BIOTIC SURVEY OF ROSS LAKE BASIN

Report for

July 1, 1975 -- June 30, 1976

Conducted by the Center for Ecosystem Studies, College of Forest Resources, University of Washington, Seattle -- in cooperation with the City of Seattle, Department of Lighting, and the State of Washington, Department of Game -- under contract with the City of Seattle, Department of Lighting.

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INTRODUCTION

This report covers the fifth field period in the investigation of the general topic of determining what effects the raising of Ross Lake level would have on the Basin biota, and how undesireable effects could be avoided or compensated for.

In earlier reports bird and mammal populations near the lake level have been described, and predictions made of the consequences of raising the lake level on them. It has been apparent that the lakeside zone is more snow-free in winter than adjacent parts of Canada where there is no lake, and it has been postulated that the lake itself, as a relatively warm body in the winter, has a moderating effect on the lake shore. Various studies of climatic factors on transects upslope from the lake-shore, and other transects distant from the lake have been made, both directly with meteorological instruments, and indirectly, through the study of plant phenology. These studies have necessarily been tailored to the constraints of a small annual budget and a rather inaccessible landscape. However, by focussing closely on the key question: will a rise in the lake level cause a rise in the shallow-snow or snow-free zone? We have steadily approached an answer. The question we have posed is of course basic to all plans for mitigation within Ross Lake Basin, since winter snow conditions exert such strong effects on many animal populations. The species we have been particularly concerned about is the black-tailed deer, since there is ample evidence that the original flooding when the lake was established resulted in the death of many deer in ensuing winters. Further, it has been proposed that some, at least, of the measures undertaken to mitigate the effects of a rise in the present lake level should consist of manipulation of vegetation to increase deer winter forage supplies. In such a case, of course, winter snow depths in the manipulated areas will influence the actual availability of the forage for deer, so a reliable prediction of the post-rise snow regime is highly desireable.

During the 1975-6 year, then, we have concentrated on fleshing out earlier work on the postulated "warm bowl" effect and making such field measurements as we could to strengthen our understanding of winter microclimate.

1. Studies of microclimate

New data was obtained for:

1.1 Snow transects

1.2. Canadian weather records, Skagit Valley, pre- and post-floodin-

1.3. Field observations of winter weather conditions.

1.4. Plant phenology.

CLIMATE

1.1 Snow Transects

- One of our continuing objects has been to understand the factors controlling the accumulation of snow around the lake. We have also been concerned with the use of snow accumulation patterns to indicate the extent of the warm bowl effect. This year we continued our studies of snow accumulation, using both snow depth transects, and the solar radiation grid as a framework for sampling.

The solar radiation grid consists of a coordinate system of two scales -- 1/8 mile spacing around the shore, and 1/2 mile spacing over the surrounding mountains. Each point of this system is described for direct solar radiation (assuming a clear sky) for each of 21 days through the year. This method takes into account the effects of topographic shading, which of course is important in mountain terrain.

1.1.1. Methods:

We originally had planned to sample only on the basis of the solar radiation grid system, with hopes of correlating the snow accumulation with solar radiation values previously calculated. One series of grid snow depth measurements was taken, but logistic constraints led us to develop a different approach.

The final method employed was that of systematic transects run up slope perpendicular to the lake shore. We selected the following sites: Hidden Hand Pass, Little Jack Mt. trail, Devils Dome, Lightning Creek, and Desolation Mountain on Ross lake; Buster Brown Flats and Sourdough Mt. trail on Diablo lake; and an unnamed slope on Gorge Lake. These areas were selected because of their uniformity of slope, aspect, and vegetation types, as well as their accessibility. We measured the snow depth at 100 foot elevation intervals, from lake level to 3,000 feet. We were trying to determine whether the presence of a large body of water caused more rapid spring snowmelt than a small body of water, with our transects ranged as follows:

Near a large water body:

Hidden Hand Pass

Little Jack Mountain Trail

Devil's Dome

Lightning Creek

Desolation Mountain

Near a body of water of intermediate size:

Gorge Lake shore

Buster Brown Flats

Sourdough Mountain trail

Sampling was conducted on these transects December 30 (1975) January 1 (1976). It was found that several transects were too dangerous to allow safe and careful sampling, so the Hidden Hand, Devil's Dome, and Gorge Lake transects were then dropped. Another reading was made February 20-22. After this, the lake level had become so low that the Desolation Mountain and Lightning Creek sites were practically high and dry. This made access difficult, but more important the withdrawal of the lake water negated the supposed "warm bowl" we were studying, so those two transects were dropped after the February reading. A transect on Pumpkin Mountain was added as a replacement.

There was a hiatus in March because of road closures and a failure in boat access, and the next sample was obtained April 9-12. A final reading was made May 3-5.

1.1.2. Results

The results of the February transects are summarized in Figure 1, which shows snow accumulation patterns for four of the transects. The Desolation Mt. transect is not shown since it is identical to the Lightning Creek transect. The lines plotted are the results of simple linear regression analysis on the data. Figure 2 shows an example of the actual data, with its great variability.

There are two important results demonstrated by Figure 1. First, the slopes of the regression lines are almost equal, indicating similar patterns of accumulation of snow. Second, the "y" axis intercepts of these lines are directly related to the amount of total

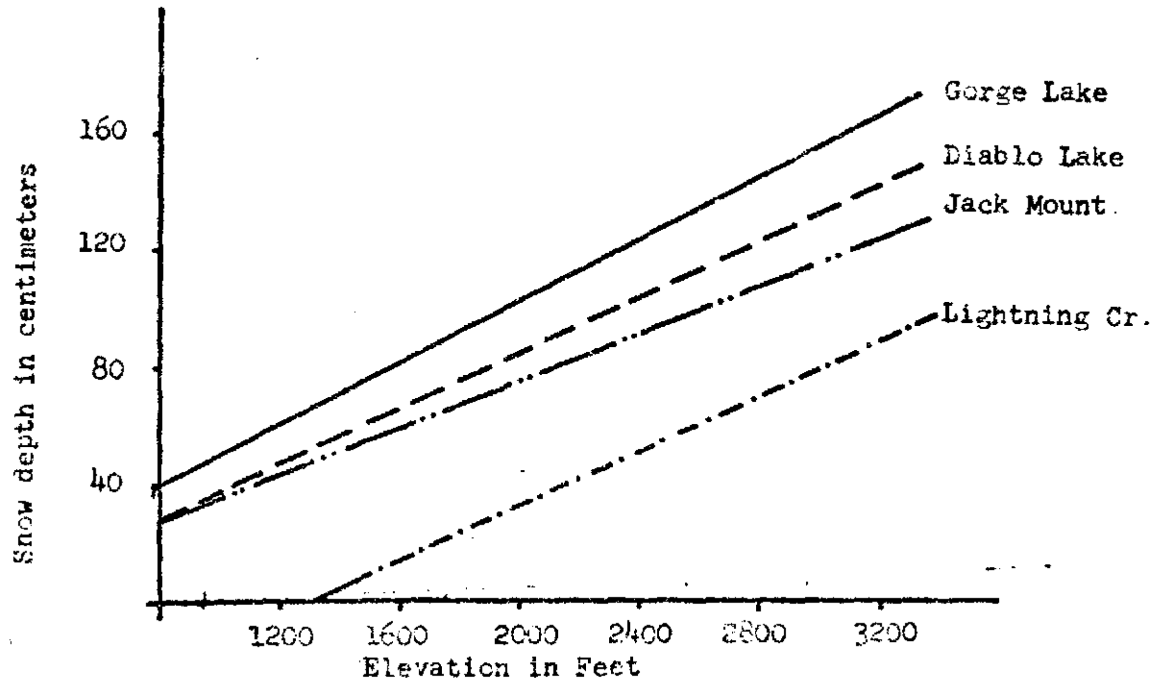

Figure 1. Snow accumulation versus elevation on four transects in the Skagit Valley on February 21, 1976.

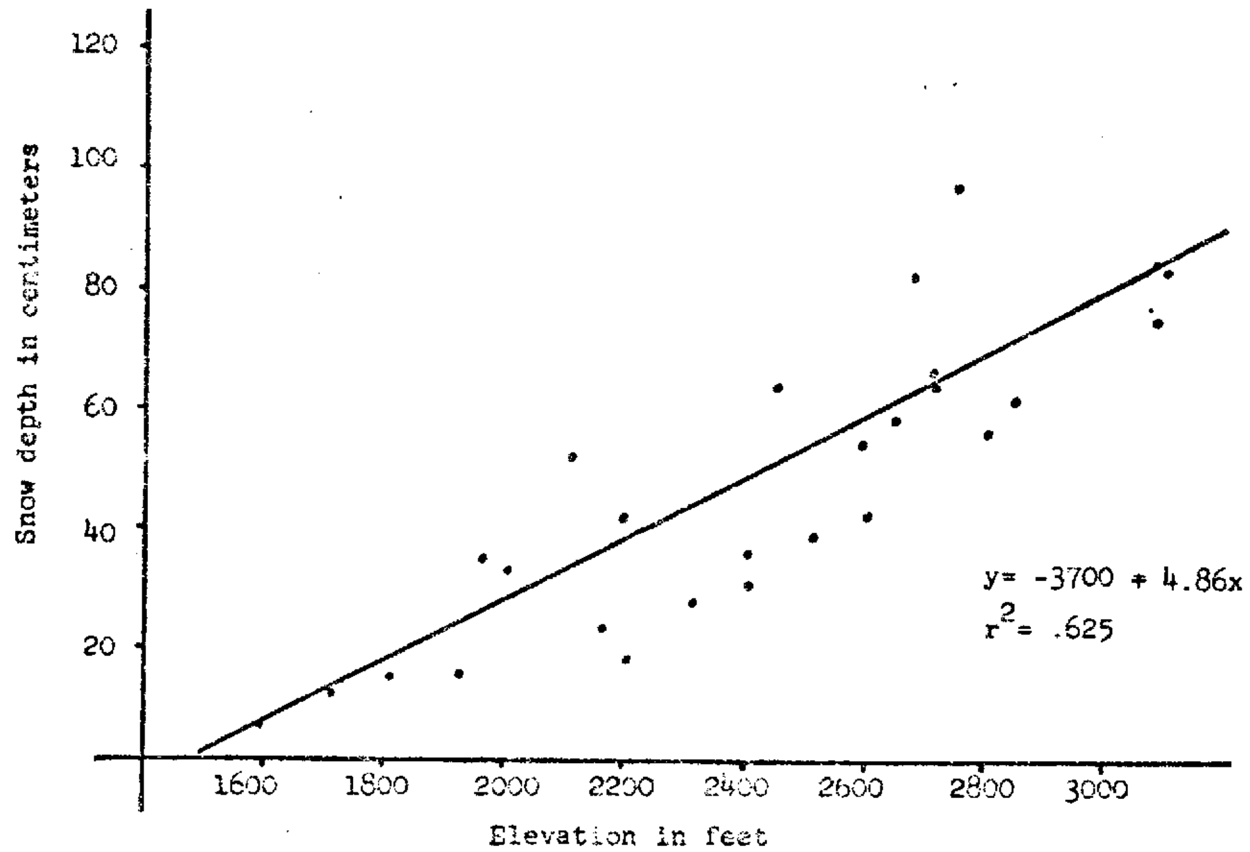

Figure 2. Snow accumulation versus elevation on February 21, 1976.

precipitation for the different areas. Desolation Mountain-Lightening Creek have the least, and Gorge Lake the most precipitation.

As is generally known, the Ross Lake Basin lies in the rain-shadow of the high mountains to the west. In earlier days a flat near the mouth of Lightning Creek was known as Little Sahara because of its hot and dusty aspect. And it has been shown in our own work that much of the east side of Ross Lake Basin is characterized by plant communities more characteristic of regions east of the Cascade crest. At the same time, it is useful to describe this rainshadow more precisely and quantify it as much as possible. This we have done. Figure 3 illustrates the amount of rainfall for a number of locations from the coast to Ross Lake. The data for the United States stations come from the U.S. Weather Bureau 30 year records. The Desolation Mountain data is from our 1975 report, and is based on one year of records. The Canadian Station is based on the period from 1936 to 1955. On the basis of this data we have mapped the isohyets for the Ross Basin, given in Figure 4, which is a modification of Figure A-29 in Climatological Handbook, Columbia Basin States, Precipitation, Vol. 2. 1969.

These graphs clearly illustrate the rainshadow effect of the western North Cascades, and account for the different amounts of snow found on the different transects at equal elevations.

Our next data were collected on April 10-11, after the beginning of the spring snow melt. These data are given in Figure 5. The most significant results here are the Jack Mountain and Buster Brown Flats transects. In Figure 1 (Feb.) these two transects were almost identical, both in slopes, and intercepts. However, now in April, they are radically different. Jack Mountain, on Ruby arm of Ross Lake, is snow free up to 2400 feet,

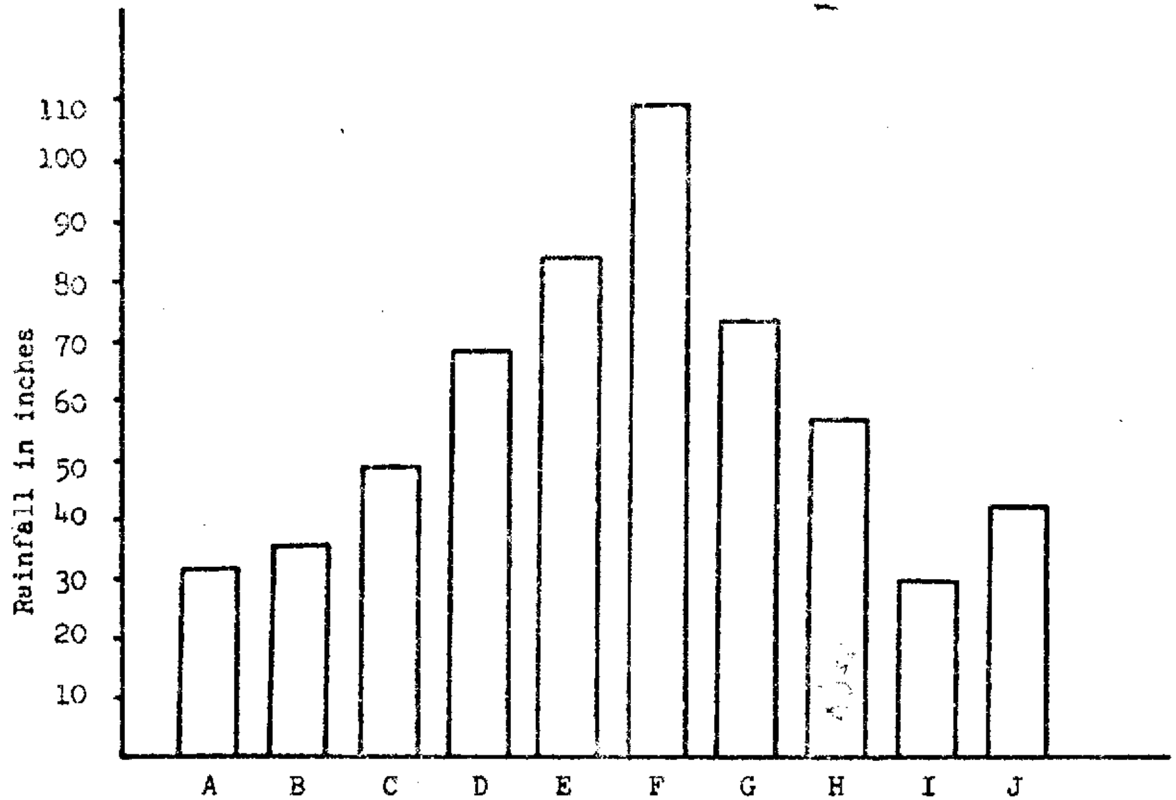

Figure 3. Annual rainfall for various locations in northwest Washington. A. Mount Vernon; B. Bellingham; C. Sedro Woolley; D. Concrete; E. Newhalem; F. Mt. Baker; G. Diablo Dam; H. Ross Dam; I. Desolation Mountain; J. Skagit River, B.C.

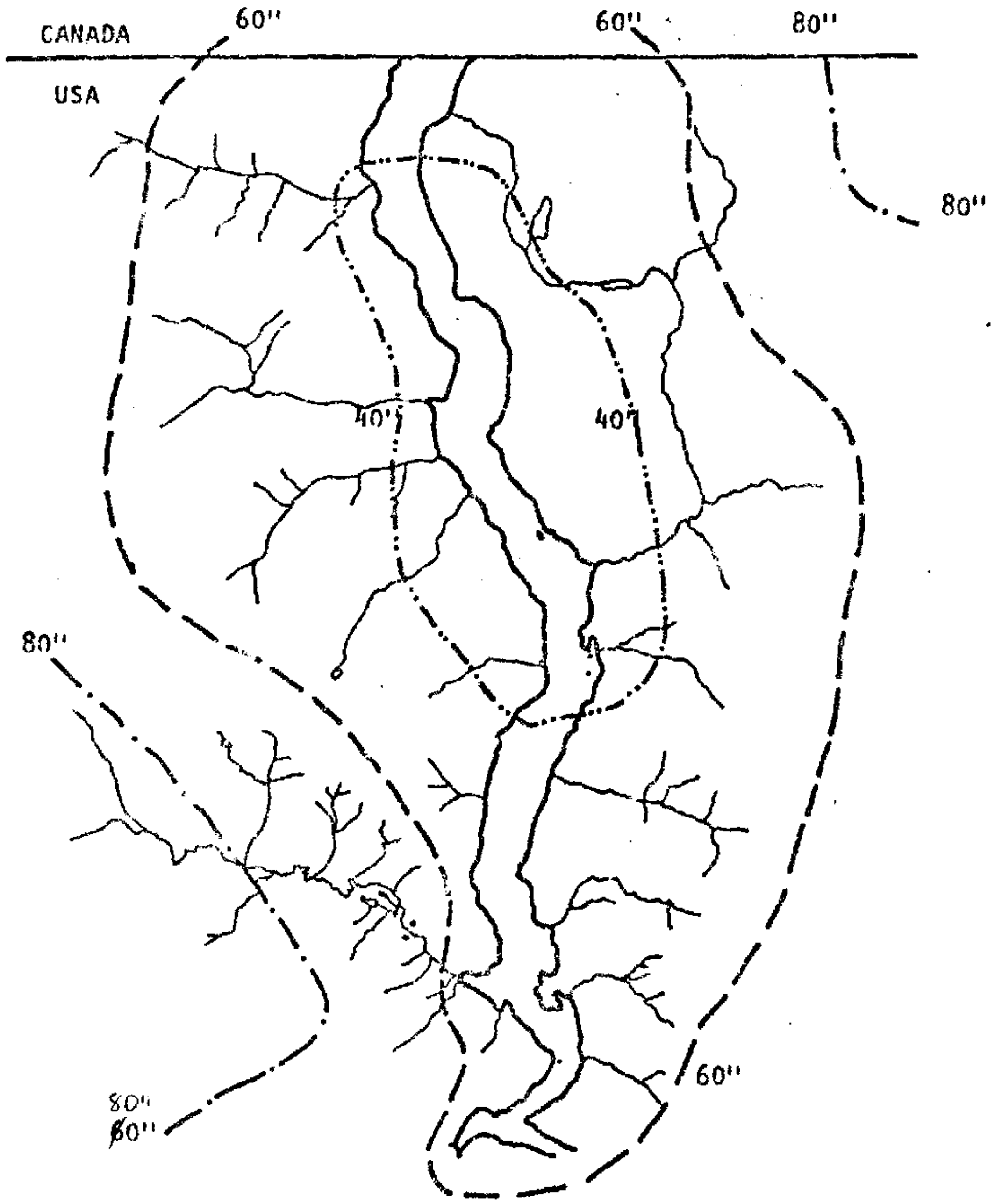

Figure 4. Rainfall isohyets for the Ross lake Basin, demonstrating the rainshadow of the western Cascades.

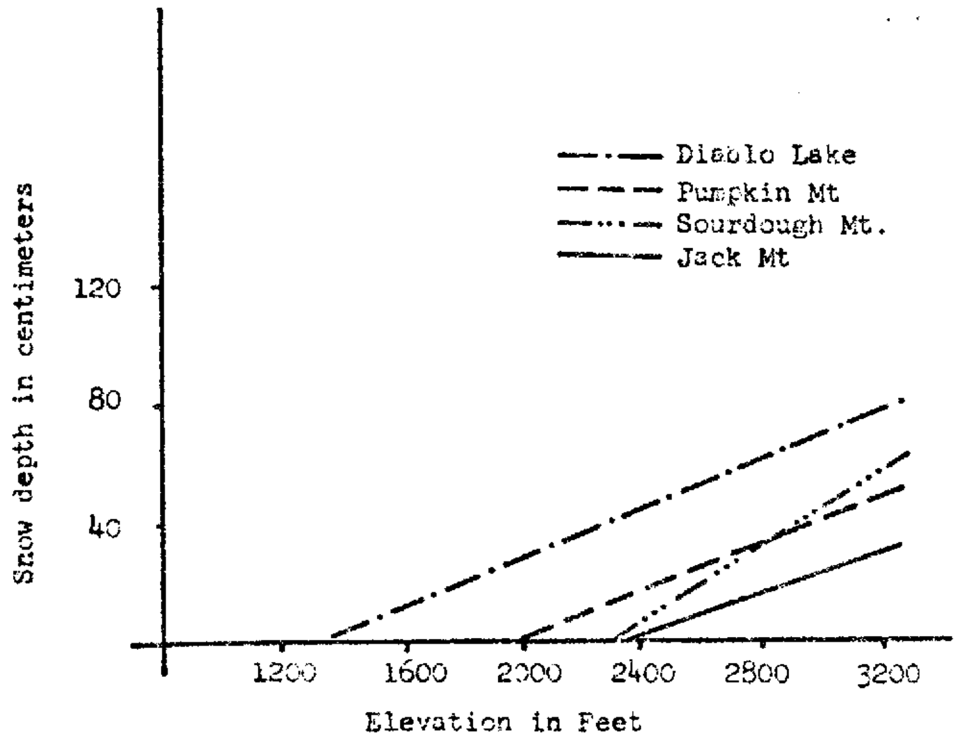

Figure 5. Snow accumulation versus elevation for the four transects on April 10, 1976.

whereas Buster Brown Flats transect still has snow at 1400 feet. This supports the hypothesis that snow-melt at low elevations is proportional to the size of the adjacent water body.

Our next data were collected on April 10-11, and are plotted in Figure 5. It is obvious that there are differences in snow-depth which correlate positively with the size of the nearby water body. Whereas the transects for Diablo Lake and Gorge Lake (intermediate) and Ross Lake (large) were all much the same in February (Fig. 1), by April they showed melt-back to 1300 ft. (Diablo), 2000 ft. (Gorge) and 2400 ft. (Ross).

While these data support the hypothesis that the rate of spring snow-melt is affected by size of the nearby body of water, it would be useful to obtain more evidence, particularly for the critical late winter period, during another year. The Pumpkin Mountain transect, also shown in Fig. 5, would be a good addition, if followed throughout the winter.

1.2. Effects of Ross Lake on Canadian Skagit weather.

Perhaps the most conclusive evidence of climatic modification by the warm bowl effect could be demonstrated through the analysis of weather records from a long term station, located within the area of influence of a reservoir. If data were available for a long period before the creation of the reservoir, and continued after its construction, then it would be a simple matter to compare the weather patterns of the two periods to determine what the effects had been on the local micro-climate. We do have records for a station, Whitworth Meadow, at the edge of the projected zone of influence of the lake, for the period 1936 to 1955. The dam was completed in 1943 and filled in 1947, and so we have approximately nine years of record before the creation of the lake, and eight years of record after the creation of the lake. Although the available record is not long nor ideally located, some conclusions can be drawn from it. These data are described and interpreted below.

First of all, we have hypothesized that the warm bowl effect would moderate the temperatures, warming cold periods, and cooling hot periods. The average temperatures within the zone of influence would probably be somewhere between the pre-impoundment temperatures and the temperature of the reservoir water. Our predicted results are given in Figure 6, which plots average monthly temperatures for Ross Lake, the period previous to the creation of Ross Lake, and our prediction of the average monthly air temperatures after the lake had been created.

Before we can begin our analysis of the temperature trends for this station, we must be certain that there has not been some regional trend either cooling or warming, during the periods in question. To test for any regional trends, we analysed the long term temperature data for the Diablo Dam Station over these same periods. The results are graphed in Figure 7, and are divided into "pre" and "post-Ross Lake" periods, with the average monthly air temperatures plotted. A "t-test" for differences in the means of the "pre-" and "post-" monthly averages was done and showed no significant difference for any month at the $P = .05$ level. In other words, the temperatures of the two periods have not changed to any significant amount. Thus, we may conclude that any changes that we might detect in the temperatures for the Ross Lake station are not due to any regional trends.

The weather records examined were gathered by the Canadian weather

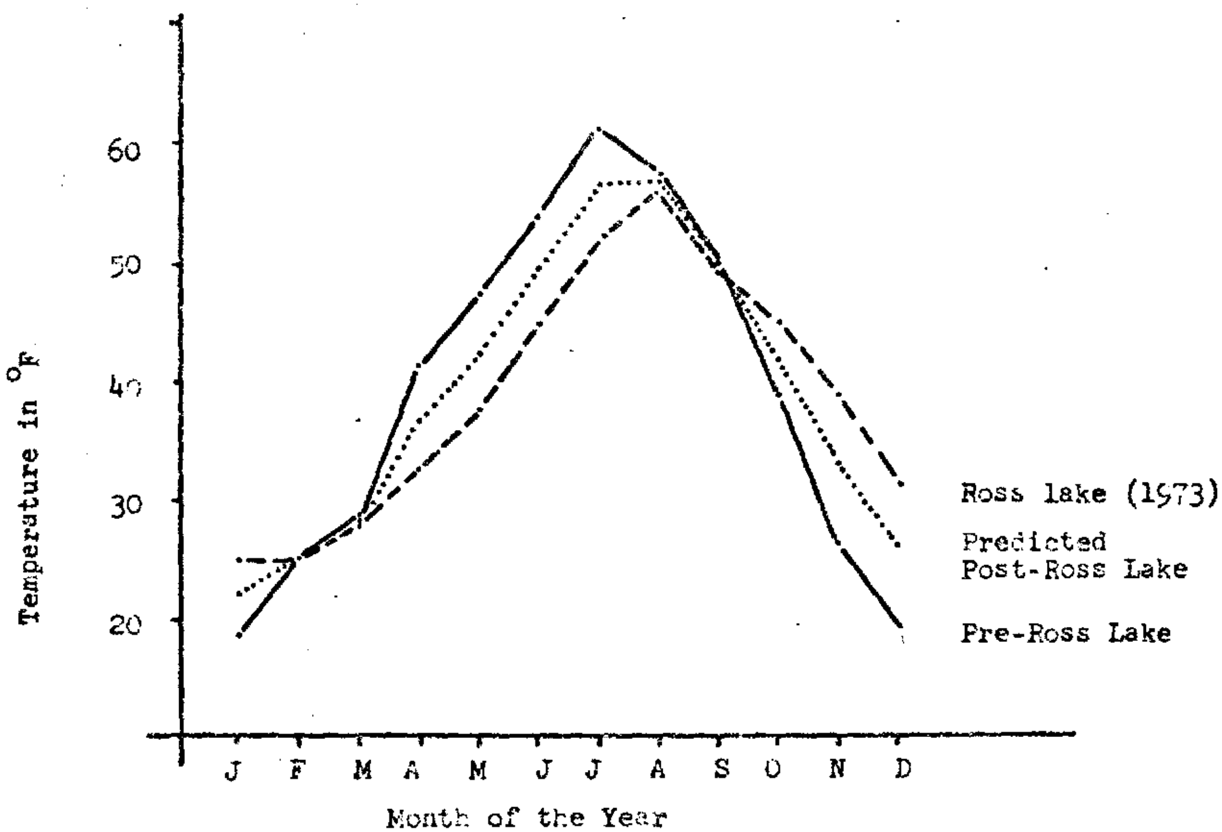

Figure 6. Monthly average air temperatures at the Skagit River station, British Columbia, previous to the construction of Ross Dam, after the construction of the dam, and the predicted post dam temperatures.

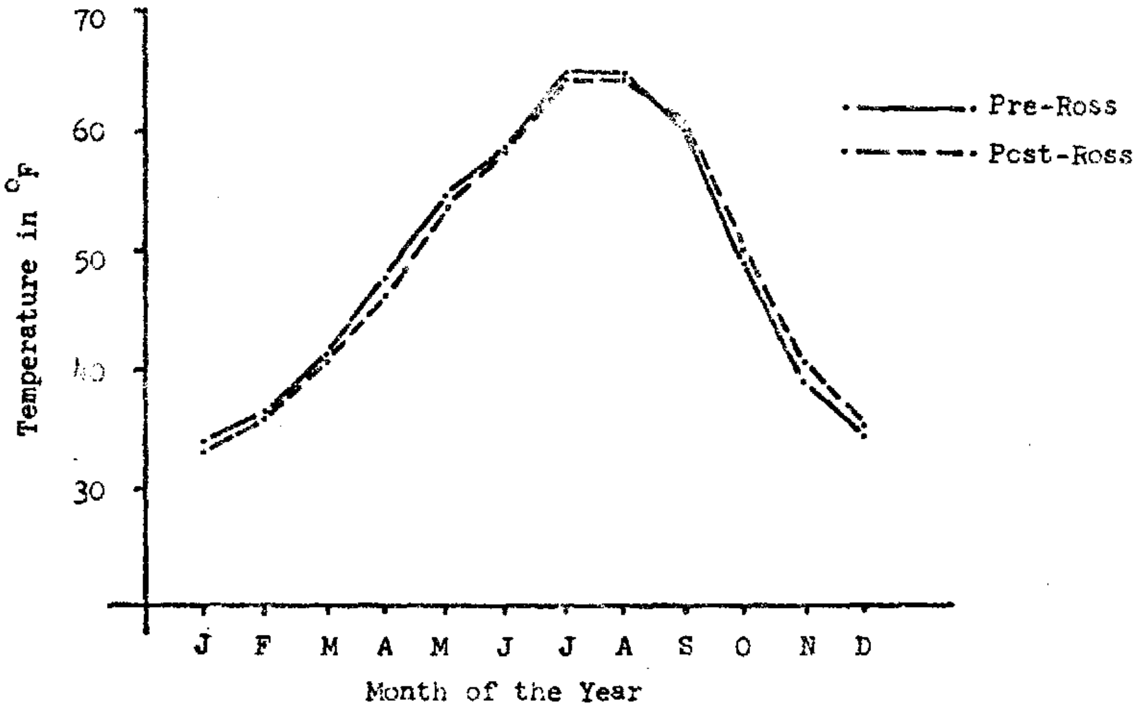

Figure 7. Average monthly air temperatures for the Diablo Dam Station for the periods before and after the construction of Ross dam.

service, and are recorded in Ref. 003.00821.001, Table 037. This station was located in the Whitworth Meadows, British Columbia, near Hozomeen, about a mile from the present lake shore, and at approximately the same elevation as the lake. Temperature records are available for the period 1939 to 1955, and precipitation records from 1936 to 1955.

1.2.1. Results and Discussion:

The results of our analysis are given in Table 1. This table compares the monthly period averages of pre-Ross and post-Ross temperatures. To test for a statistically significant difference in the monthly temperatures of the two periods, a "t-test" was used on each set of monthly averages. The results show a significant difference in the pre and post temperatures for the months April through October at the $P = .05$ level. In the months, November through March, there was no significant change in average monthly temperatures. Figure 8 shows the monthly average, comparing pre-Ross with post-Ross temperatures, together with the lake water temperatures from near Devil's Creek for 1973 (this is the only year for which a complete record of water temperatures was available.)

Figure 9 compares the expected or predicted post-Ross temperatures with the observed post-Ross averages. In all cases the post-Ross temperatures are cooler than we predicted.

These results raise two questions. First, why is the post-Ross climate much cooler all year? And secondly, why is there no warming effect in the winter? Both of these questions can be best answered by looking at Figure 10, which plots pre-Ross and post-Ross temperatures, and also the temperature of the Skagit River for 1973 at Chittenden's Bridge Station, near the weather station from which this data comes. Due

Table 1. A comparison of the average monthly air temperatures for the pre and post Ross Lake periods, from the Whitworth Meadow Station, in degrees F.

Month	Pree Ross	Post Ross
January	27.6	22.4
February	33.6	31.2
March	38.3	34.7
April	49.9	42.9
May	57.3	54.3
June	62.6	56.9
July	71.4	62.9
August	67.6	62.0
September	62.0	55.7
October	48.4	44.6
November	35.6	36.9
December	29.4	29.9

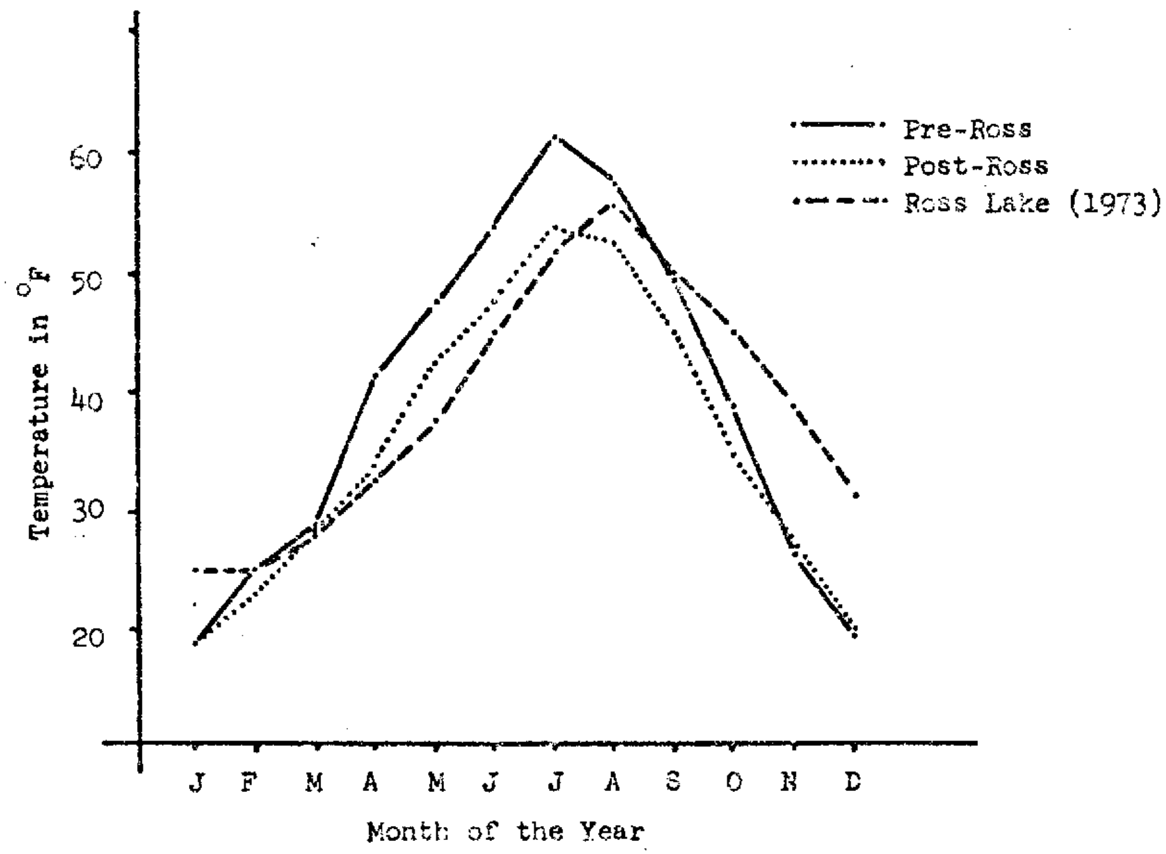

Figure 8. Average monthly air temperatures for the periods previous to, and after the construction of Ross dam compared to the average month water temperature of Ross lake during 1973.

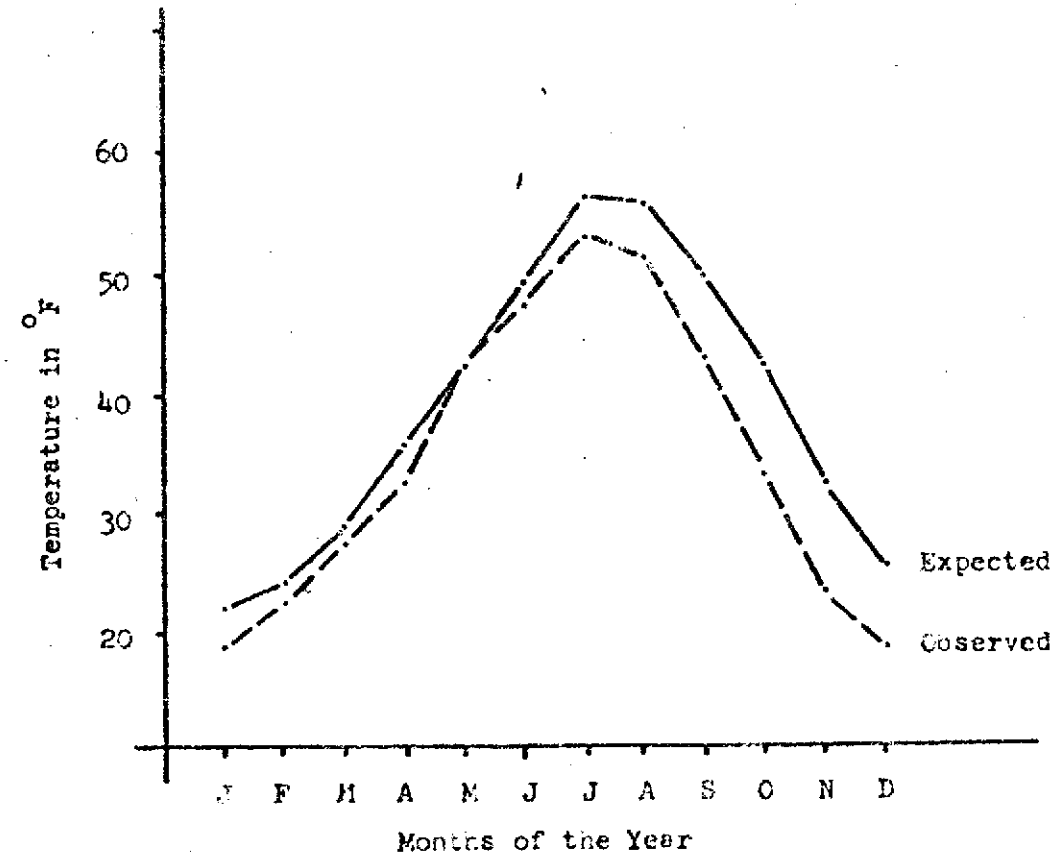

Figure 9. A comparison between the predicted or expected and observed post-dam monthly average air temperatures.

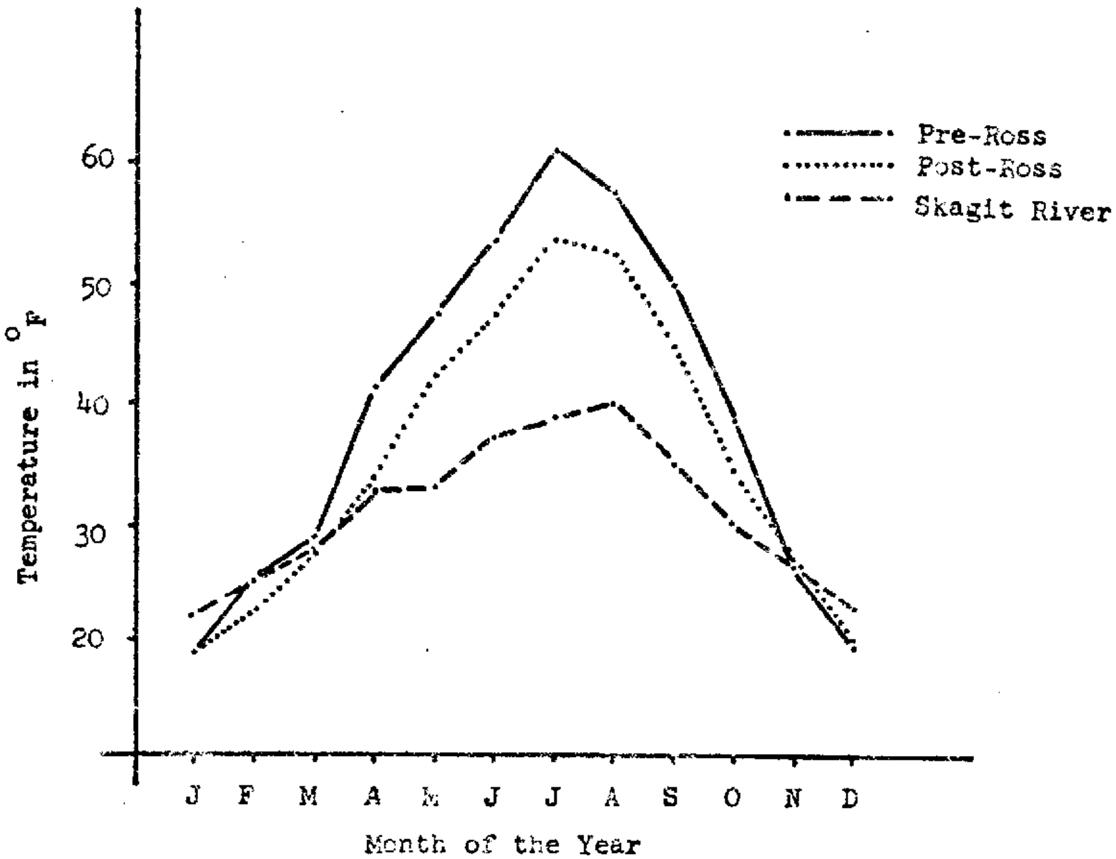

Figure 10. A comparison between the average monthly air temperatures before the construction of Ross and post dam temperatures with the temperature of the Skagit River at the Chittendem Bridge, B.C.

to the fact that the upper end of Ross Lake is very shallow, a large river such as the Skagit will greatly modify the lake water temperature and cool the lake. Thus the actual body of water influencing the temperatures at this weather station is much closer in temperature to the Skagit River than to the Ross Lake temperatures in the previous figure. Hence the resultant temperatures are colder than expected, and we see no winter warming effect.

The effect of the Skagit River on the temperature of the Ross Lake in the vicinity of the Canadian border is accentuated by the fact that Ross Lake is quite shallow there. Often, in the winter, the lake level recedes altogether and in years of extreme drawdown the lake extends only to about Lightning Creek, ten miles from the Canadian line.

These observations do not negate the hypothesis that the main body of the lake acts as a warm bowl in winter, moderating the shoreline temperature.

1.3. Field observations of the warm bowl effect on snowlines

On many occasions we have observed the influence of Ross Lake on the weather patterns of the surrounding areas. Often, for example, we have noted that it was raining at the lake level, but snowing just above the lake. Such an event is not unusual and happens in other areas, the change occurring when the freezing isotherm is crossed. We believe, however that the warming effect of Ross Lake is real, not merely coincidental with a regional freezing isotherm. This is substantiated by the observations on at least one occasion of a snowline shift caused by the proximity of Ross Lake, causing rain to fall on Ross Lake, when at the same elevation it was snowing over Diablo Lake.

For example, on December 29, 1975, the regional snowline was at 6,000 feet, with warm temperatures. During the night of the 29th, a cold front moved into the area, dropping temperatures, and bringing new snow. On December 30 Air temperatures at the Ross dam were: minimum of 29°, 32° at 0800, and 36° at 1200 hours and the water temperature of Ross Lake was 40°.

On the ferry trip to Ross Dam on December 30, 1976, we observed that the 1300 foot snowline was increased in elevation to 1,500 feet and was horizontal as far as we could see.

In approaching Ross Lake, we travelled from Newhalem, where the new snowline was at 1300 ft., up Diablo Lake, where the new snowline was 1500 ft. and horizontal (i.e., parallel to the lake surface) until close to Ross Dam, when it angled up to 1765 ft. Around Ross Lake the new snowline seemed parallel to the lake surface, except for a dip at Big Beaver. Struck by the regularity of this phenomenon, we ran transects up the slopes around the lake to determine the elevation of the new snow line, with the results in Table 2.

Table 2. Lower elevation of new snow, December 30, 1975

Diablo Lake -	Buster Brown Peak	1500'
Ross Lake	Ross Dam	1765'
	Ruby Arm (north side)	1800'
	Roland Point	1800'
	Rainbow Point	1820'
	Big Beaver Valley	1600'
	Pumpkin Mt.	1780
	Skymo Brush field	1800'
	Devils Pass Trail	1860'
	Lightning Creek Tr.	1860'
	Little Beaver Trail	1765
	Hozomeen Camp	1625'
	Silver Cr. Delta	1600'

Figure 11 shows this snowline, how it is clearly related to the elevation of Ross and Diablo Lakes, and how the snowline drops to lake level at the north end of the lake, where the water is very shallow and much colder due to the large amounts of very cold Skagit River water entering the lake. It is also interesting to note how the cold air drainage from Big Beaver Creek again causes a shift in the snowline back down to lake level (See Table 2). Several photographs of the snowline are included.

These observations clearly demonstrate the role of the warm Ross Lake water in modification of the temperatures of the basin, and its role in the modification of precipitation from snow to rain.

1.4. Plant phenology

Evidence of microclimate variation around the lake was sought through the study of the pattern of plant development and growth (phenology) in the spring. Plants are generally reliable integrators of environmental variables, and microclimate patterns are generally reflected in patterns of phenology (bud burst, blooming, flowering, etc.). Past studies have demonstrated that there is a zone from lake level to about 2000 to 2500 feet within which plant development immediately upslope from the lake is rather uniform. In fact, it was this early observation that first attracted our attention to the possibility of a "warm bowl" effect. Through various studies (reported earlier) we found that on slopes distant from the lake shores, but at the same elevation, plant development was as much as two weeks delayed.

This year we approached this problem in another way, by using the nearby, but lower lakes as reference points. There were two major possibilities:

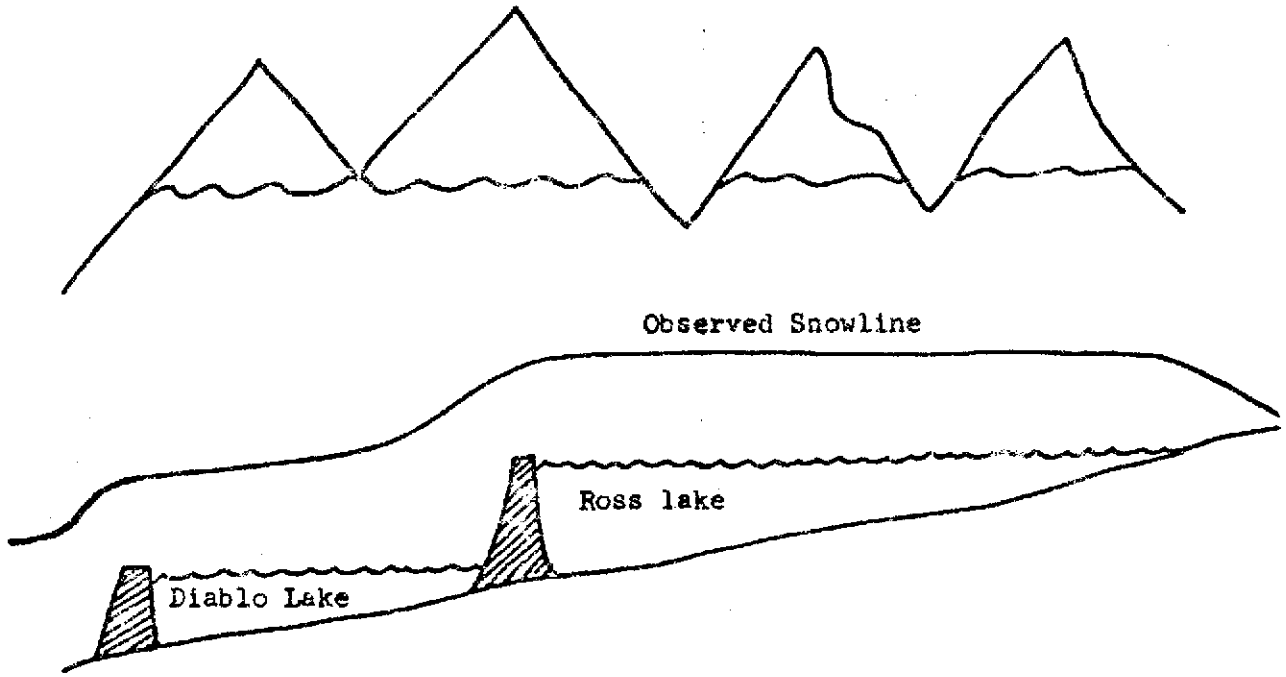

Figure 11. The snowline observed on December 30, 1975 during travels from Newhalem to Hozomeen, in relation to Ross Lake and Diablo Lake.

Photograph 1. Ross lake from Pumpkin Mt. to Skymo burn, Dec. 30, 1975.

Photograph 2. Ross lake, Pumpkin Mountain area on Dec. 30, 1975

Photograph 3. Thursday Creek, Ross lake, Dec. 3 , 197 . The white in the foreground is the sandy area of drawdown, and not snow.

1. That the "early zone" around Ross Lake was due to a regional phenomenon such as a temperature inversion. In such a case the upper border of the "early zone" would be at about the same contour line above Diablo and Gorge Lakes as above Ross Lake (as in Figure 12).

2. That the "early zone" around Ross Lake was due to the influence of the lake itself. In such a case the upper border of the "early zone" for Diablo and Gorge Lakes would be lower than that around Ross Lake (as in Figure 13).

To obtain sufficient evidence from which to judge which of these alternatives was more nearly correct, we established four transects, matched for uniformity of slope, aspect, and vegetational cover, two on Ross Lake and one each on Diablo and Gorge Lakes. Each started at lake level: Ross Lake - 1600 ft; Diablo Lake - 1200 ft., Gorge Lake - 900 ft. These transects were each run three times, and the phenological status of the following species recorded: serviceberry; oceanspray; bitter cherry; vine maple; red alder; redstem ceanothus; and Oregon grape. The three dates were April 10, and 24, and May 8, 1976.

In general, in reference to all species of plants observed, except vine maple, the upper limit of bud burst was higher on the Ross Lake transects than on the other two. The difference was approximately 400 vertical feet between the Ross limit and the Diablo-Gorge limit. The difference between Diablo and Gorge transects was minimal. These results are given graphically in Figures 14-17. These results indicate that microclimate of the Ross Lake Basin is influenced by the presence of the lake itself, and that the evidence supports our second alternative above.

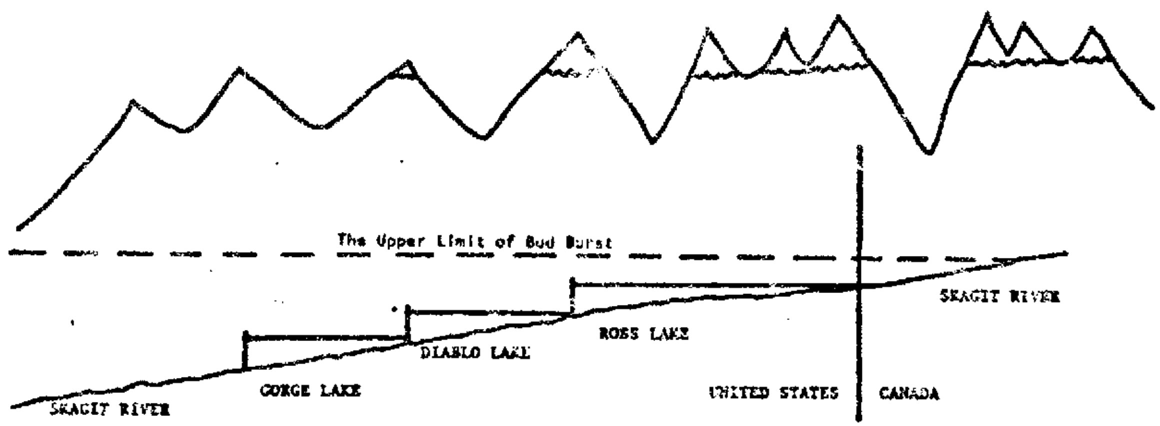

Figure 12. A crossectional view of the upper limit of bud burst in early spring if the lakes have no effect on the microclimate.

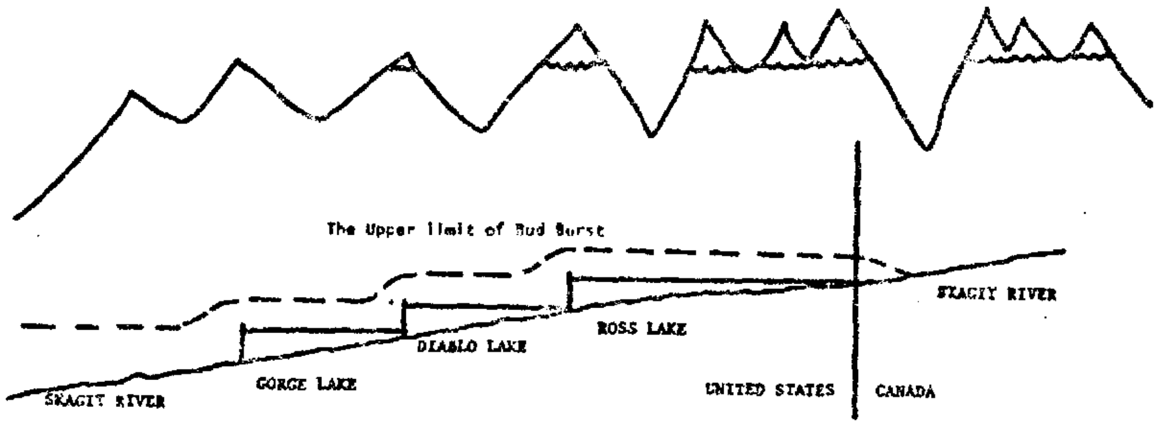

Figure 13. The same crossectional view showing the position of the upper limit of bud burst in early spring if the lakes do function as "warm bowls".

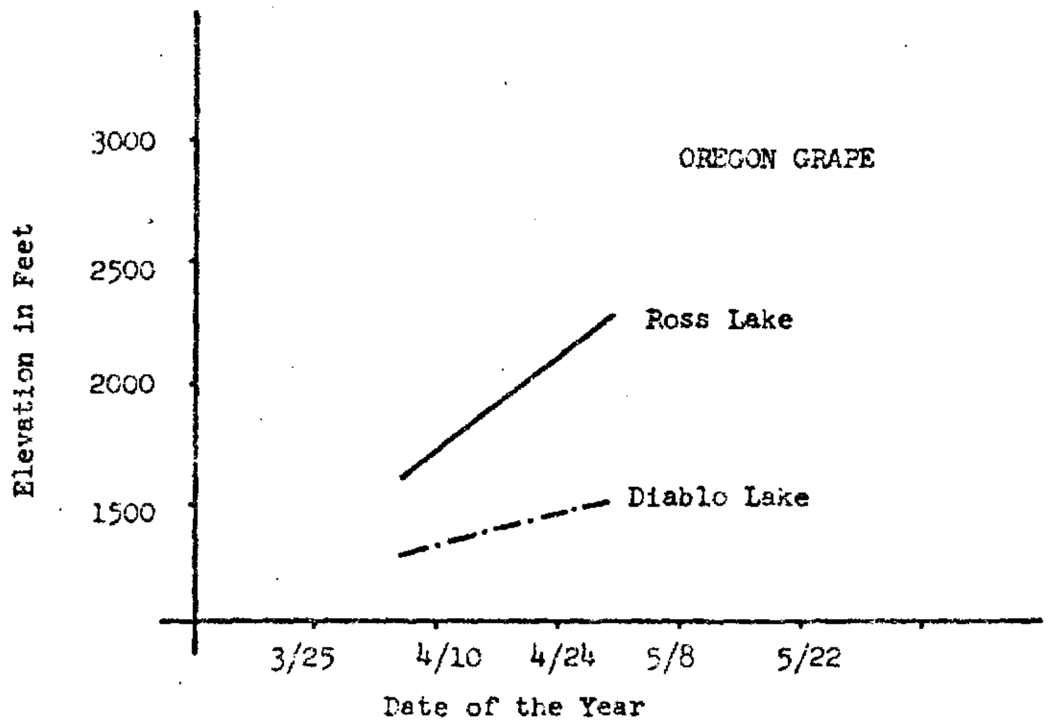

Figure 14. The upper limit of bud burst for Oregon grape for the transects above Ross Lake and Diablo Lake.

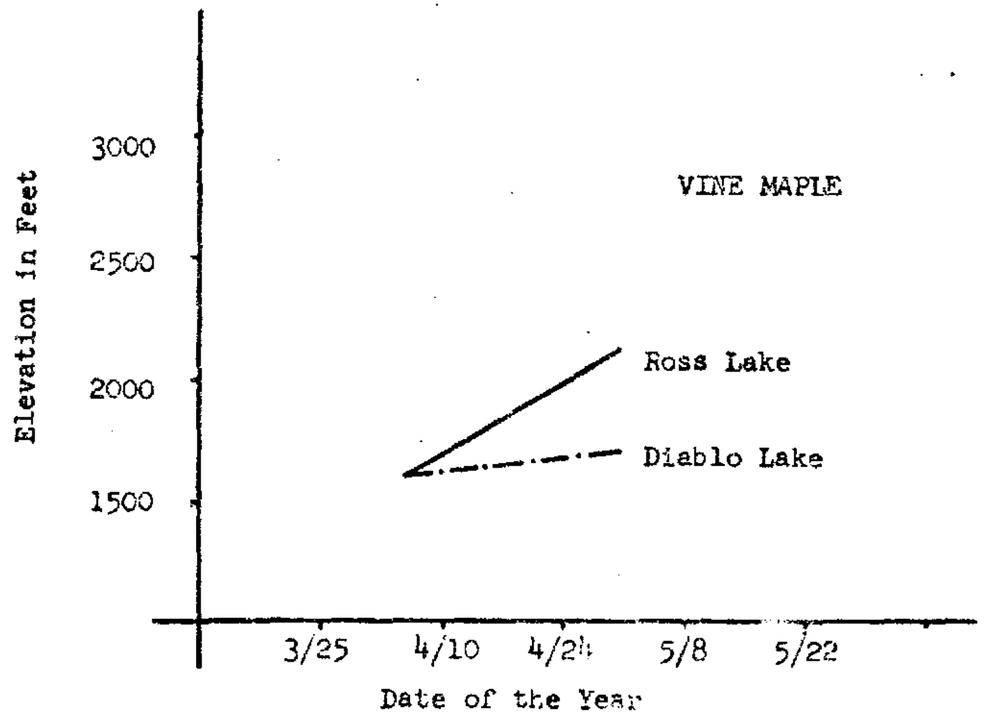

Figure 15. The upper limit of bud burst for Vine maple on the transects above Ross and Diablo Lakes.

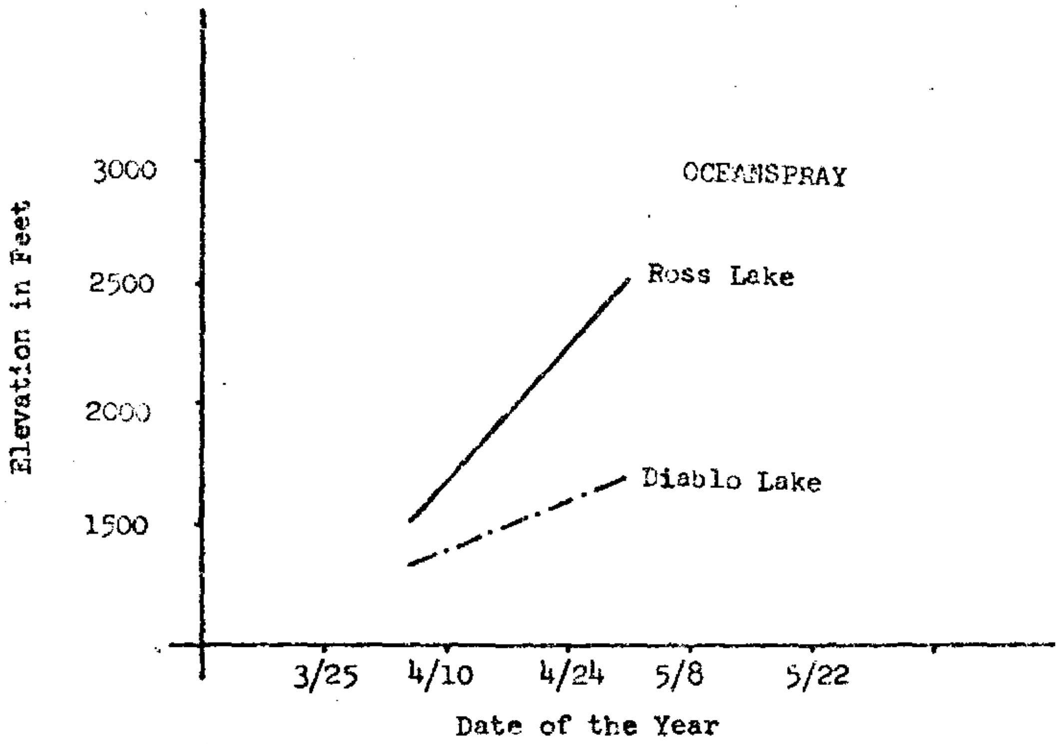

Figure 16. The upper limit of bud burst for Oceanspray on the transects above Ross and Diablo Lakes.

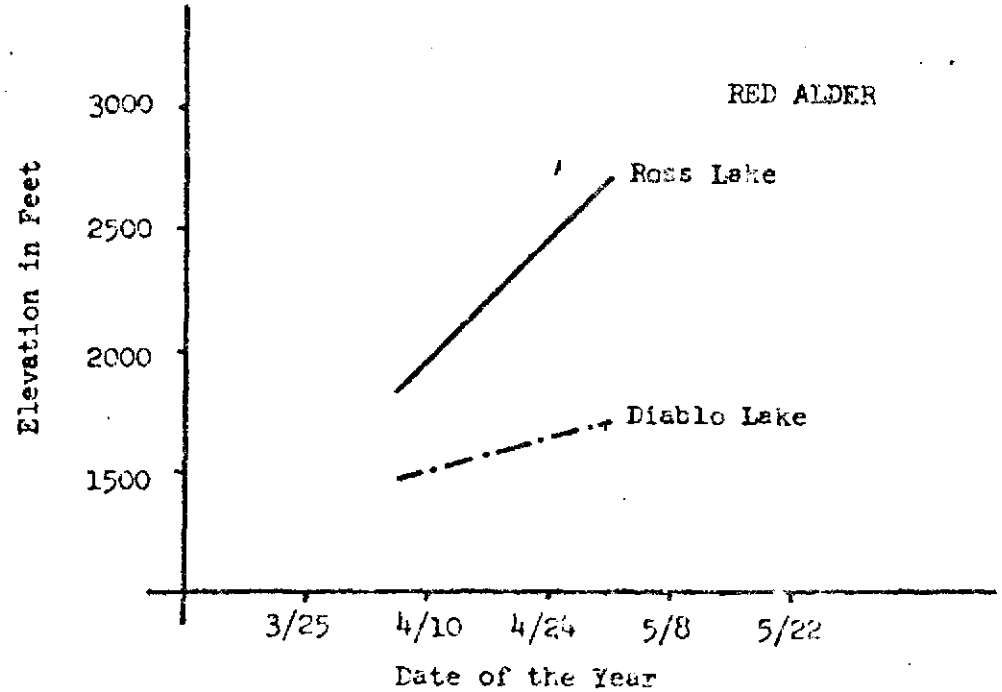

Figure 17. The upper limit of bud burst for Red alder on the transects above Ross and Diablo Lakes.

These various observations and measurements add support to the idea that Ross Lake does indeed exert a "warm bowl" effect on its shores, principally through changing winter snows to rain, and perhaps also to raising air temperatures in early spring.

At the same time, however, we cannot discount the possibility of a general regional pattern upslope away from the effect of the lake surface. Throughout western Washington there is a more or less sharp transition from the western hemlock forest to the true fir firest at about 2500 ft. It appears that this zone is marked by a sudden increase in the depth and duration of snow. Working upslope from Ross Lake shore we have found this line evidenced by rather abruptly deeper snow and corresponding lag in season of plant development.

So now the question is: can we expect to find the workings of the "warm bowl" effect confined largely to the zone below 2500 ft. or so; or will an enlarged lake cause a corresponding upslope shift of the "deep snow" line we now find around 2500 ft? The general regional nature of the type break between forest zones inclines us to the first alternative. However, if the lake level is raised it will be possible to obtain direct evidence through snow and phenological measurements.

Meanwhile, our attention is directed at the zone from lakeshore to 2500 ft. This is the zone in which we expect the "warm bowl" effect to be most marked. Now, if opportunity occurs for further work, we should study winter snow accumulation and spring phenology on a much finer grid, with more closely spaced points along each transect, and more transects around the lake shore. This will be for the purpose of developing predictions regarding the effects of a raised lake on specific deer winter ranges. We are developing plans for the establishment of permanent plots on which through a series of measurements we obtain data on sky radiation, slope, aspect, elevation, plant community, snow regime, and winter use by wildlife, particularly deer. The limited elevational scope of these transects, which will only extend to about 2500 ft., will make these studies much easier to accomplish than our earlier ones, which have ranged much higher.

DEER WINTER RANGE

2 Observations on deer in relation to snow

During this year we have made some new field observations and have also reviewed our earlier records, to develop a better understanding of the winter use of the lakeshore zone by deer.

We have found that in the winter, snow is the most important factor limiting the distribution and movements of deer. Specifically, the snow condition and depth are the most important factors. In general, deep, loose snow prevents the deer from moving freely, and so forces them to lower elevations where snow is reduced in accumulation. On the other hand, hard, crusted snow allows the deer freedom of movement, and if the deer are at lower elevations under the latter conditions they will presistently move up the hillside. The deer continually attempt to move uphill or maintain altitude throughout the winter, when snow conditions permit. Consequently, the areas that are most heavily used are the middle elevations, between 2000 and 2500 feet. The exception to this occurs in the extreme winters, whether very mild or harsh. In mild winters, with reduced or delayed snow fall, the higher elevations will receive most use, and conversely, in harsh winters, the range areas at lower elevations, at lake's edge, will receive the heaviest use. The following observations are given to substantiate these generalizations:

First, this past year's first snow falls were extremely early and heavy. Snows in October and November accumulated to great depth throughout the North Cascades. Snowfall at Stevens Pass and Snoqualmie Pass were near records. The early snows drove the deer to lower elevations, to the traditional winter ranges, much earlier than normal. The result was a greater than normal deer harvest. The elk harvest in the state was almost a record. In the Ross Lake basin, the normal deer kill in the regular season is less than 5 deer. This past year, 18 deer were killed in the area between Ross Lake and Diablo Lake (Marvin VanMeer, per. comm.). Several hikers reported seeing "several large groups" of deer near the Lightning Creek campground. The snow was just too deep and soft for the deer to remain at higher elevations.

Then in mid-November the snows stopped, and a warming trend moved through the area. With the melting snows, the deer moved back up the hillside. In December, during a four day field trip in the basin, only 5 deer were seen below 2500 feet. The ground was free of snow up to 2500 feet, and only light, new snow was present up to 3000 feet. Deer sign was abundant in the new snow up to 3400 feet, with most of the sign and tracks from 2500 to 3000 feet. The deer remained at this elevation till February, when conditions changed.

In late February and March we had another series of heavy snowfalls, and again the deer were driven down to lower elevations. But, with warm weather in April, the snow began to melt. On April 10, the continuous snow line was at 3000 feet with patches of snow below. THe deer were again at the lower limit of the heavy snow, with the heaviest sign around 3000 feet. During this period, while running the phenology transects, we noted that the heaviest utilization of browse species was between 2000 and 2500 feet. Here most browse plants like ceanothus, serviceberry, bitter cherry, oceanspray, and Oregon grape were browsed almost to capacity. At both higher and lower elevations the deer use of the browse was considerably less intense. During the April 9-12 field work, we observed only a few deer below 2500 feet, and these were on a cold northeast slope where snow accumulation was greatest, and remained the longest.

In summary, we can make the following general points:

1. Deep soft snow forces the deer to lower elevations where snow accumulation is less.

2. With crusted snow conditions the deer move uphill.

3. When the snow retreats uphill with warm conditions the deer move uphill also, even in the middle of winter.

4. The middle elevations are the most heavily used range areas under normal conditions.

Applying our findings on the "warm bowl" effect, we should expect that a rise in the lake level would make the 2000-2500 ft. zone, which the deer now favor, available for them on more winter days than is now the case. In addition, the identification of this zone of heaviest deer use is a useful guide if it becomes necessary to develop plans for mitigation.

3. Discriminant analysis applied to winter deer distribution

The overall objective of our various studies is to predict correctly what the effects of a rise in the lake level on the wildlife will be, and to provide a factual basis for the development of plans of mitigation, if these are needed. If we were able to distinguish between the sites

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on which deer were found in winter, and sites where they were not found, in terms of attributes which we could measure, then we would be in a position to extrapolate this information into a map of the lakeshore, identifying all areas which were and were not suitable for deer in their present state. If we then introduced a factor for vegetation management, we could identify the sites which could be converted to acceptable deer habitat by management measures. Finally, if we could add the effects of a rise in lake level, we would be in a good position to recommend measures to maintain deer winter carrying capacity despite flooding. X

It was our intention in this year to develop a viable approach to describing the landscape in terms of winter deer use and non-use as related to measureable landscape attributes. This would make use of our work thus far, and indicate where more depth of detail was needed. The approach we took was that of discriminant analysis. Discriminant analysis begins with the desire to statistically distinguish between two or more groups of cases. These "groups" are defined by the particular research situation. Some biological science examples of groups of cases would be: a group of laboratory animals given drug A versus a group given drug B versus a group given no drug; a group of different vegetation associations; trees used by nesting birds versus those not used for nest sites.

To distinguish between the groups, the researcher selects a collection of discriminating variables that measure characteristics on which the groups are expected to differ. For instance, in the laboratory example, the various physiological features of the animals may have been observed; data on the climate, soil, and fire history may be collected for the vegetation types; and the different aspects of tree geography, physiology and structure could be considred. The mathematical object. e of discriminant analysis is to weight and linearly combine the discriminating variables in some fashion so that the groups are forced to be as statistically distinct as possible. In other words, we want to be able to "discriminate" between the groups in the sense of being able to tell them apart.

In the cases to be discussed here, we want to be able to determine what are the characteristics of areas used by deer in the winter in the Ross Lake basin, or how can we discriminate between areas used by the deer in the winter and areas not used by the deer in the winter. We have chosen the following variables which are expected to differ between range and non-range areas: elevation, aspect, slope, vegetation type, and total potential solar radiation as determined by Fritschen (1972). The different groups of cases considered are: deer range versus non-deer range; and high versus low deer density within different radii of the grid point. The mathematics of this type of analysis is discussed in Morrison (1969), and the statistical program used is part of the Statistical Programs for the Social Sciences, therein called "Discriminant Analysis" (1975).

3.1 Methods:

To sample the Ross Lake Basin, the large scale solar radiation grid was used as the coordinate system dividing the landscape into standard cell units. At each intersection point on the 1/2 mile grid the following data were recorded.

1. Deer range or non-range area

2. The number of deer within a one square mile circle centered around the intersection point

3. The number of deer within a 1/4 square mile circle centered at the grid point.

4. The elevation at the grid point

5. The slope at that point

6. The aspect of the point

7. The vegetation type for that point

The deer numbers, and deer range areas are those described in earlier reports, resulting from the initial years of study (Raedeke, et al, 1972; Stevens, et al 1973). These groups of deer range, deer densities, and deer numbers, were then analyzed using the remaining variables as our discriminating variables. Approximately 280 grid points were sampled, 25 being on deer range areas. All points that were below 5000 feet, and within the immediate drainage basin of Ross Lake were included,

3.2 Results

The results from this type of analysis are two fold: first, the program ranks the different independent variables in the order of their importance, or even eliminates them if they do not contribute significantly to the results; and second, it then uses these characteristics and reclassifies all the previously analyzed cases, and determines the percentage of cases that it correctly classified. This is a test of the ability of the program to correctly identify the different cases on the basis of the different independent variables. The results are given in Table 3.

Table 3

Groups

Rank of order of importance	Deer winter range vs. non-range	High vs. low deer densities	
		1 sq. mil area	1/4 sq. mi. area
1	Elevation	Elevation	Elevation
2	Aspect	Aspect	Aspect
3	Solar Radiation	Vegetation	Solar Radiation
4	Slope	Slope	Vegetation
5	Vegetation	--	--
Not significant	--	Solar radiation	Slope
% of correct reclassification	64.3%	70.7%	71.7%

3.3. Discussion:

As can be seen in the table, the two most important variables (elevation and aspect) are the same in all three analyses. These are also the two classic variables on which most deer ranges have been defined. However, once we go beyond the first two most important variables, the results get a bit erratic. Reasons for this include the following: first the sample size for the analysis is fairly small considering the amount of variation in the variables (eg. there are 11 vegetation units, 8 aspect units, etc.). Also, of the 280 points sampled, only about 25-40 were in the deer range, or areas of high deer density.

Secondly, because of the complexity of the vegetation mosaic on the range areas, we can expect to get a rather poor correlation between specific units and deer range since the larger deer ranges may contain all of the vegetation types.

Furthermore, as we reduce the area being considered around the point, we increase the accuracy of the method. Specifically, when using the number of deer with 1/4 square mile of the point as our basis of the low-high deer density groupings, we get a greater accuracy rating than if we use the deer numbers within 1 square mile of the point.

Another apparent conflict arises in the second analysis where the groups are: deer densities (high vs. low) based on the number of deer in the one square mile area around the point. In the analysis, solar radiation was not a significant discriminating variable, and was rejected. This is interesting since solar radiation is based on elevation, slope, and aspect, in addition to horizon. Thus solar radiation should be a more complete measure for these variables than the three taken seperately.

Also, there is a significant difference in the amount of solar radiation between deer winter range areas and non-winter range areas at the P = .05 level. The probable cause of this problem is the use of the one square mile area for our index of selection by the deer for this grid point and its characteristics. The large area must dilute the selection or rejection of the deer for point in question. For examples, at a given point on the grid, we might have a very low solar radiation value (low amounts of direct sunshine), thick vegetation and deep snow due to shading, and a northerly aspect. Few deer would be likely to select this landscape unit for winter range due to these characteristics. But, if within the one square mile area there existed more favorable conditions, and the deer selected this site for winter range, this grid point would be classified as winter range, and these characteristics used as those of winter range areas. The results would be a very low correlation between some of the variables and the groups (winter range vs.non-range), and low accuracy or rejection of one or more of the variables. The only cure for this problem is the use of a finer grid system, more points, and a more realistic means of classifying deer selection or rejection of the point in question.

Even with these problems this type of analysis gives us very interesting results. A few of the specific findings are:

1. Deer are selecting or rejecting fairly small, well defined landscape units.

2. The classic variables, elevation and aspect are very important variables for distinguishing deer range areas.

3. With the information we now possess we can correctly classify

any given point on the landscape as deer range or not approximately 70% of the time.

In order to make full use of this method, we will need to obtain a larger sample of smaller plots, and to have more accurate data with regard to each of these plots. As will be seen in the subsequent section we have been moving in that direction, making earlier data more useable and perfecting our vegetation map, for example. Now, if we have an opportunity for more field work we will have a well-defined plan of sampling and analysis. The sampling pattern which we will employ can be the same one which we will use to obtain data on snow-regime and plant phenology, thus making the most efficient use of field time.

The landscape of the Ross Lake shore is characterized by a small-scale mosaic of soil depths due to highly uneven deposition by glacial processes. Soil depth controls the amount of moisture which will be available for plant growth, and so influences plant composition and production. Any sampling scheme, in order to provide reliable data, will have to be at the same small-scale mosaic level. Plot size, in other words, must be small enough so that each plot consists of but one unit in the mosaic. When we use a plot size of one-fourth mile on a side, as we did in the discriminant analysis above, each plot contains a great many mosaic units. In future work, then, we will use more and smaller plots. For each plot we will need to determine degree of deer use: -- this will be done by winter observations, pellet-group distribution, and evidence of deer use on plant species. Such data, subjected to the discriminate analysis method, should provide us with a firm basis for mapping the whole lakeshore below 2500 ft. with regard to present, potential, and post-flooding deer habitat.

Literature Cited:

Fritschen, L. et al. 1973. Climatological studies.
Appendix D. Biotic Survey of Ross Lake (1972). Vol. 2. 58 pp.

Morrison, D. G. 1974. Discriminant Analysis, in Robert Ferber, Handbook of Marketing Research. New York: McGraw Hill.

Raedeke, K. J. et al. 1972. Deer Populations and Deer Range.
Appendix E. Biotic Survey of Ross Lake (1971) Vol. 1. 30 pp.

Stevens, W. F. 1973. Deer Populations and Deer Range. Appendix.
Biotic Survey of Ross Lake (1972). Vol. 2. 26 pp.

4. Data Compilation

4.1. Introduction:

During the course of the past years of study, a considerable amount of information has been compiled about the Ross Lake ecosystem. Much but by no means all of this information has been included in annual reports. Some of the unreported information will be useful in the development of a mitigation plan. Therefore we have undertaken to convert it into a form that is readily useable. During this past study period, a major object of the work has been to sort through the past studies, and identify that material that is necessary for the completion of mitigation plans, and to standardize, and improve on the data that has been collected. A brief summary of this work, and the end products now available follows.

4.2 Vegetation maps:

Since the development of our first vegetation map we have obtained new photographic imagery, so a more detailed and refined map of the vegetation associations is now possible. During this past year, Dr. Hollis Barber revised the original vegetation type map produced during the early stages of these studies. His work consisted of redefining the vegetation units; the enlargement of the original map to standard USGS 1:24,000 map scale by use of the Bausch and Lomb ZOOM TRANSFER SCOPE: checking the map for acoracy with the use of new photographs; and the preparation of a final map. This final map has had the large solar radiation grid imposed upon it, and so can readily be used to subdivide the area into working units.

4.3. Deer observations:

During the initial stages of this research, intensive field observations were made of the seasonal distribution of the deer of the Ross Lake basin. These sightings, along with those of other fauna of the area were recorded on sighting cards, and also on large scale maps. Much of this date has been summarized in earlier reports. The cards are on file in the Ross Lake Data Files, along with the original maps of these sightings. Since these sightings were recorded on several different maps, of varying scales, it has been necessary to replot this information on standard USGS 7 1/2 minute maps. These are compatible with our other maps. The deer observations are now plotted on maps that include the vegetation units, deer range areas, and also the solar radiation grid.

4.4 Deer Winter Ranges

Since the major focus of the past few years has been on the deer winter range areas, we have compiled all possible information on these areas, and plotted these on large scale (1:6,000)maps.

These maps include the following:

1. Vegetation units
2. Deer range areas
3. The solar radiation grids, both the 1/2 mile and 1/8 mile.
4. Other information when available

Additionally, on several of the ranges we have plotted the deer sighting, and solar radiation values for winter dates, as a graphic aid in the analysis of this data.

4.5 Solar Radiation Grids:

The solar radiation grids have been adopted as the coordinate system with which we can relate the various types of information collected to date.

This grid has now been included on all maps produced. The grid system allows us to compare many types of information at the same time, as for example in the discriminant analysis covered in the previous section. This grid will be the basis for any future sampling.