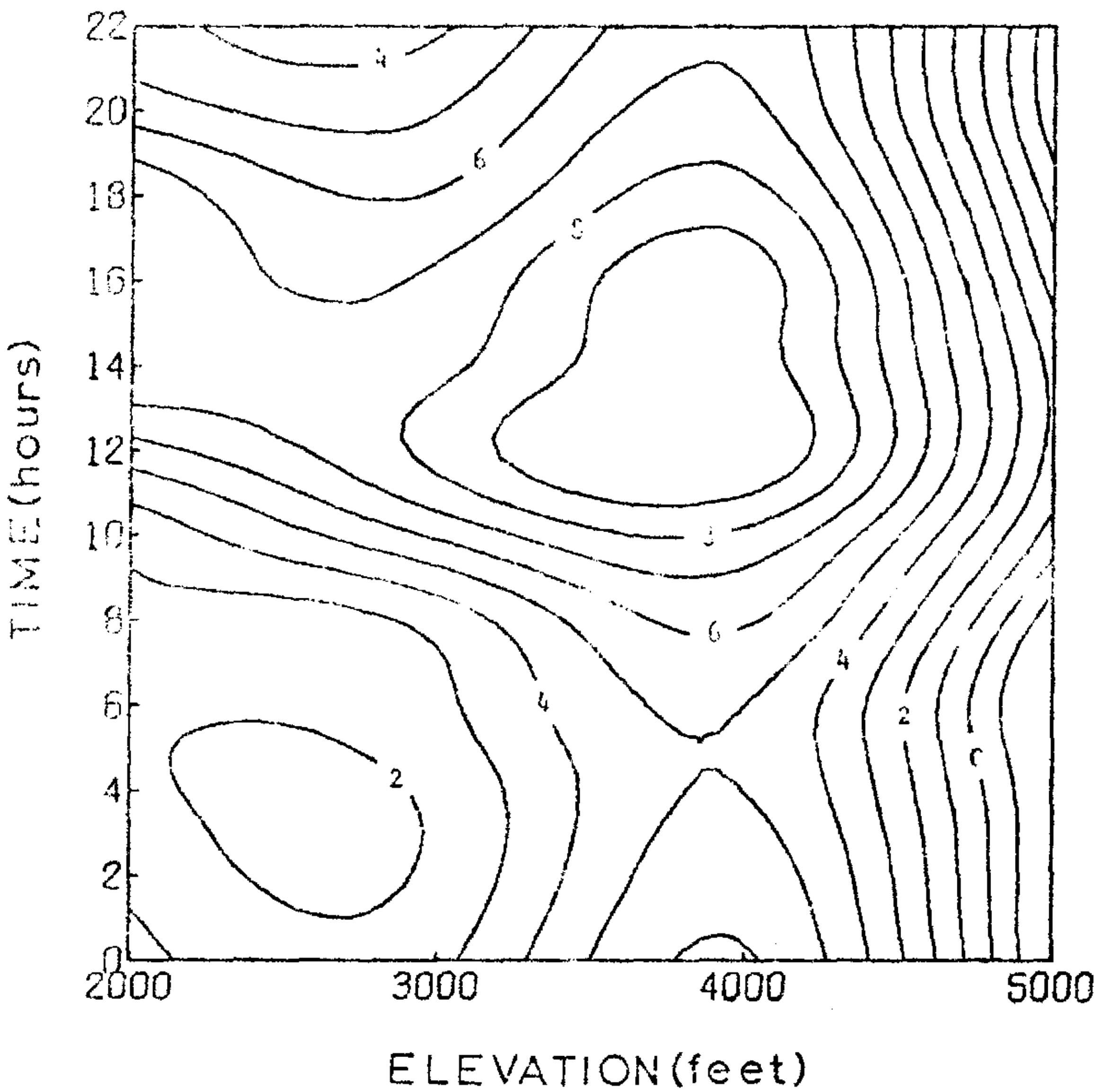

Figure 38. Isotherms (°C) from 15-30 September 1972 on East Desolation.

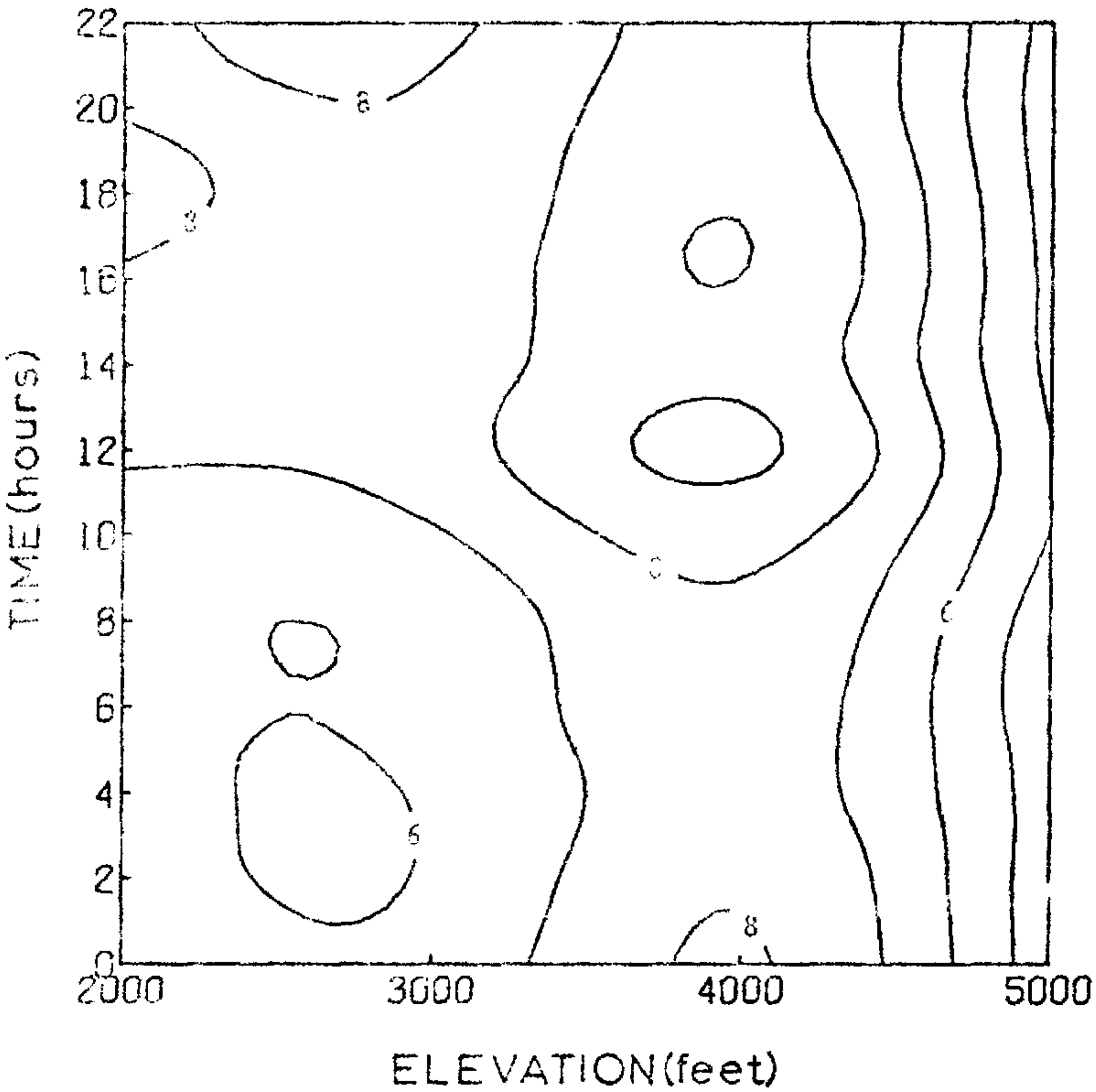

Figure 39. Vapor pressure (mb) from 15-30 September 1972 on East Desolation.

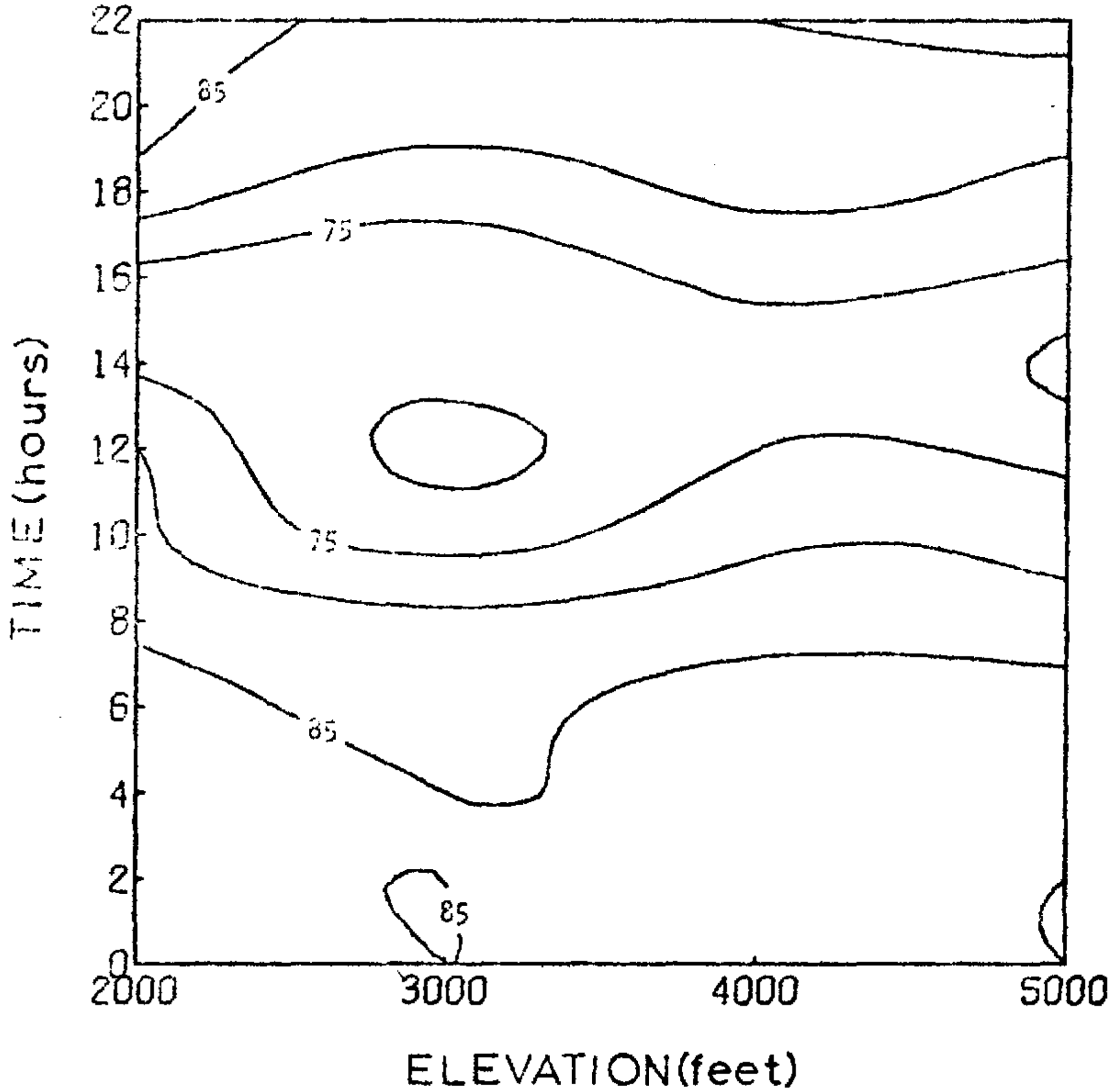

Figure 40. Relative humidity (%) from 15-30 September 1972 on East Desolation.

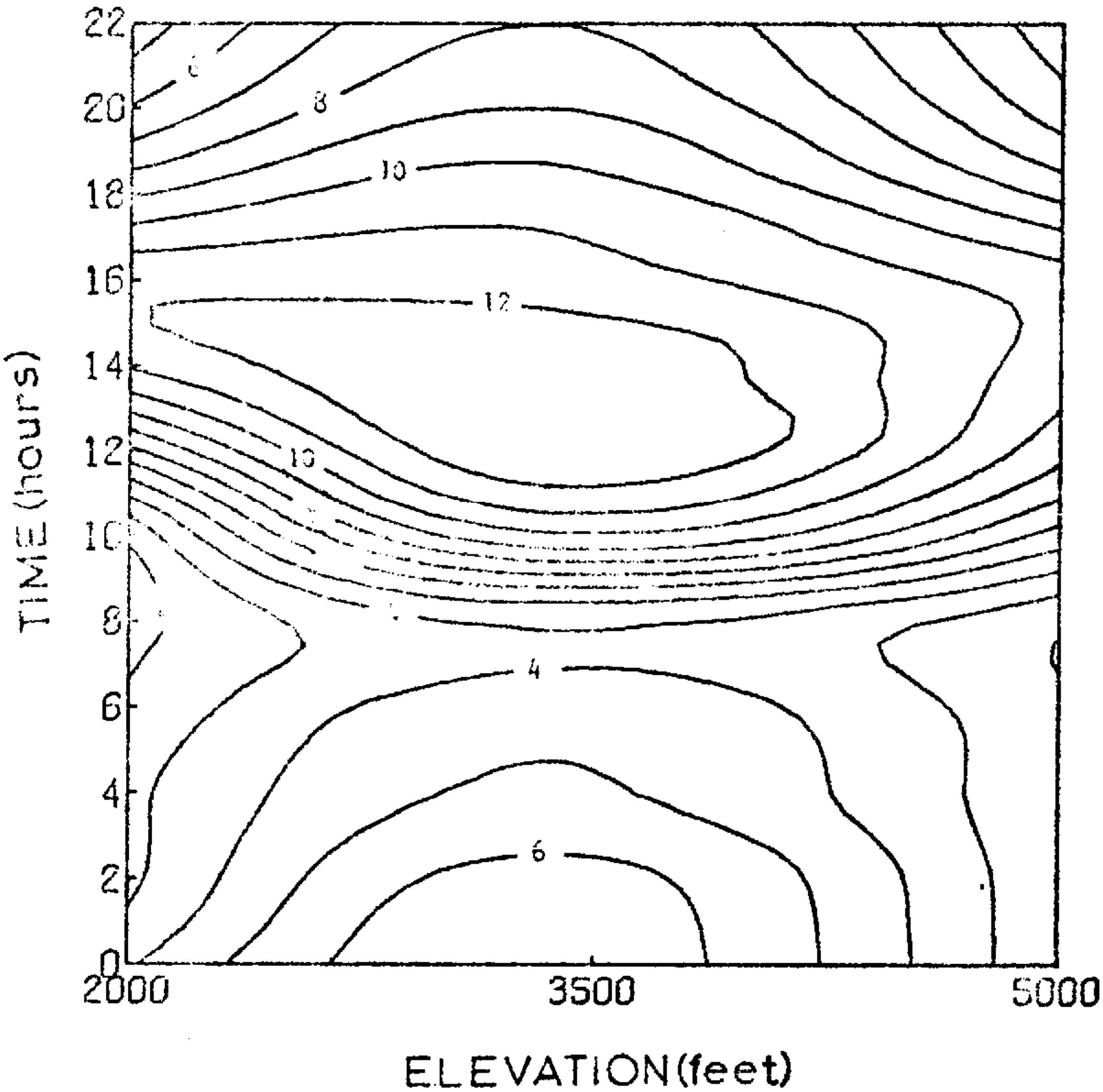

Figure 41. Isotherms (°C) from 1-8 October 1972 on East Desolation.

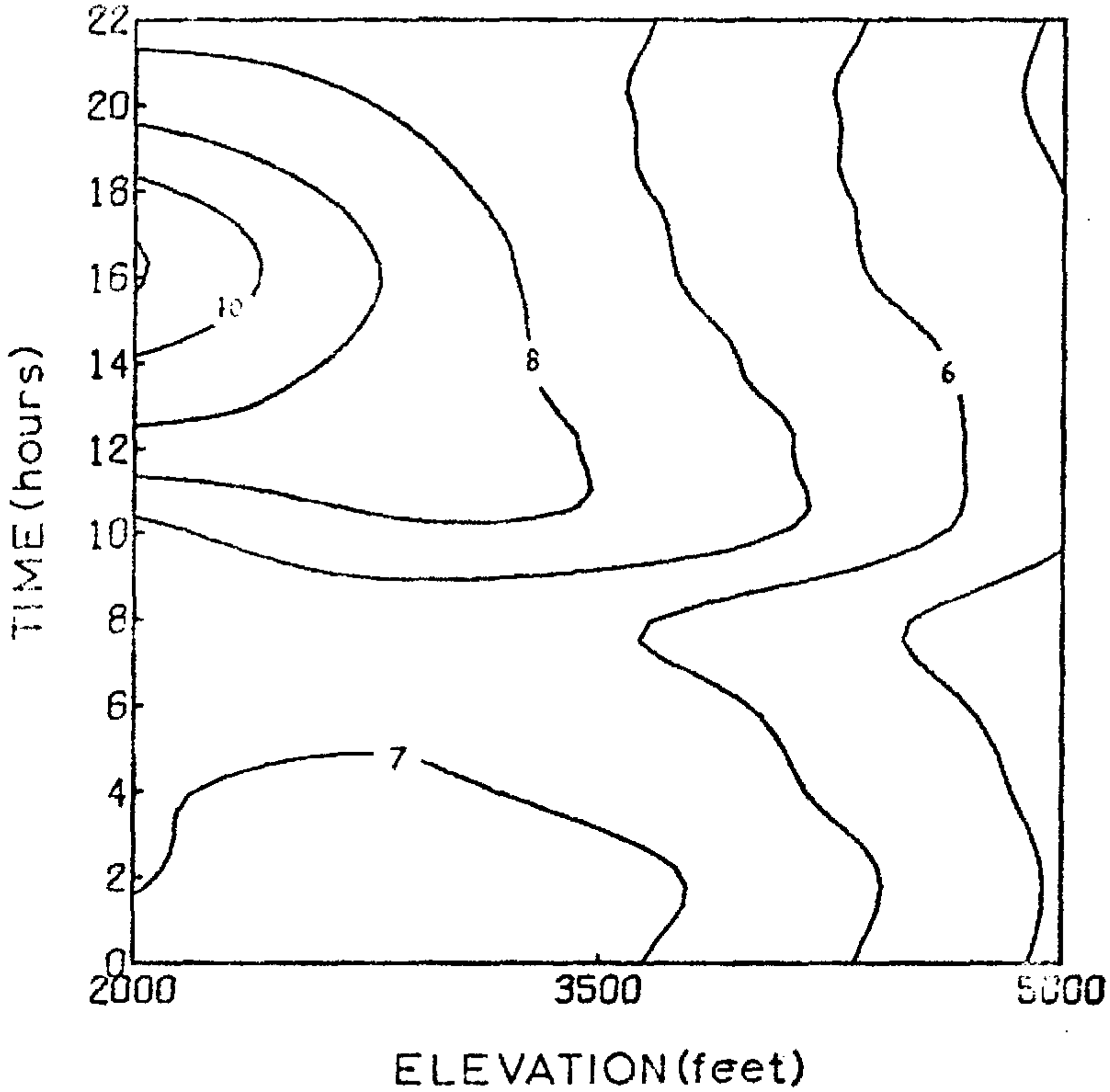

Figure 42. Vapor pressure (mb) from 1-8 October 1972 on East Desolation.

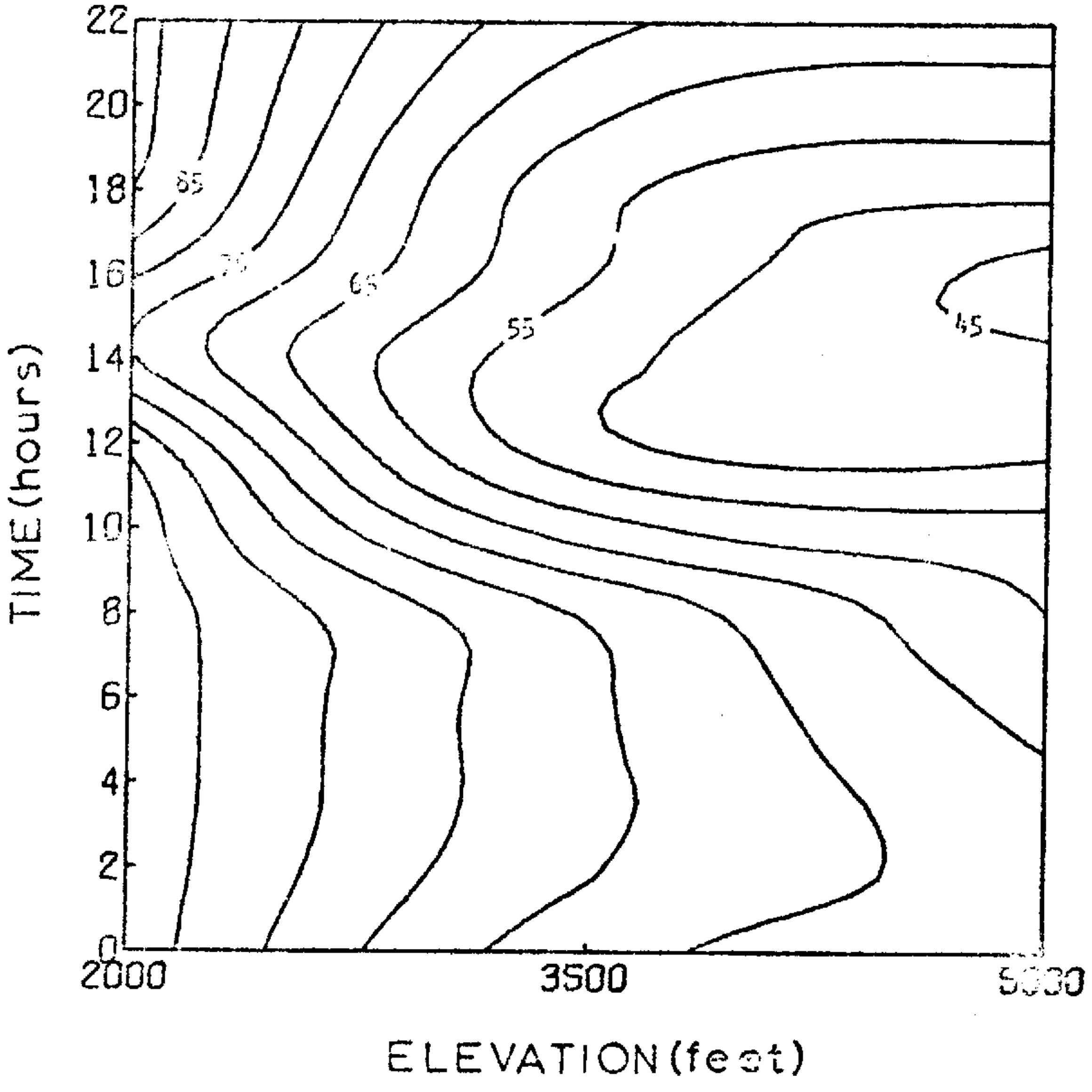

Figure 43. Relative humidity (%) from 1-8 October 1972 on East Desolation.

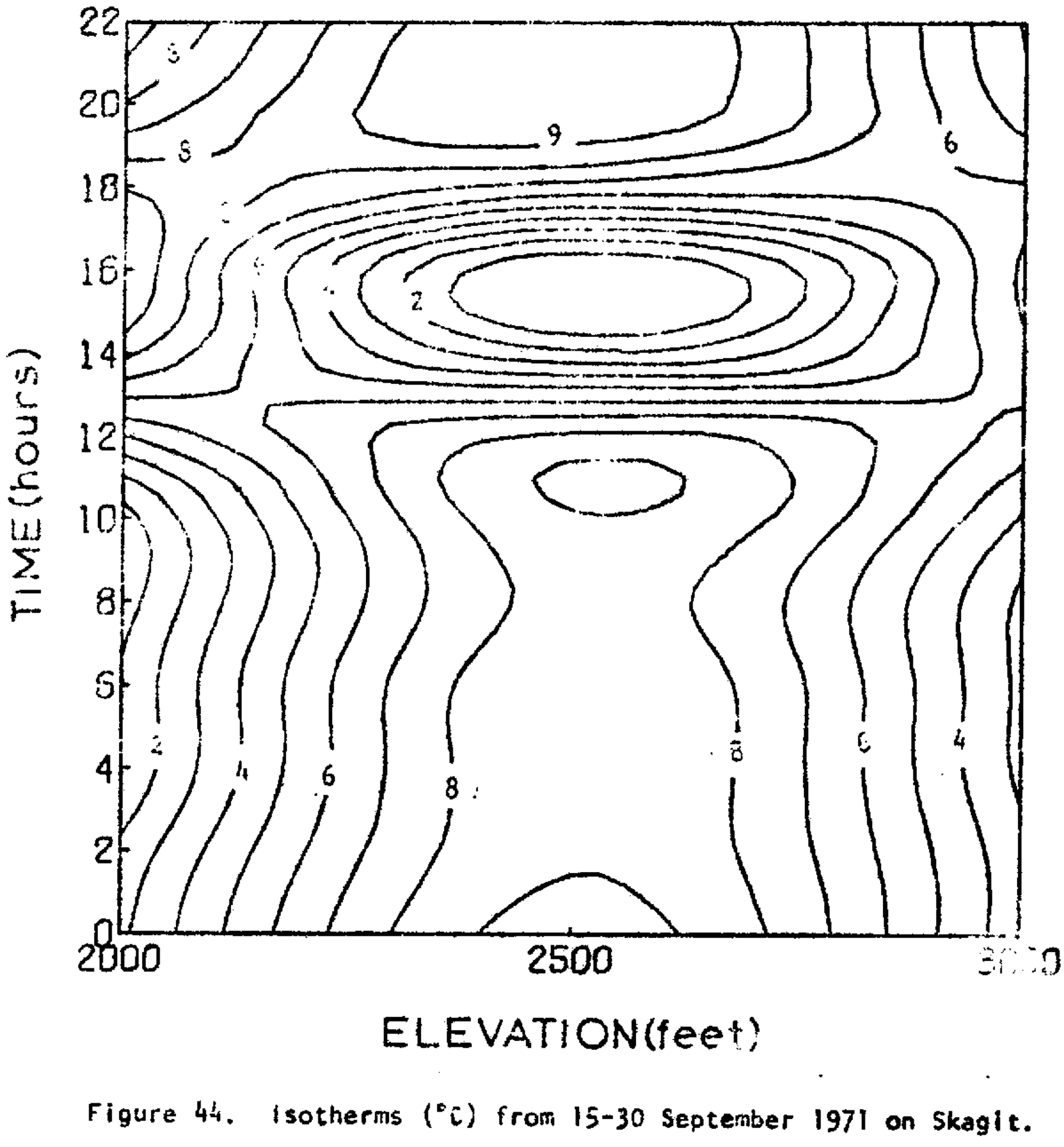

Figure 44. Isotherms (°C) from 15-30 September 1971 on Skagit.

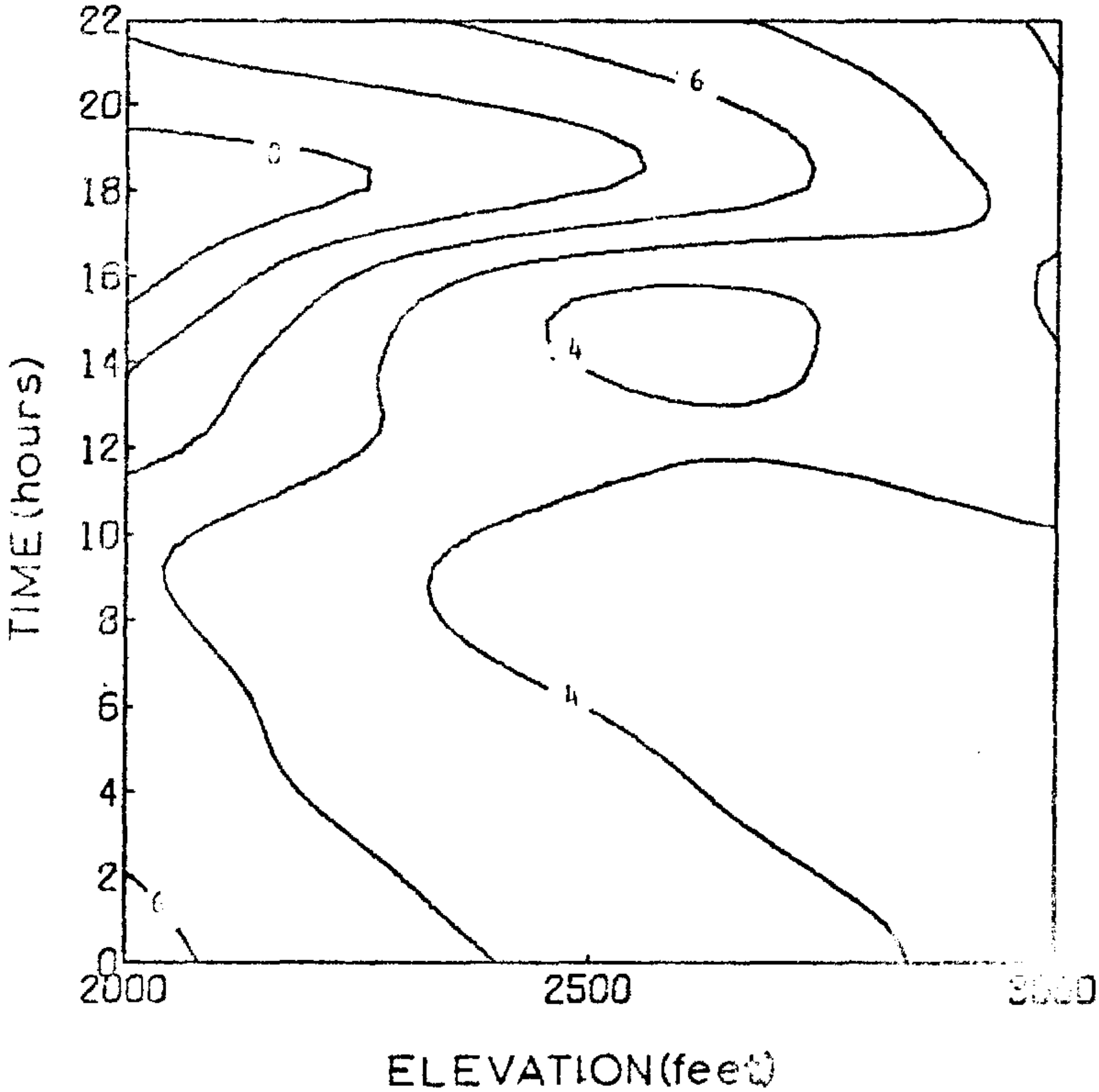

Figure 45. Vapor pressure (mb) from 15-30 September 1971 on Skagit.

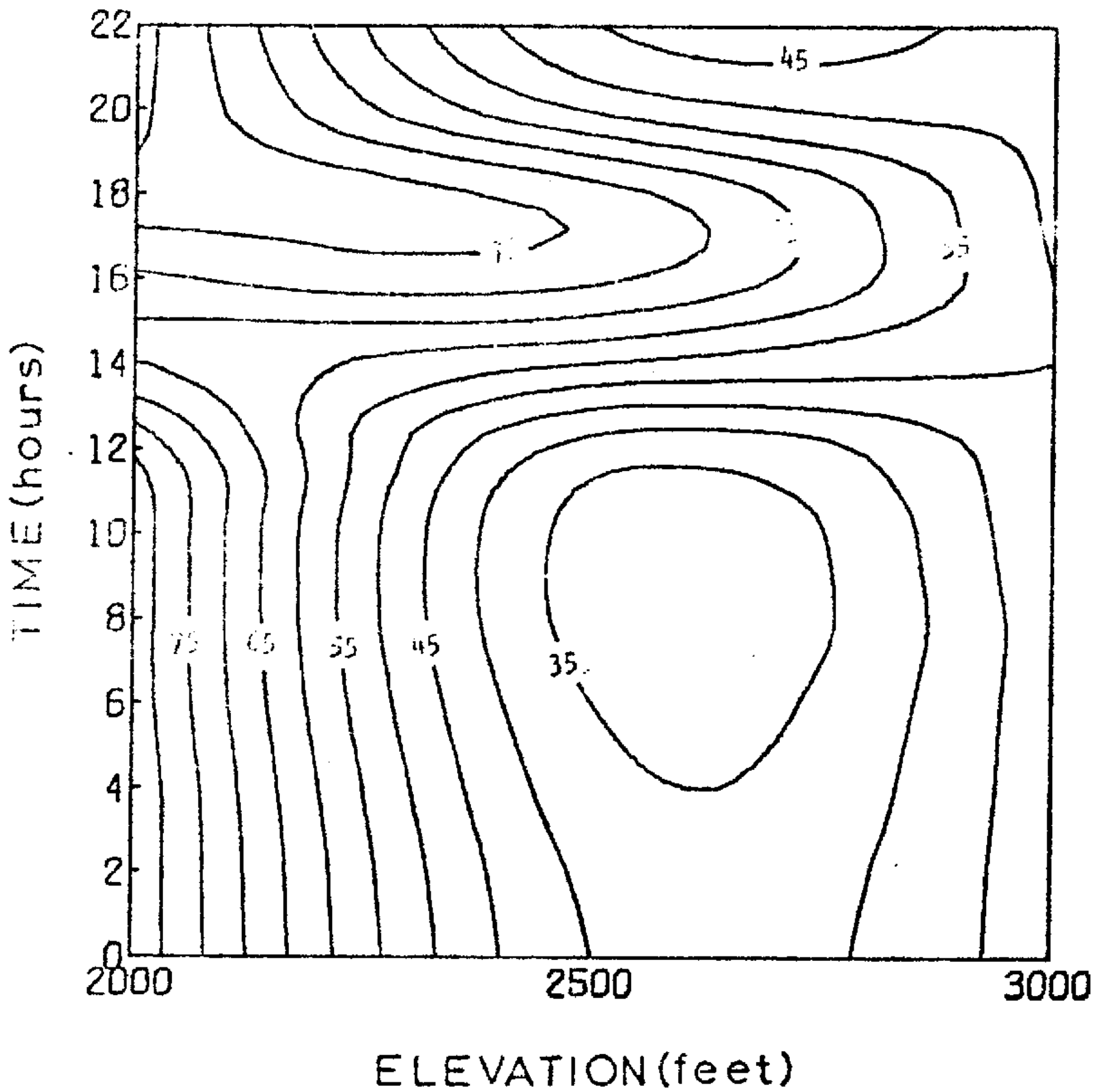

Figure 46. Relative humidity (%) from 15-30 September 1971 on Skagit.

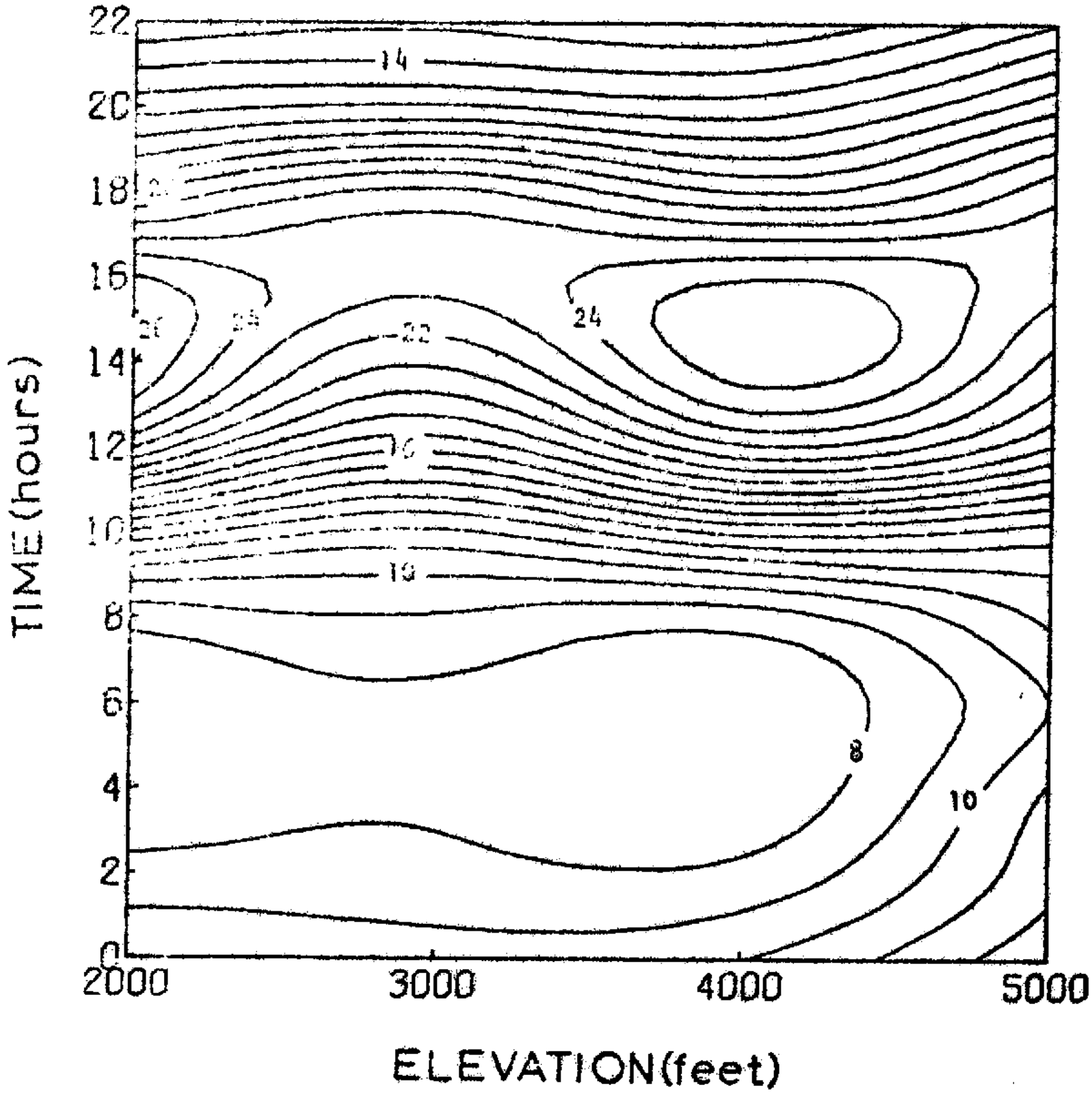

Figure 47. Isotherms (°C) from 22 July - 5 August 1972 on Skagit.

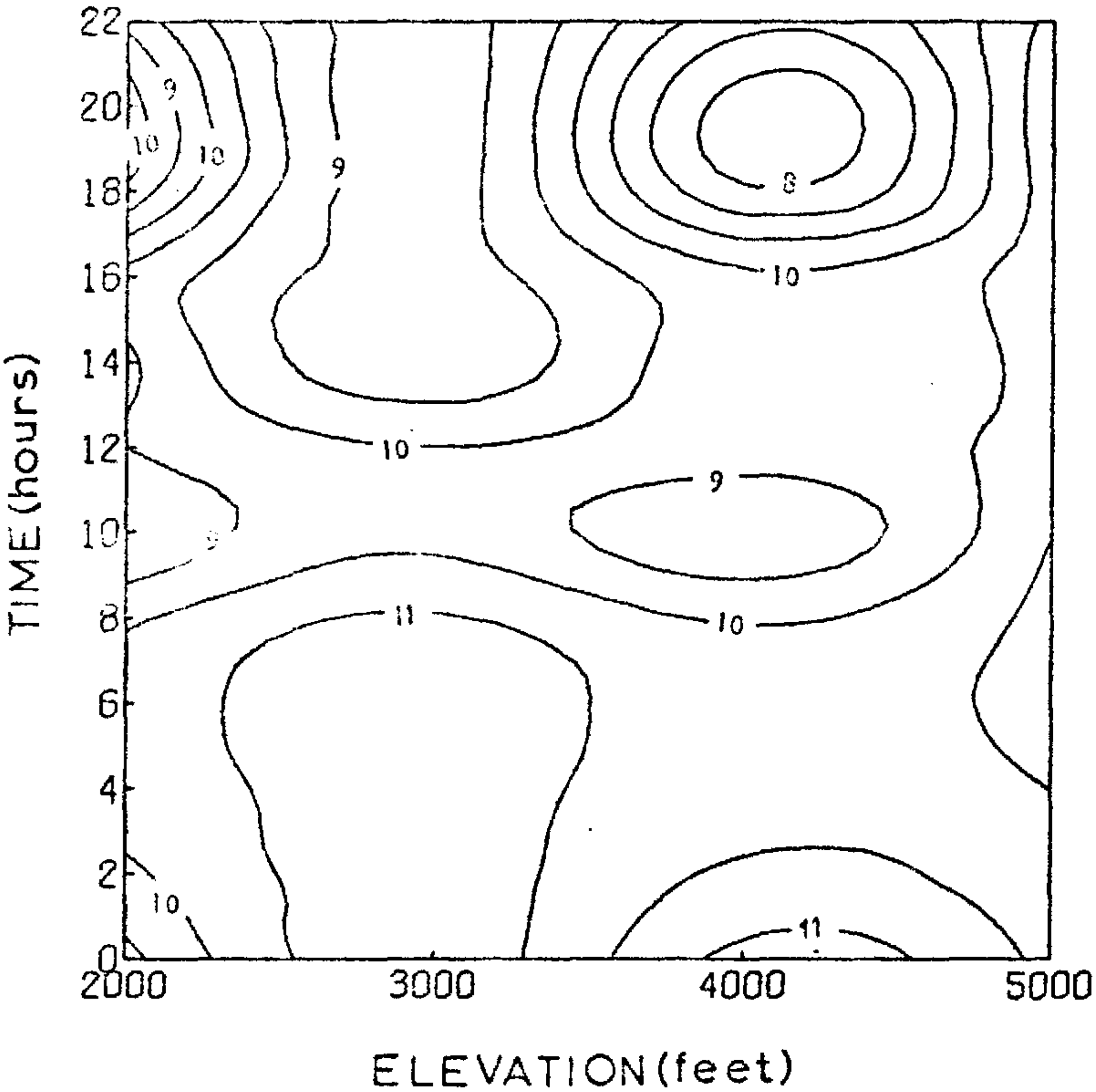

Figure 48. Vapor pressure (mb) from 22 July - 5 August 1972 on Skagit.

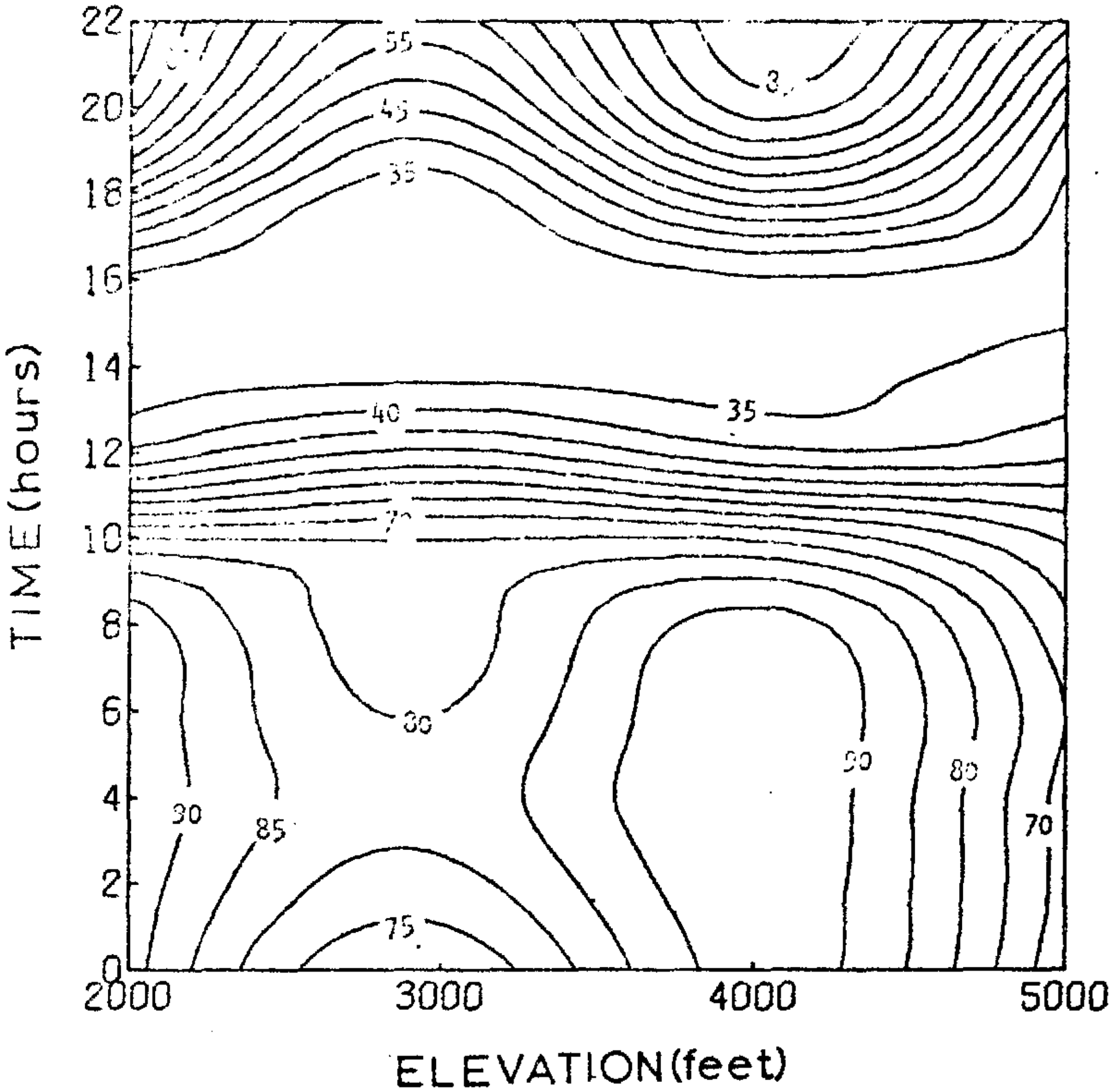

Figure 49. Relative humidity (%) from 22 July - 5 August 1972 on Skagit.

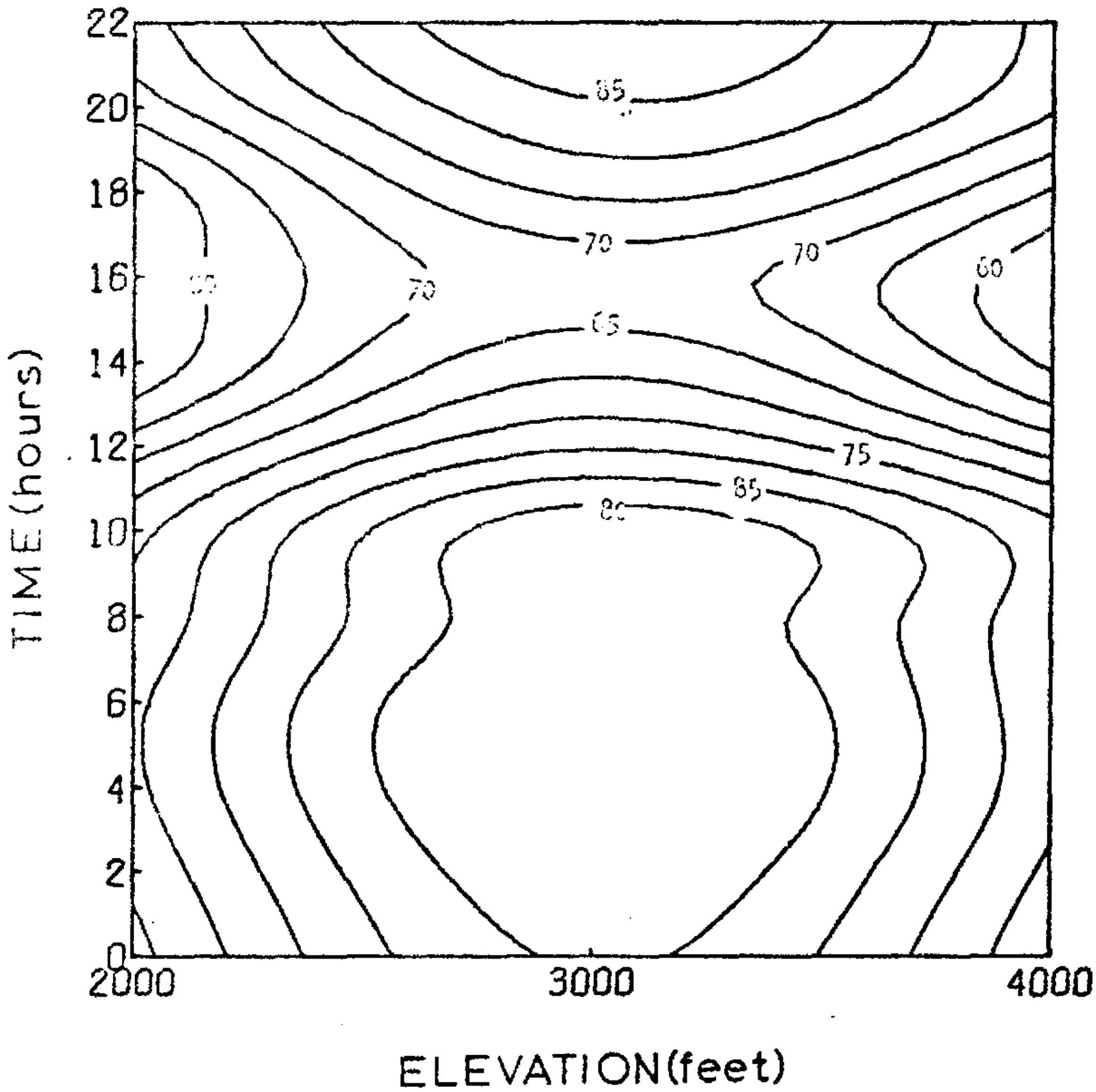

Figure 50. Isotherms (°C) from 15-30 September 1972 on Skagit.

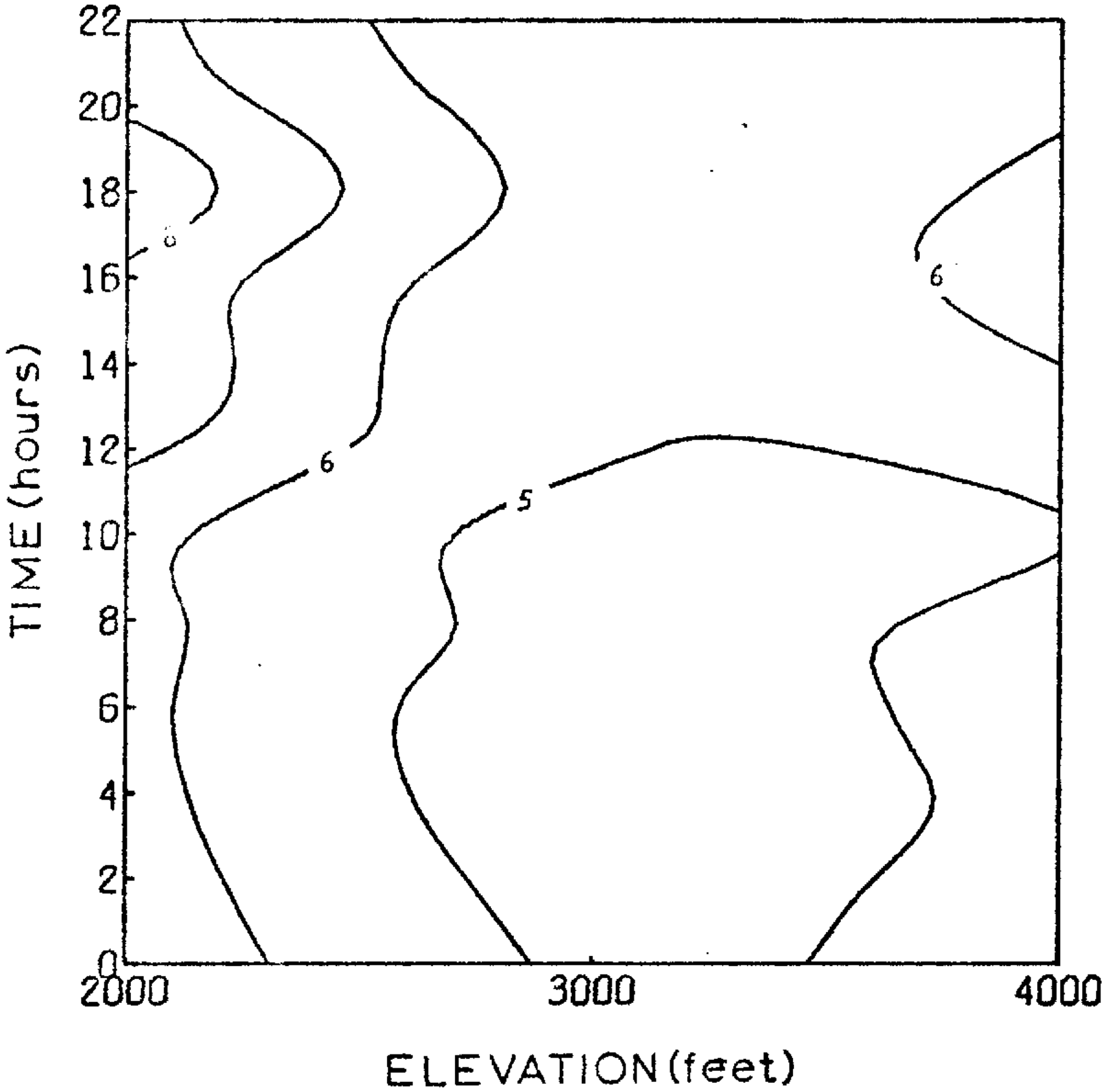

Figure 51. Vapor pressure (mb) from 15-30 September 1972 on Skagit.

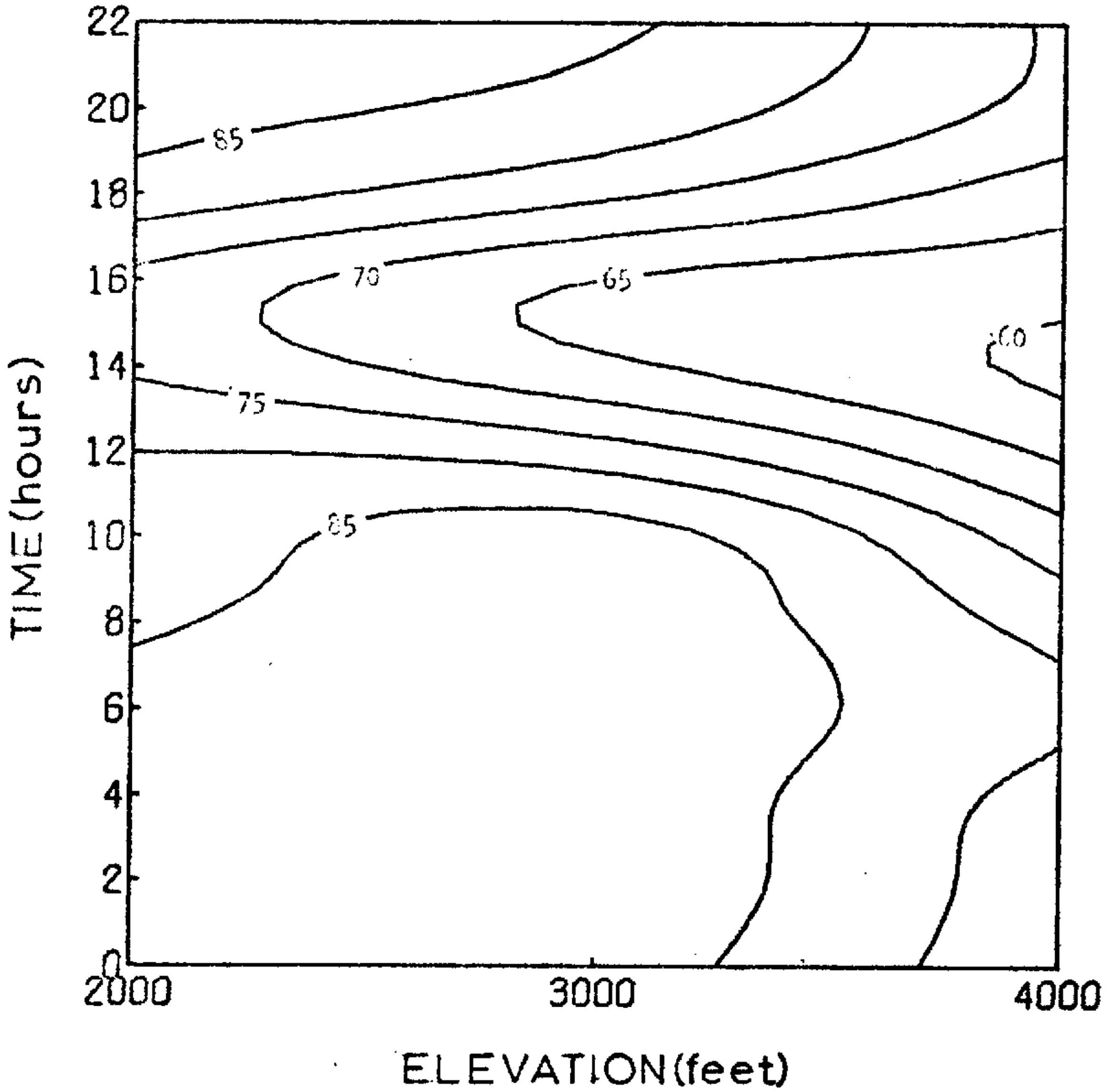

Figure 52. Relative humidity (%) from 15-30 September 1972 on Skagit.

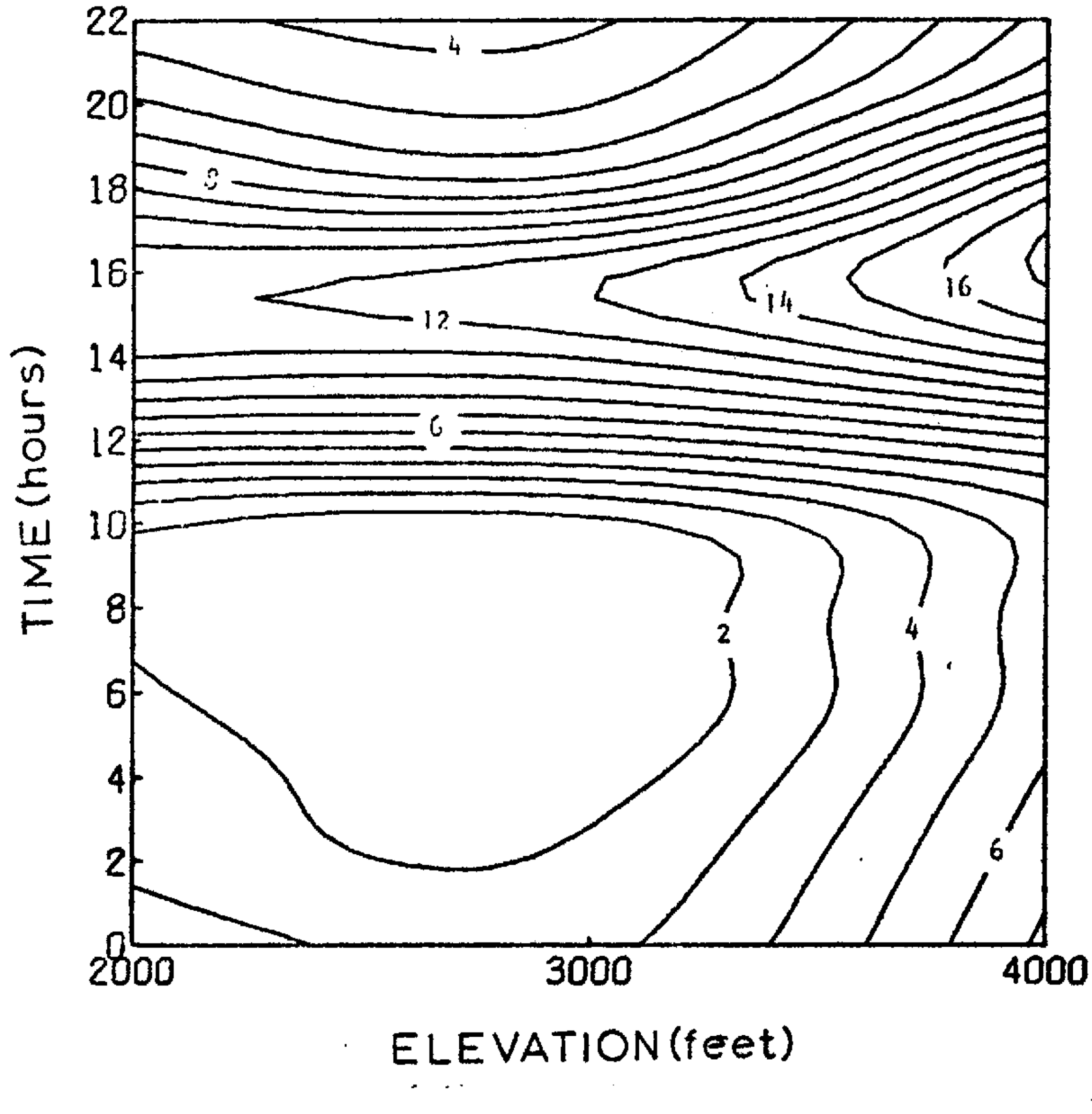

Figure 53. Isotherms (°C) from 1-8 October 1972 on Skagit.

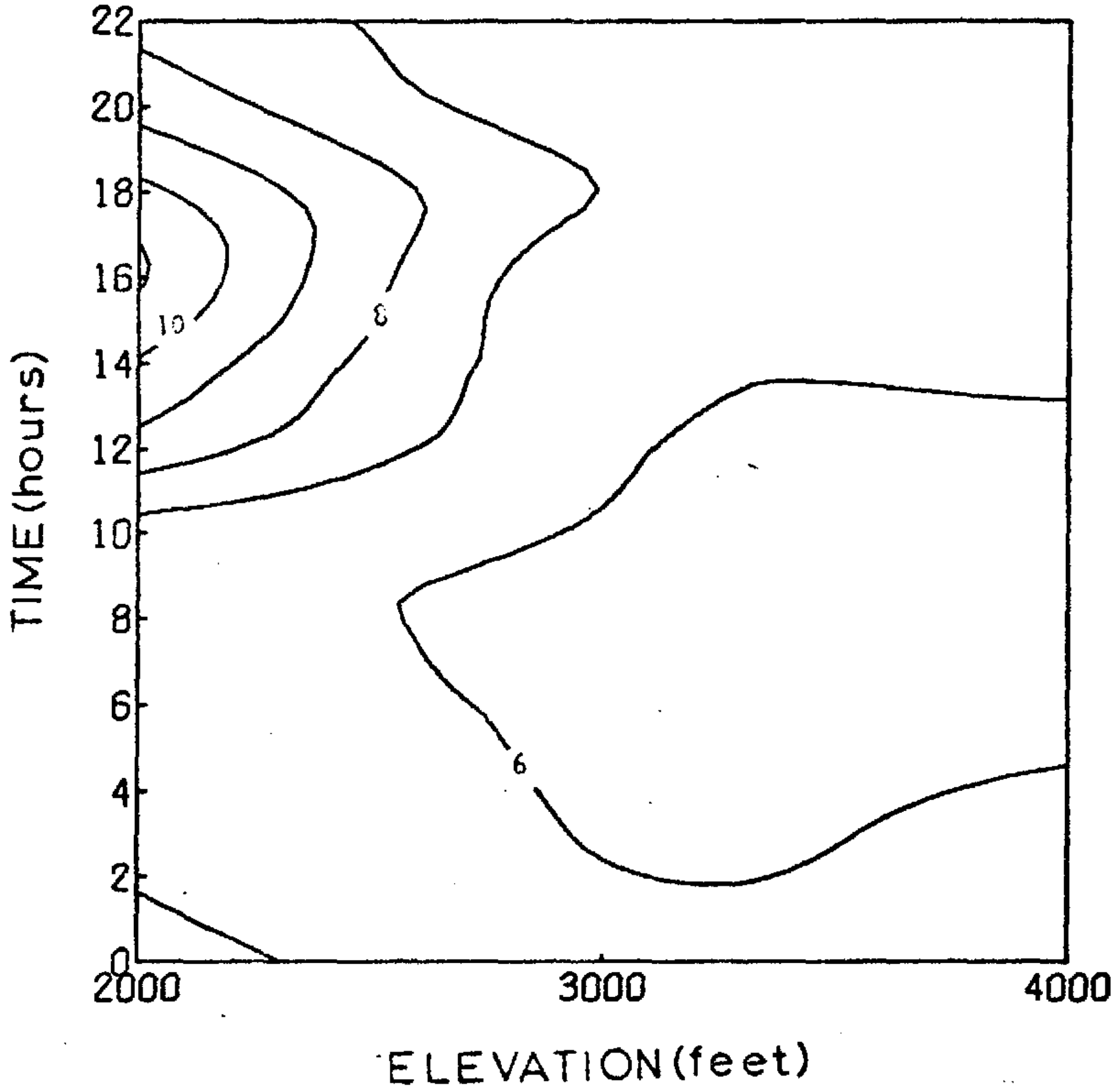

Figure 54. Vapor pressure (mb) from 1-8 October 1972 on Skagit.

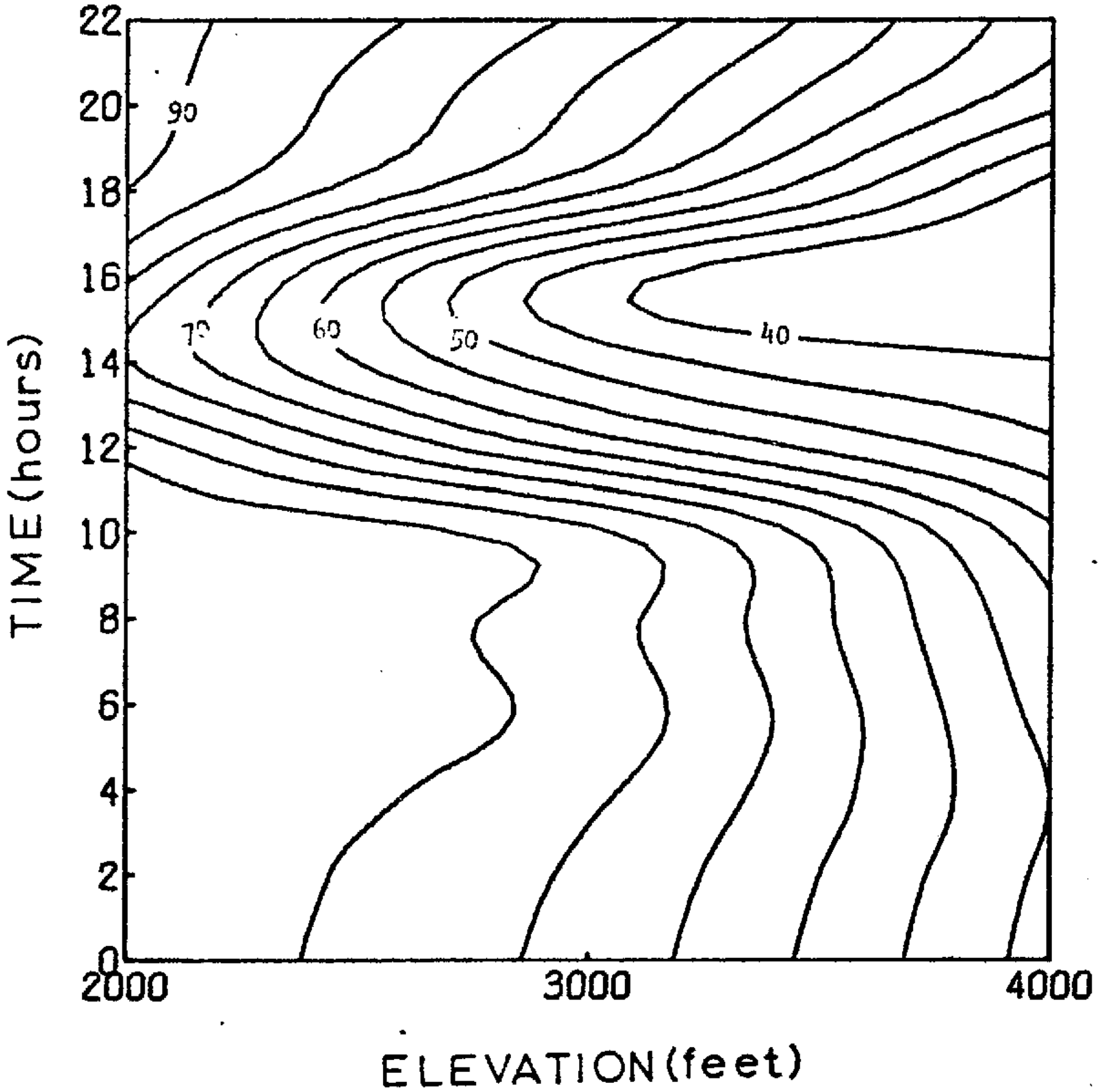

Figure 55. Relative humidity (%) from 1-8 October 1972 on Skagit.

APPENDIX E: BIRDS OF ROSS LAKE BASIN

(A Revision of 1971 Appendix H)

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Seattle, Washington

January, 1973

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INTRODUCTION

Over the past two year study period a sighting record has been accumulated on the birds occurring in the Ross Lake Basin. A species list is included within this Appendix. In most cases a rise in the lake level will flood only a minor portion of their total range, but in the case of a few lowland species a rise in the lake will largely eliminate them as breeding birds from the shores of Ross Lake.

METHODS

Most identifications were made with binoculars and other optical aids. On occasion, specimens were collected for laboratory identification, usually when field identification was questionable. In several instances, photographs were taken in an effort to substantiate sightings (e.g., Common Merganser, Eared Grebe).

Secondarily, an attempt was made to intensively cover certain selected areas of Ross Lake rather than superficially examine the entire area. Since more bird species are found in complex habitats than in simple ones, areas such as Lightning Creek, Dry Creek Point, Skymo Brushfield, Ruby Horse Pasture, and Desolation and Pumpkin Mountains were covered more intensively than areas such as Roland Bay, Ruby Point, and Boundary Bay.

Waterfowl and other aquatically oriented bird species were observed as we came upon them. Since the study team traveled frequently by boat, Ross Lake received daily coverage for observation of water birds.

Standard references for field identification were Robbins et al. (1966), Peterson (1969), and Pough (1951). Laboratory identification of collected species was with Blair et al. (1957). Detailed life history information came from Gabrielson and Jewett (1940), A.C. Bent series, and Larrison and Sonnenberg (1968).

Species were not listed unless identifications were positive. Questionable identifications were mentioned in field notes for future reference, but, in most cases, further intensive investigations either confirmed or denied a species' presence. In this manner, species such as Myrtle Warbler, Blue-winged Teal, Western Kingbird, and Pomarine Jaegar became positive identifications. Unconfirmed species are listed at the end.

RESULTS AND DISCUSSION

At the end of the two-year study, in November 1972, 132 avian species were positively identified as occurring on the American side of Ross Lake. Certain trends may be noted.

First, Ross Lake is not particularly attractive for waterfowl and diving birds. With the exception of the Common Loon and Western Grebe, the lake is too deep for most divers while, because of the drawdown and the resultant lack of aquatic vegetation in the shallow areas, there is little food for dabblers. Most water bird sightings were of individuals which probably use the lake for resting only. Exceptions to this tendency are Big Beaver Valley and isolated points around the lake. Nesting waterfowl were observed by Miller and Miller (1971) in Big Beaver Valley and by the study group in Boundary Bay and Dry Creek Point.

Second, as discussed by Odum (1971), species diversity is proportional to habitat diversity. Taken as a whole, Ross Lake is basically a monotypic sub-climax Douglas-fir association which is generally "upland" (Humid Transition Zone). However, within the basin, there are several pockets of residual riparian (mesic hardwood) types normally associated with "lowland" habitats. The plant communities of these pockets are characterized by Birch, Black Cottonwood, Alder, Vine Maple, Cherry, Willows, and in the marsh areas, Sedges. In terms of avian species diversity, these pockets are extremely productive, especially where other habitat types converge (such as Dry Creek Point/Bay which is possibly the most diverse area in the basin, closely followed by Big Beaver Valley). Species characteristic of these moist areas include Ruffed Grouse, Band-tailed Pigeon, Hairy Woodpecker, Traill's Flycatcher, Stellar's Jay, Chestnut-backed Chickadee, Orange-crowned Warbler, Western Kingbird, Yellow Warbler, Black-throated Gray Warbler, Song Sparrow, and Warbling Vireo. The areas in which this biotic community is found include Big Beaver Valley (3,600 acres), Hozameen (American side, 300 acres), Dry Creek Point/Bay (60 acres), Lightning Creek Campground (10 acres), Little Beaver (5 acres), and Silver Creek (10 acres) for a total of 4,065 acres. All of this acreage lies below 1725 feet elevation and, for this reason, we believe that if Ross Lake is raised, the basin will largely lose this lowland biotic element. Therefore, the following species will probably no longer be found breeding around the lake: Traill's Flycatcher, Chestnut-backed Chickadee, Orange-crowned Warbler, Western Kingbird, Yellow Warbler, Black-throated Gray Warbler, Song Sparrow, Warbling Vireo, and Downy Woodpecker.

Other areas of relatively high diversity in both plant and bird species include Hozameen area, Jack Point, west Desolation Mountain, Lightning Creek to south Desolation Mountain, Lightning Creek Campground, Skymo brushfield, Pumpkin Mountain (southwest brushfield), and Ruby Horse Pasture. Areas of lower diversity include Silver Creek, Boundary Bay, May Creek--Rainbow Point, Roland Point/Bay, and behind Cougar Island.

Third, Ross Lake apparently is not part of major migration routes. While spring migration is occurring in other areas of the Pacific Northwest in March and April, Ross Lake is still enjoying winter. In Cedar River watershed of the City of Seattle, at the end of April 1972, most deciduous plants were well into the leaf stage (as long as 1 1/2 inches) while, at Ross Lake, spring buds were only just popping and many patches of snow at lake level were still evident. Most spring migratory birds sighted were either summer residents or late migrants. In a similar manner, fall migration at Ross Lake is minimal. Snow fell on the lake in September and October 1972 when, in Seattle, the birds were only just beginning to flock.

Of the resident birds, Ruffed Grouse, which is a lowland species, will be strongly affected through flooding of the streambottom habitat. Observations have shown that the Ruffed Grouse tend to occur along the lakeshore at all times of the year, but they are found above as well as below the 1725-foot level. Several flush-censuses in June, July, and August along the Lightning Creek--Dry Creek Point trail produced a maximum of two birds per trip with most trips producing only one or none. Assuming a flush distance of 50 feet on either side of the two-mile trail, this would calculate to a maximum estimated density of one grouse per 12.1 acres for summer 1972. This is in contrast with one per two acres in prime grouse habitat in upper New York State (Bump, et al., 1947). In general, the Ruffed Grouse of Ross Lake probably occupies habitat no further back than

1/2 mile from the lake (the maximum distance our group found grouse on the east shore). For waterfowl, it will be difficult to compensate for the loss of Big Beaver Valley where the highest number of nesting aquatic birds occur. Two possibilities for mitigation might be considered: (1) withholding (in lieu of cutting) many large trees at or just below the new high water mark in Big Beaver Valley to be utilized as nesting snags after the rising water drowns them; and (2) construction of small retainer ponds just above high water (1725 feet) at the juncture of the many small streams draining into Big Beaver. These ponds, when vegetated, could be utilized by the ground-nesting waterfowl.

BIRDS BY SPECIES

The following is an annotated species list.

Explanation of codes used in list:

I. Occurrence--use of Ross Lake as determined by observation:

MS	Spring Migrant
MF	Fall Migrant
MSF	Spring and Fall Migrant
RW	Winter Resident
RSn	Summer Resident, presumed or proven to nest at Ross
RSu	Summer Resident, nesting status unknown or in doubt
NM	Non-migratory (permanent) resident, as opposed to species in which different populations occur as summer and winter residents
RWS	Resident in winter and summer
W	Wanderer, casual out of its normal range or habitat
U	Status unknown

II. Relative Sighting Index

1. Very common. May be sighted almost daily during its season.

2. Common. Regular observations, but not as common as #1.

3. Occasional. Regular, but infrequent sightings (usually less than 15 sight records during the two-year study).

4. Uncommon. Irregular and infrequent observations, but not a rare nor unexpected bird.

5. Rare and unexpected. Only one to three sight records. Not meant to imply a rare and endangered bird, just that it does not normally occur at Ross Lake.

Annotated Bird List--Ross Lake, Whatcom County, Washington

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index
Common Loon	Gavia immer	MSF,RWSn	2

Observed on all sections of the lake; juveniles observed in fall; possibly two nesting pairs.

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index
Horned Grebe	Podiceps auritus	MF?	5

Small flock (seven birds) observed on south end of lake in early October 1972.

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index
Eared Grebe	Podiceps caspicus	W	5

Single individual observed for several days in late June near Lightning Creek.

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index
Western Grebe	Aechmophorus occidentalis	W,MSF	2

Single birds and small flocks sighted in Fall, Spring, and, less frequently, singly in the Summer.

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index
Green Heron	Butorides virescens	U	5

Single individual identified in Big Beaver Valley in October 1971.

Annotated Bird List--Ross Lake, Whatcom County, Washington

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index
Whistling Swan	Olor columbianus	U	5

Two adults and two juveniles observed from a short distance near Cougar Island in late October 1972.

Canada Goose	Branta canadensis	MSF	4

Although a few sightings, Ross Lake is not a major resting area for geese.

Mallard	Anas platyrhynchos	RSn	3

At least two nesting pairs, probably more.

Pintail	Anas acuta	MSF	4

Occasional migrants sighted, mostly on the southern half of the lake.

Blue-winged Teal	Anas discors	U	4

Infrequent sightings of individuals and pairs in protected bays in central part of lake.

Shoveler	Spatula clypeata	U	4

Five birds sighted in flight near Big Beaver in July 1971.

Redhead	Aythya americana	W	5

One pair observed near Dry Creek Point in May, 1972.

Greater Scaup	Aythya marila	MS	4

Several late spring sightings on various parts of the Lake.

Lesser Scaup	Aythya affinis	MS	4

A couple sightings on the southern part of the lake.

Common Goldeneye	Bucephala clangula	U	4

Winter and early spring sightings; possibly, they were blown in on storms.

Annotated Bird List--Ross Lake, Whatcom County, Washington

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index
Barrow's Goldeneye	Bucephala islandica	MSF,RWSn	3
Nesting on Willow Lake SE of Hozameen; several small flocks (10-15 birds) observed in winter on northern end of lake.			
Bufflehead	Bucephala albeola	RW,MSF	2
Probably the most common waterfowl in winter.			
Oldsquaw	Clangula hyemalis	MS	4
Several small flocks (5-6 birds) sighted in southern end of lake.			
Harlequin Duck	Histrionicus histrionicus	RSu	4
A few sighted up Ruby Arm in summer; possible nester.			
White-winged Scoter	Melanitta deglandi	MSF,W	2
Medium-sized flocks (10-30 birds) observed from May to September. Apparently not a resident.			
Hooded Merganser	Lophodytes cucullatus	RSn	3
Observed by Millers (1971) in Big Beaver Valley.			
Common Merganser	Mergus merganser	U	4
Several birds sighted on northern and southern parts of lake in 1971; none observed in 1972; dead duckling found at mouth of Big Beaver in summer 1972. (Evidence of breeding)			
Red-breasted Merganser	Mergus serrator	U	5
Single bird observed near Lightning Creek in early October, 1972. Only known sighting.			
Goshawk	Accipiter gentilis	RSn	3
Several individuals sighted in late spring and early summer. Fledglings sighted in summer 1971.			

Annotated Bird List--Ross Lake, Whatcom County, Washington

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index
Sharp-shinned Hawk	*Accipiter striatus*	RSu	4

A few observations made at higher elevations (above 4000 feet in vicinity of Desolation Mountain.

Cooper's Hawk	*Accipiter cooperii*	RSu	4

Sightings at higher elevations on Pumpkin and Desolation Mountains.

Red-tailed Hawk	*Buteo jamaicensis*	RSn	2

Many sightings along lake, mostly on east shore in central part; nest on Dry Creek Point.

Swainson's Hawk	*Buteo swainsoni*	RSu	4

A few high elevation sightings in vicinity of Desolation Mountain.

Golden Eagle	*Aquila chrysaetos*	MSF,RSu	3

Observed near lake level in spring and fall; at higher elevations in summer.

Bald Eagle	*Haliaeetus leucocephalus*	MSF,W	3

Observed year around; probably wanders north from nearby Skagit River, a major wintering area.

Marsh Hawk	*Circus cyaneus*	U	5

Single sighting in Big Beaver Valley in summer 1972.

Osprey	*Pandion haliaetus*	RSu	3

Sighted several times near lake; on two occasions, was observed making a kill from lake.

Peregrine Falcon	*Falco peregrinus*	RSu	5

Three positive sightings of this rare and endangered bird in vicinity of Desolation Mountain.

Annotated Bird List--Ross Lake, Whatcom County, Washington

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index
Pigeon Hawk	Falco columbarius	RSn	4
Several sightings near lake and in higher elevations; fledglings observed in 1971.			
Sparrow Hawk	Falco sparverius	RSn	2
Probably the most common Falconiform in the area; sighted in all areas.			
Blue Grouse	Dendragapus obscurus	NM	2
Ubiquitous at all elevations. Probably most common Galliform.			
Spruce Grouse	Canachites canadensis	NM	5
Two sightings only on Desolation and Little Jack Mountains at high elevations.			
Ruffed Grouse	Bonasa umbelius	NM	3
Frequent sightings in brush areas and dense understory of forests near lake level. None at higher elevations. Probably a sustaining populations.			
White-tailed Ptarmigan	Lagopus leucurus	NM	4
In alpine and sub-alpine areas year around.			
Killdeer	Charadrius vociferus	RSn	2
Sighted in several areas next to lake. Have the unfortunate habit of nesting in the drawdown during spring melt.			
Common Snipe	Capella gallinago	U	5
Single individual bird sighted near mouth of Big Beaver in early May; only sighting record known.			
Spotted Sandpiper	Actitis macularia	RSn	4
Common around the creek mouths on east side of lake.			

Annotated Bird List--Ross Lake, Whatcom County, Washington

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index
Pomarine Jaeger	Stercorarius pomarinus	W	5
Probably the most unusual bird sighted at Ross Lake; single individual observed repeatedly 17-19 September 1972 near Cougar Island.			
Glaucous-winged Gull	Larus glaucescens	W	4
Few sightings, but apparently a single resident bird near Hozomeen campground in summer 1972.			
California Gull	Larus californicus	W	3
Frequent sightings on south central part of lake in summer; probably not nesting.			
Ring-billed Gull	Larus delawarensis	W	3
Occasional adults and immatures sighted on southern half of lake in summer. Probably no nesting.			
Mew Gull	Larus canus	W	4
A few sightings in various sections around the lake in summer.			
Bonaparte's Gull	Larus philadelphia	W	3
Several small flocks (5-7 birds) sighted in spring and summer on southern half of the lake.			
Band-tailed Pigeon	Columba fasciata	RSu	2
Several large flocks (30-50 birds) observed around lake in spring and summer, particularly around Lightning Creek.			
Mourning Dove	Zenaidura macroura	RSu	[illegible]
Many sighted in small groups in late spring and early summer, mostly on the east side of the lake.			
Great Horned Owl	Bubo virginianus	[illegible]	[illegible]
Commonly heard in winter; adult and five fledglings observed in Big Beaver Valley in summer 1971.			

Annotated Bird List--Ross Lake, Whatcom County, Washington

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index
Pygmy Owl	*Glaucidium gnoma*	U	5

Single sight identification in April 1972 near Roland Point. Only known record.

Spotted Owl	*Strix occidentalis*	U	5

Single sight observation near May Creek in July 1972. No other record known.

Common Nighthawk	*Chordeiles minor*	RSn	2

Observed in most areas around the lake from lake level to elevation about 3000 feet.

Black Swift	*Cypseloides niger*	RSu	2

Many mixed flocks (with Vaux's Swift) of various sizes (up to 30 birds) over the north half of the lake.

Vaux's Swift	*Chaetura vauxi*	RSu	2

Somewhat more common than the Black Swift; observed mostly over water on the northern half of the lake, but also sighted frequently in small flocks on the southern half.

Rufous Hummingbird	*Selasphorus rufus*	RSn	1

Ubiquitous up to elevation about 4000 feet.

Calliope Hummingbird	*Stellula calliope*	RSn	3

Several sightings at higher elevations (usually above 2000 feet), especially on Desolation Mountain.

Belted Kingfisher	*Megaceryle alcyon*	RWSn	4

A few sightings in Lightning Creek and Big Beaver Valley.

Red-shafted Flicker	*Colaptes cafer*	NM	2

Many sightings in all areas around the lake, but they seem to be concentrated on the east side around Lightning Creek-Dry Creek Point area. Less common in winter.

Annotated Bird List--Ross Lake, Whatcom County, Washington

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index
Pileated Woodpecker	*Dryocopus pileatus*	NM	3
Elusive, but found in all areas of the basin.			
Lewis' Woodpecker	*Asyndesmus lewis*	U	5
One sighting near mouth of Big Beaver Valley in 1971.			
Yellow-bellied Sapsucker	*Sphyrapicus varius*	RSn	4
A few observations of both common and red-breasted subspecies in dense coniferous forest away from lake.			
Hairy Woodpecker	*Dendrocopos villosus*	NM	3
Observed in most areas of dense coniferous forest in the basin.			
Downy Woodpecker	*Dendrocopos pubescens*	NM	5
Two observations in two years, both near shoreline in dense forestation; probably an occasional wanderer.			
Northern Three-toed Woodpecker	*Picoides tridactylus*	U	5
Single specimen collected at Roland Bay in February 1972. Only observation.			
Western Kingbird	*Tyrannus verticalis*	U	4
A few observations in late June near Dry Creek Point; possibly a wanderer or a late migrant.			
Traill's Flycatcher	*Empidonax traillii*	RSu	3
Many observations of the confusing *Empidonax* complex made; only a couple were positively identified, both as *E. traillii*; it is entirely probable that other *Empidonax* occur at Ross Lake, especially *E. hammondii*.			

Annotated Bird List--Ross Lake, Whatcom County, Washington

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index
Western Wood Pewee	*Contopus sordidulus*	RSn	2

Observed most often in Lightning Creek--Dry Creek Point area from late spring through late summer; occur most often in diverse deciduous habitats.

Olive-sided Flycatcher	*Nuttallornis borealis*	U	5

Single adult identified in summer 1971 near McMillan Park.

Horned Lark	*Eremophila alpestris*	U	4

Two small flocks (10-15 birds) observed in drawdown of Roland Bay in February 1972.

Violet-green Swallow	*Tachycineta thalassina*	MS?	2

Many birds observed over the lake, usually in company with Tree Swallows, from early April through June. Probably not nesting in the area.

Tree Swallow	*Iridoprocne bicolor*	MS?	2

Again, usually associated with Violet-green Swallows. Possibly nesting up Big Beaver Valley.

Bank Swallow	*Riparia riparia*	MS	3

Several sightings in May and June at mouth of Big Beaver.

Rough-winged Swallow	*Stelgidopteryx ruficollis*	MS	4

Observed in various areas around the lake, usually near creek mouths, in May and June.

Barn Swallow	*Hirundo rustica*	RSn	1

Observed over all parts of the lake. Nests found in various buildings at Hozameen and Ross floating camp.

Cliff Swallow	*Petrochelidon pyrrhonota*	MS	4

Small flocks and individuals sighted at mouth of Big Beaver in late spring.

Annotated Bird List--Ross Lake, Whatcom County, Washington

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index
Gray Jay	_Perisoreus canadensis_	NM	3
Infrequent sightings in dense forest areas around the lake.			
Stellar's Jay	_Cyanocitta stelleri_	NM	2
Elusive, but is found in all wooded areas around the lake.			
Black-billed Magpie	_Pica pica_	W	5
Three sightings at Ross Lake, two of them in winter. An "east side" species.			
Common Raven	_Corvus corax_	NM	2
Many identified by sight and voice in the southern half of the lake; nest-building observed near Roland Point.			
Common Crow	_Corvus brachyrhynchos_	MS,RSn	2
Very common in the northern half of the lake; among the first migratory birds to return to Ross (early April).			
Clark's Nutcracker	_Nucifraga columbiana_	NM	4
Occasional observations in various wooded areas, mostly on the east side of the lake. Also sighted in sub-alpine areas of Desolation Mountain.			
Black-capped Chickadee	_Parus atricapillus_	NM	1
Ubiquitous. Almost always observed in medium-sized flocks (10-20 birds); particularly common on west Desolation Mountain.			
Mountain Chickadee	_Parus gambeli_	U	4
Several identified in sub-alpine areas in 1971; none observed in 1972; possibly a wanderer.			
Boreal Chickadee	_Parus hudsonicus_	U	5
Single individual observed building a nest on Jack Point in early June 1972. Only record. Nest success not known.			

Annotated Bird List--Ross Lake, Whatcom County, Washington

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index
Chestnut-backed Chickadee	Parus rufescens	RW,RS?	2
Common in early and late spring; is not normally a migratory species, but may disperse from the lake basin in summer.			
Red-breasted Nuthatch	Sitta canadensis	NM	4
Infrequently sighted in a few areas in the southern half of the lake; usually in small flocks (5-10 birds).			
Brown Creeper	Certhia familiaris	RWSn	3
Shy and cryptic, occurs in the cooler and damper areas of Ross Lake, particularly up Ruby Arm.			
Dipper	Cinclus mexicanus	NM	1
Observed in almost all streams feeding into Ross Lake.			
Winter Wren	Troglodytes troglodytes	RWSn	2
Heard and sighted in most dense, wet coniferous forests, particularly Ruby Arm and Little Beaver.			
Robin	Turdus migratorius	MS,RSn	1
Probably the most common bird at Ross Lake in the summer; one of the early (April) migrant birds to arrive.			
Varied Thrush	Ixoreus naevius	RWSn	2
Heard and sighted in most dense forests in the basin.			
Hermit Thrush	Hylocichla guttata	U	5
Three sightings in 1972, all in "lowland" areas; possible nester in Big Beaver Valley.			
Swainson's Thrush	Hylocichla ustulata	RSn	2
Occurs in most wooded areas in southern two-thirds of lake (from Jack Point south).			

Annotated Bird List--Ross Lake, Whatcom County, Washington

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index
Mountain Bluebird	_Sialia currucoides_	MS,MF?	3

Several medium to large flocks (up to 40 birds) sighted in the central portions of the lake, usually feeding in the drawdown.

Townsend's Solitaire	_Myadestes townsendi_	RSu	3

Observed from late May through mid-July, but no sightings after then. Most sightings in southern half of lake.

Golden-crowned Kinglet	_Regulus satrapa_	RW	1

Very common in medium-sized flocks in dense conifers in winter; often in company of Ruby-crowned Kinglets.

Ruby-crowned Kinglet	_Regulus calendula_	RW	2

Small flocks (up to 10 birds) in similar areas to Golden-crowned Kinglets; ubiquitous except in the northern area of lake near Canadian border.

Water Pipit	_Anthus spinoletta_	MS	3

Small migratory flocks sighted in drawdowns of middle and northern sections of lake.

Bohemian Waxwing	_Bombycilla garrulus_	RSu,W	4

Probably not a permanent resident, but a huge flock (several hundred) was present on the lake in June and July 1972. Known to be irregular in distribution (Gabrielson and Jewett, 1940).

Cedar Waxwing	_Bombycilla cedrorum_	RSu,W	4

Status similar to Bohemican Waxwing; when Bohemians moved out in July, several hundred Cedar Waxwings moved onto the lake, mostly in the central areas.

Starling	_Sturnus vulgaris_	U	5

Only two sightings of these normally common birds of the lowlands--two pairs near Dry Creek Point and one individual at Hozameen, both in spring.

Annotated Bird List--Ross Lake, Whatcom County, Washington

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index
Solitary Vireo	Vireo solitarius	RSn	4

Only a few positive identifications, including a collection; sometimes confused with Empidonax; probably more common than is evident by sight-index; observed in open woodlands.

Red-eyed Vireo	Vireo olivaceus	U	5

A single observation in Big Beaver Valley in spring 1971.

Warbling Vireo	Vireo gilvus	RSu	3

Occasionally sighted on Pumpkin Mountain, Skymo Burn, and near Hozameen, usually in late spring and early summer.

Nashville Warbler	Vermivora ruficapilla	MS	4

A few migratory individuals identified in Skymo brushfield in early May of 1971 and 1972.

Yellow Warbler	Dendroica petechia	MS,RS?	2

Many sightings in spring and early summer, but none after mid-June. Possibly not a nester on American Ross Lake except, perhaps, in Big Beaver Valley.

Myrtle Warbler	Dendroica coronata	MS	4

Several individuals identified in Skymo Brushfield and Lightning Creek areas; often with Audubon's Warblers.

Audubon's Warbler	Dendroica auduboni	MSF,RS?	2

Sighted frequently in spring and early summer; possibly nests outside the basin.

Black-throated Gray Warbler	Dendroica nigrescens	MS	5

A few occurrences in Ruby Arm and Big Beaver Valley; possibly these were just wandering migrants.

Annotated Bird List--Ross Lake, Whatcom County, Washington

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index
Townsend's Warbler	Dendroica townsendi	RSu	3
Observed well into the summer (July) in various parts of the lake, mostly northern.			
MacGillivray's Warbler	Oporornis tolmiei	RSn	3
Sighted occasionally in dense thickets on the eastern side of the lake.			
Wilson's Warbler	Wilsonia pusilla	MS	4
A few migrants identified in deciduous areas of Lightning Creek and Pumpkin Mountain.			
Western Meadowlark	Sturnella neglecta	MS	5
Three sightings, all migratory individuals, in "pseudo" meadows of Ruby Horse Pasture and Dry Creek Point.			
Yellow-headed Blackbird	Xanthocephalus xanthocephalus	W	5
Single female sighted in spring 1971; single male observed for several days in May 1972 with 5 pairs of Brown-headed Cowbirds in drawdown of Lightning Creek Camp.			
Red-winged Blackbird	Agelaius phoeniceus	RSn	3
Observed only in Big Beaver Valley where they nest (Miller and Miller, 1971).			
Brewer's Blackbird	Euphagus cyanocephalus	MS	4
A few sightings of straying migrants; usually in pairs; observed in open habitats.			
Brown-headed Cowbird	Molothrus ater	RSn	1
Very common in all areas around the lake, especially near the lakeshore; usually in small flocks of two to three pairs.			

Annotated Bird List--Ross Lake, Whatcom County, Washington

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index
Western Tanager	Piranga ludoviciana	RSu	3

Identified infrequently in Ruby Horse Pasture and Lightning Creek; nesting status unknown, but they probably nest in the Ruby Horse Pasture area.

Black-headed Grosbeak	Pheucticus melanocephalus	RSn	4

Not often sighted because they are secretive; most observations on eastern and central part of lake.

Evening Grosbeak	Hesperiphona vespertina	RSn	3

Frequent sightings in Ruby Horse Pasture, but this is the only apparent area of occurrence.

Cassin's Finch	Carpodacus cassinii	U	5

Single identification at Lightning Creek Camp on 31 May 1972; probably a wandering migrant.

Pine Grosbeak	Pinicola enucleator	RW	3

Observed occasionally near lake in mid-winter; possibly a summer nester at high elevations.

Pine Siskin	Spinus pinus	NM	2

Generally observed in small flocks (10-15 birds) in heavily wooded areas around the lake; especially common near Ruby Horse Pasture.

American Goldfinch	Spinus tristis	U	5

Single individual identified at Canadian border north of Hozameen; possibly nesting in the lowland Canadian Skagit Valley.

Rufous-sided Towhee	Pipilo erythrophthalmus	RSn	1

Very common in its habitat of open and closed brush; found in most brushfields around the lake.

Annotated Bird List--Ross Lake, Whatcom County, Washington

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index
Oregon Junco	Junco oreganus	NM	1

Common along the lake in winter; at somewhat higher (above 1900 feet) elevations during the summer.

Chipping Sparrow	Spizella passerina	RSn	2

Common in open brush and forest areas of all parts of the lake.

White-crowned Sparrow	Zonotrichia leucophrys	MS	3

Sighted in open areas around southern half of lake in spring; possibly nesting at higher elevations in sub-alpine meadows.

Golden-crowned Sparrow	Zonotrichia atricapilla	MS	5

1971 sightings on Pumpkin Mountain and Skymo brushfield; none in 1972.

Song Sparrow	Melospiza melodia	MSF	3

Heard and identified in various open areas around lake; possible nester at higher elevation and/or up Big Beaver Valley.

UNCONFIRMED SIGHTINGS

The following species are only possible identifications without confirmation from any other source, thus is not included in the above list.

Double-crested Cormorant — Phalacrocorax auritus

A single Cormorant of some species was sighted flying over the lake in spring, 1971; identification as a Double-crested Cormorant was only a guess since it is the most common Cormorant.

Sandhill Crane — Grus canadensis

A fisherman reported seeing one in the marshes at the north end of the lake late in spring 1972; immediate investigation revealed nothing.

Annotated Bird List--Ross Lake, Whatcom County, Washington

Common Name	Scientific Name	Probable Occurrence	Relative Sight-Index

Screech Owl *Otus asio*

Possible voice identification in late summer 1972; no sighting confirmation.

Short-eared Owl *Asio flammeus*

One adult sighted in Devil's Park in summer 1971. This was not a positive identification.

Yellowthroat *Geothlypis trichas*

Single adult male sighted on Pumpkin Mountain in spring 1971. Not a positive identification.

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