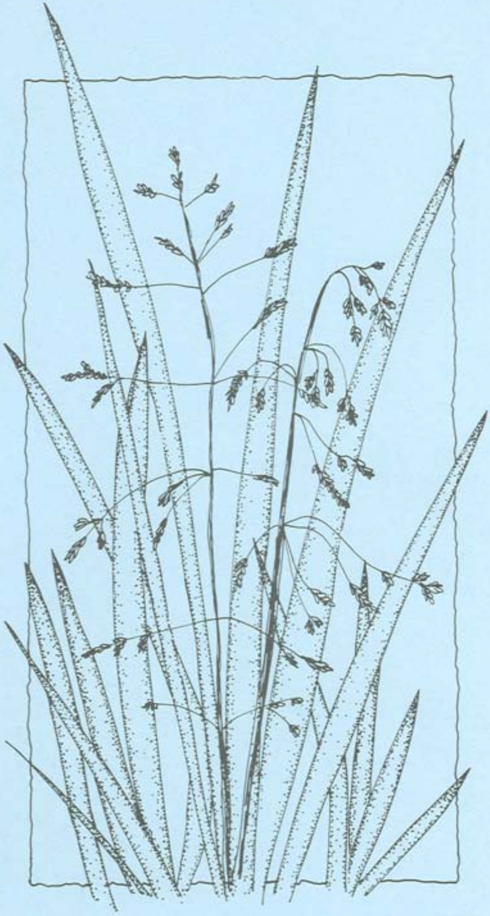
REVEGETATION WITH ARCTOPHILA FULVA

Final Report 1985 ~ 1989



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Alaska Department of NATURAL RESOURCES

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Executive Summary

From 1985 to 1989, the Plant Materials Center and ARCO, Alaska conducted studies investigating techniques for transplanting Arctophila fulva (Arctic Pendant grass). These studies were large in scope but small in scale. Even so, the studies have shown that it is possible to transplant Arctophila, however, the economic feasibilty of transplanting remains uncertain.

The study tried to identify the most successful transplanting technique which had the least impact on the donor community. The following points describe this technique: 1) Arctophila should be harvested with a potato fork and separated into clumps consisting of several shoots, roots and rhizomes; 2) plantings made with clumps have had higher survival and vigor than plantings with a smaller, single sprig planting unit; 3) plantings should occur at sites with minimal wave energies and preferably at sites with a relatively firm lake bottom; 4) an inflatable raft should be used to facilitate planting if walking in lakes is difficult; 5) each clump should be anchored to the substrate with one or two jute mesh staples, and fertilized; 6) harvesting and planting is best conducted by teams of two; 7) plantings can occur in either the fall or the spring, however, harvesting is easier in the fall.

Although progress has been made in identifying planting techniques, many issues need a more thorough investigation. The best formulation for the fertilizer needs to be determined. The rate that clumps spread needs to be studied so that planting densities can be defined and success standards need to be developed.

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Acknowledgements

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Also, Dawnelle Sheaver has been particularly helpful preparing the multiple drafts of this document.

Introduction

In 1985, the Alaska Plant Materials Center (PMC) in cooperation with ARCO Alaska, began investigating the feasibility of transplanting the emergent grass, Arctophila fulva. The scope of the study was limited both in the time allocated for the project and the extent that various parameters were investigated. The study was never intended to be an exhaustive study of ecological characteristics of Arctophila fulva and its population ecology. Rather, this study was a cursory investigation of the species and its potential for revegetating natural or man-made lakes, waterfowl habitat enhancement and mitigation. Final evaluations for the initial phase of this study were conducted in 1989.

The study began by investigating selected baseline ecological parameters of Artophila fulva communities. Data were collected on water depths and percent cover in selected communities, and chemical and physical properties of the substrate. Limited investigations on planting techniques were also initiated. These early efforts tried to determine an acceptable planting unit and identify methods for harvesting and transplanting Arctophila.

In 1986, investigation of techniques for transplanting Arctophila fulva became the primary focus of the study. The study remained focused on the harvest, preparation and transplanting of Arctophila through 1989.

Initially, PMC and ARCO staff conducted the transplanting, however in 1987 and 1988, general labor crews were trained to harvest and transplant Arctophila. The crews were timed for different steps of the transplanting process. This information should help determine the feasibility of a large-scale revegetation project. No plantings were made in 1989 so that the previous plantings could be evaluated and the success of the previous work could be assessed.

The report is divided into three sections; baseline ecological studies, Arctophila planting techniques and impacts to donor communities. Methods, results and discussions will be discussed for each section and conclusions for the entire study will occur at the end of the report.

Selected Baseline Ecological Studies

METHODS

In 1985, line transects were established to collect the baseline data from the Arctophila communities. Water depths, species of live plants, plant litter and unvegetated areas were recorded at one meter intervals along the transects.

A soil probe was used to collect 16 ounces of soil from the lake at selected sites along each transect. Multiple collections were necessary to provide sufficient soil for analysis. The shallow depth of thaw and unconsolidated substrates in some lakes made soil collections difficult at times. The samples were analyzed by the Agriculture and Forestry Experiment Station Soils Lab for particle size: percent clay, silt and sand; and nutrients: NH_4, NO_3, total N, P, K, pH and organic matter. Soil samples were also collected from proposed planting sites, CPF2 Lake, Pipeline Lake and Minesite D and copared with the samples collected from Arctophila communities.

Transects were placed in three to four Arctophila communities in each of the four study lakes. Figure 1 shows the location of the baseline ecology study sites as well as the harvest and planting sites. Although most transects were oriented perpendicular to the shoreline, some transects were oriented on other axes if a different orientation helped sample the diversity of the Arctophila communities. As a result, transects often intersected sparse stands of Arctophila, unvegetated areas, and Arctophila stands again. Depths of water to the substrate were measured at meter intervals along the transects. The species of vegetation intercepted by the transect at the meter interval were also recorded. Percent cover was calculated using all sample points, unvegetated areas included.

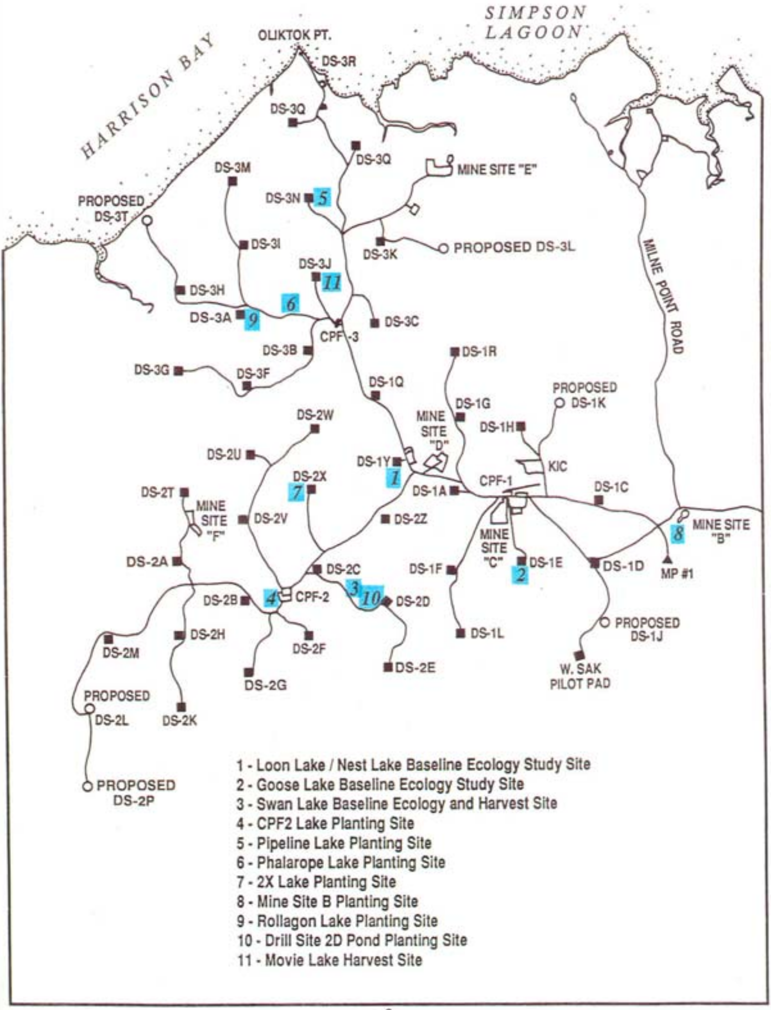
Water samples were also collected for chemical analysis from four sample points, two within vigorous Arctophila communities and two from potential planting sites. At each sample point, pH was measured in the field with litmus paper. The water samples were collected from the lake surface and from approximately 45 centimeters below the surface.

In August, 1986, stem densities were counted along three of the four transects that had been established at Swan Lake in 1985. The number of live stems were counted in one quarter meter square plots. A minimum of five equally spaced plots were counted on each transect. Percent cover for Arctophila, Hippuris sp. and Carex sp. were also recorded.

Swan Lake was selected as the site to measure stem density because transects were already established and the soil tests suggested that Swan Lake has some similarities to those conditions that may be encountered when revegetating mine sites or other disturbed areas.

KRU Arctophila Study Sites - 1985 ~ 1989

Figure 1. Location of Study Sites



RESULTS

The following narrative describes the transect locations in the four study lakes sampled in 1985. Seasonal variations in cover exist and therefore cover would have been higher if it had been recorded in August.

Loon Lake

Loon Lake is an elliptically shaped lake located southwest of the 1-Y workpad (Figure 2). The Arctophila communities in Loon Lake were small, semi-circular shaped communities along the shoreline extending 12-16 meters towards the center of the lake. On June 27, 1985, transects were established perpendicular to the shoreline in four communities on the western lakeshore. Water depths increased quickly with distance from the shore. Arctophila was found growing in water to a maximum depth of 81 centimeters on transect 1 and litter was present in water 86 centimeters deep (Figures 3, 4, 5, and 6).

Arctophila cover ranged from 27 to 42 percent in the four transects and Arctophila litter ranged from 21 to 42 percent. Sedge (Carex sp.) was the only other plant recorded in the Loon Lake transects (Table 1). Sedges occurred along the lakeshore.

Soil samples were collected at two and ten meters from the shore for each transect. Soils in transects 1 and 2 contained slightly more sand than those in transects 3 and 4 (Table 2). Soils from transect 3 contained a higher percentage of clay and organic matter. The high organic matter and also high total nitrogen values, 80.15 percent loss on ignition and 108.0 total N ppm, respectively, may have resulted in erosion of the organic mat along the edge of the lake (Table 3).

Figure 2. Loon Lake / Nest Lake Study Sites

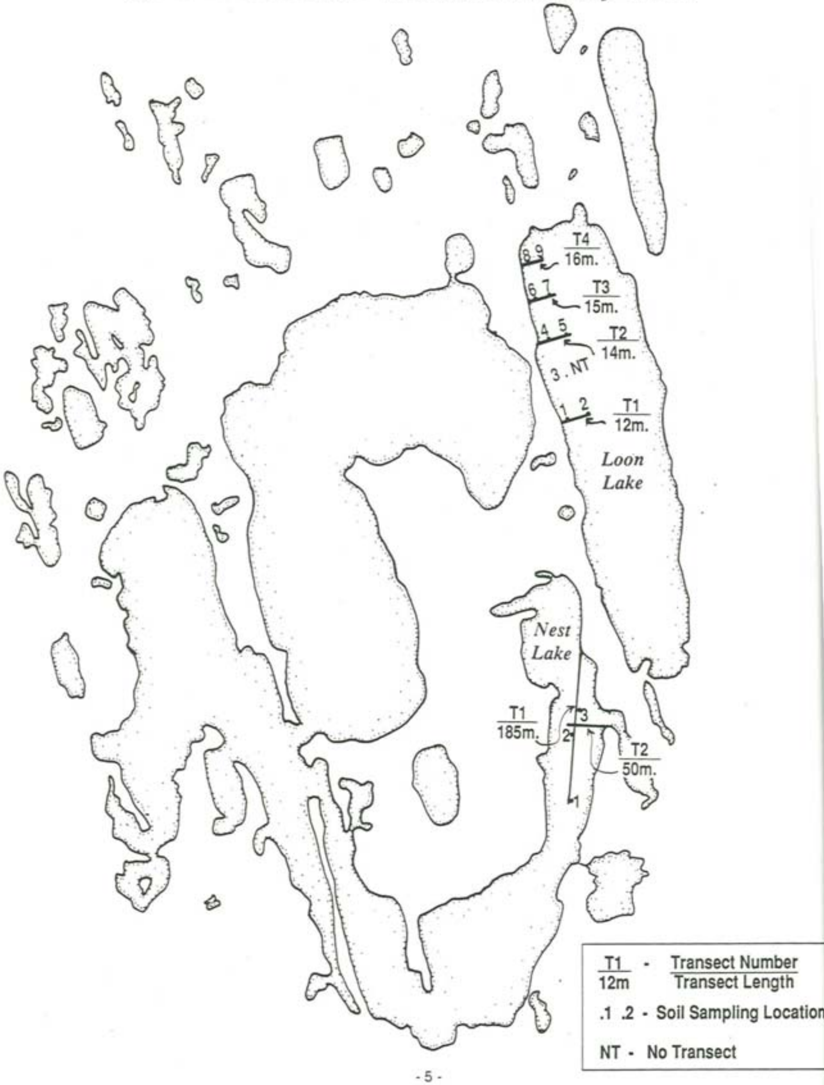


Figure 3

Water depths and species composition at meter intervals on Transect 1 at Loon Lake.

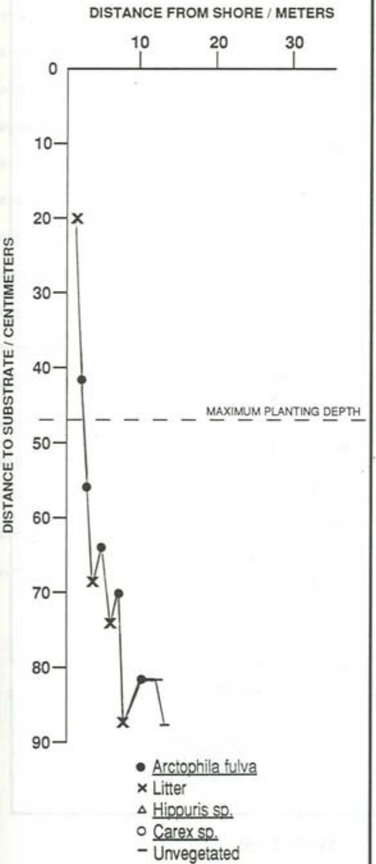


Figure 4

Water depths and species composition at meter intervals on Transect 2 at Loon Lake.

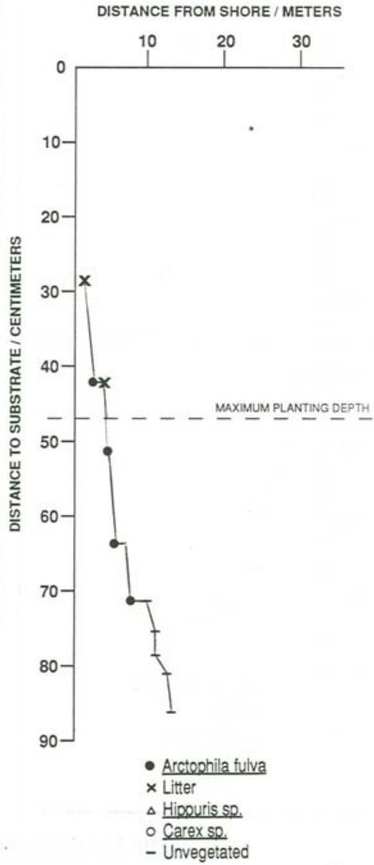


Figure 5

Water depths and species composition at meter intervals on Transect 3 at Loon Lake.

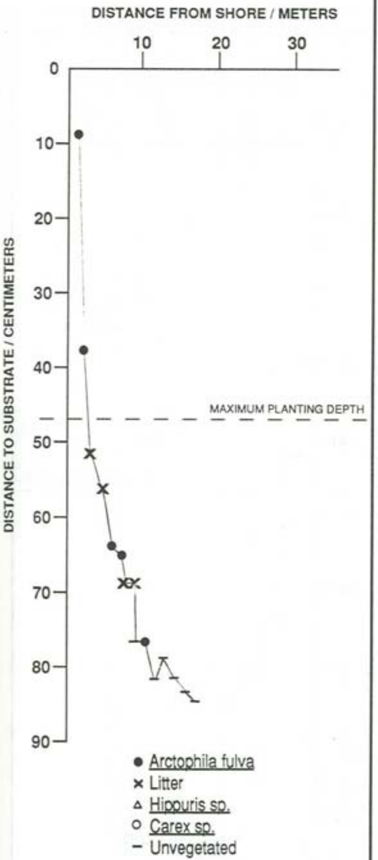
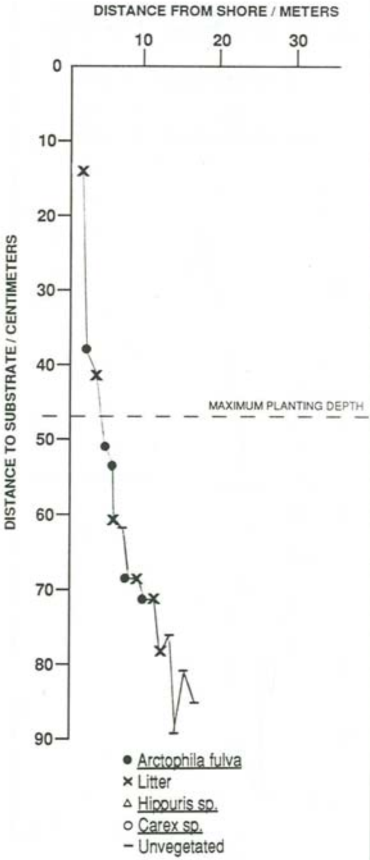


Figure 6

Water depths and species composition at meter intervals on Transect 4 at Loon Lake.



KRU Arctophila Study - 1985-1989

Table 1. Total Plant Cover (Percent) Found on Transects in Late June, Early July, 1985. KRU Arctophila Study 1985 - 1989.

	Arctophila fulva	Arctophila Litter	*Carex sp.*	*Hippuris sp.*	No Vegetation
Goose Lake T_1	10		3		87
Goose Lake T_{2a}	35	6	5		53
Goose Lake T_{2b}	35	8	25		35
Goose Lake T_3	63	29	6		13
Nest Lake T_1	32	30		14	40
Nest Lake T_2	32	56	10		4
Loon Lake T_1	42	42			17
Loon Lake T_2	29	21			50
Loon Lake T_3	27	27	7		40
Loon Lake T_4	31	38			31
Swan Lake T_1	42	34	3	19	12
Swan Lake T_2	45	24	3	29	16
Swan Lake T_3	52	52	5	5	5
Swan Lake T_4 total	36	33	12		27
Swan Lake T_4 east	31	21	5		53
Swan Lake T_4 west	38	38	15		17

Table 2. Particle Size of Soil Samples Collected From Transects and Potential Planting Sites. KRU Arctophila Study 1985 - 1989.

Soil Sample Location	Percent Sand	Percent Silt	Percent Clay
1[1] Loon Lake T_1	-	too organic	-
2 Loon Lake T_1	52.0	33.6	14.4
3 Loon Lake	68.0	25.8	6.2
4 Loon Lake T_2	69.0	5.6	25.4
5 Loon Lake T_2	63.6	9.9	26.5
6 Loon Lake T_3	-	not enough soil	-
7 Loon Lake T_3	48.6	41.1	10.3
8 Loon Lake T_4	33.4	20.0	46.6
9 Loon Lake T_4	50.4	41.0	8.6
1 Goose Lake T_1	28.4	60.4	11.2
2 Goose Lake T_1	37.1	50.5	12.4
4 Goose Lake T_2	39.1	47.4	13.5
5 Goose Lake T_2	31.6	49.2	19.2
6 Goose Lake T_2	29.6	57.2	13.2
7 Goose Lake T_3	40.0	51.6	8.4
8 Goose Lake T_3	-	not enough soil	-
1 Swan Lake T_3	32.4	51.4	16.2
2 Swan Lake T_3	90.0	4.8	5.2
3 Swan Lake T_2	79.6	14.2	6.2
4 Swan Lake T_2	81.0	11.4	7.6
5 Swan Lake T_4	74.4	15.0	10.6
6 Swan Lake T_4	79.8	13.4	6.8
1 Nest Lake T_1	64.4	26.4	9.2
2 Nest Lake T_1	39.6	53.2	7.2
3 Nest Lake T_2	-	not enough soil	-
Samples From Potential Planting Sites			
1 CPF2 Lake	89.6	4.8	5.6
2 CPF2 Lake	88.4	6.0	5.6
1 Pipeline Lake	84.4	8.0	7.6
1 Mine Site D	60.8	26.4	12.8
2 Mine Site D	72.8	18.4	8.8

[1] Corresponds with points on transect maps.

ble 3. Nutrient Content of Soil Samples Collected from Transects and Potential Planting Sites. KRU Arctophila Study 1985 - 1989.

mple Location	pH	NH_4 ppm	NO_3 ppm	Total N ppm	P ppm	K ppm	% loss on ignition
Loon Lake T_1	6.22	36.8	47.8	84.6	18.4	51	71.37
Loon Lake T_1	7.12	62.8	<.1	62.8	.8	50	49.94
Loon Lake T_1-T_2	7.22	80.4	<.1	80.4	.7	73	53.72
Loon Lake T_2	6.55	23.6	.9	24.5	.6	49	59.92
Loon Lake T_2	7.01	68.5	6.0	74.5	.6	48	54.80
Loon Lake T_3	6.43	47.5	60.5	108.0	14.7	48	80.15
Loon Lake T_3	7.08	15.3	.6	15.9	.6	45	54.57
Loon Lake T_4	6.19	23.5	1.9	25.4	.9	43	62.11
Loon Lake T_4	7.40	33.0	2.0	35.0	.4	93	57.76
Goose Lake T_1	7.69	49.3	<.1	49.3	.5	60	37.14
Goose Lake T_1	7.78	20.5	<.1	20.5	.8	36	30.01
Goose Lake T_1	7.69	35.7	1.6	37.3	.8	71	59.75
Goose Lake T_2	7.56	7.6	<.1	7.6	.4	56	40.74
Goose Lake T_2	7.16	28.4	.9	29.3	1.1	18	60.81
Goose Lake T_2	6.86	35.0	<.1	35.0	.8	45	36.81
Goose Lake T_3	6.84	84.0	<.1	84.0	1.1	76	48.88
Goose Lake T_3	6.47	21.8	<.1	21.8	2.4	55	52.98
Goose Lake T_3	6.57	9.1	.8	9.9	1.0	38	46.56
Swan Lake T_3	7.27	45.9	5.6	51.5	.4	97	40.93
Swan Lake T_3	7.40	<.1	<.1	<.1	2.4	10	3.49
Swan Lake T_2	7.22	1.6	<.1	1.6	.8	16	6.60
Swan Lake (near intersection T_1 & T_2)	7.15	3.2	1.7	4.9	.7	13	6.18
Swan Lake T_4	7.29	<.1	<.1	<.1	<.1	18	3.77
Swan Lake T_4	7.35	1.5	<.1	1.5	1.4	14	4.65
Nest Lake T_1	7.42	57.0	<.1	57.0	.5	87	37.97
Nest Lake T_1	7.60	14.3	.5	14.8	.4	50	46.88
Nest Lake T_2	7.03	32.3	.2	32.5	1.6	262	55.08

mples from Potential Planting Sites

CPF2 Lake westside	7.59	1.3	<.1	1.3	2.0	13	1.17
CPF2 Lake eastside	7.40	3.1	<.1	3.1	1.4	14	4.53
Pipeline Lake	7.61	2.3	<.1	2.3	<.1	28	1.52
Minesite D	7.57	1.0	12.4	13.4	.8	25	5.33
Minesite D	7.84	1.0	5.6	6.6	.5	31	1.49

Sample locations are marked on the map for each study site.

Nest Lake

Nest Lake lies slightly south and west of Loon Lake (Figure 2). Nest Lake has an irregular shoreline and contains several Arctophila communities of various sizes and apparent vigor.

Two transects were established at Nest Lake. Transect 1 began at a point halfway down the eastern shore and ran for 50 meters through a small, sparse Arctophila community at the shoreline, across an unvegetated area and finally through an extensive community. Transect 2 ran for 185 meters perpendicular to the shoreline and intersected Transect 1 at the 100 meter point (Figures 7 and 8).

Arctophila cover for both Transects 1 and 2 was 32 percent. Litter cover was 30 and 56 percent, respectively. Sedge, Carex sp., had a cover of 14 percent on Transect 1 and 10 percent on Transect 2 (Table 1). One section of the Arctophila stand on Transect 1 contained a dense mat of roots and rhizomes suspended a few inches above the lake bottom. This mat could support the weight of a person. This was the only site where this observation was made during this study.

Considerable variation occurred in the substrate profile in this community. Water depths ranged from 14 to 69 centimeters (Figures 9 and 10). These water depths fall within the range of rooting depths for Arctophila, so it appears that if conditions are favorable the community could expand into the unvegetated areas.

Three soil samples were collected from Nest Lake. Chemical and particle size analyses were performed on all samples except one which lacked sufficient soil for particle size analysis. The sample obtained from the margin of the Arctophila community, was sandier than the sample collected from the center of the community (Table 2). Since Arctophila plants reduce wave action, the heavier sand particles could settle out along the edges of the community.

Comparison of the soil chemistry showed two notable differences in nutrient content. Sample 3 contained three or more times the potassium and phosphorus than the other two samples from Nest Lake. Sample 3 was taken from a section of the community where the Arctophila was blooming profusely, and one of the effects of higher levels of phosphorus is to encourage flowering.

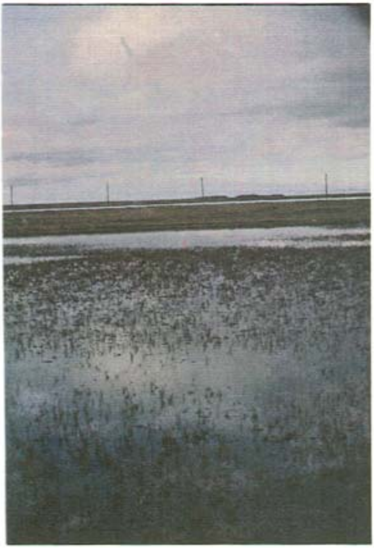


Figure 7. Transect 2 at Nest Lake, July 1, 1985.
Looking from shore towards the intersection with Transect 1.

Figure 8. Transect 2 at Nest Lake, mid-August, 1985.
Notice the increase in plant cover that has occurred in six weeks.

Figure 9

Water depths and species composition at meter intervals on Transect 1 at Nest Lake.

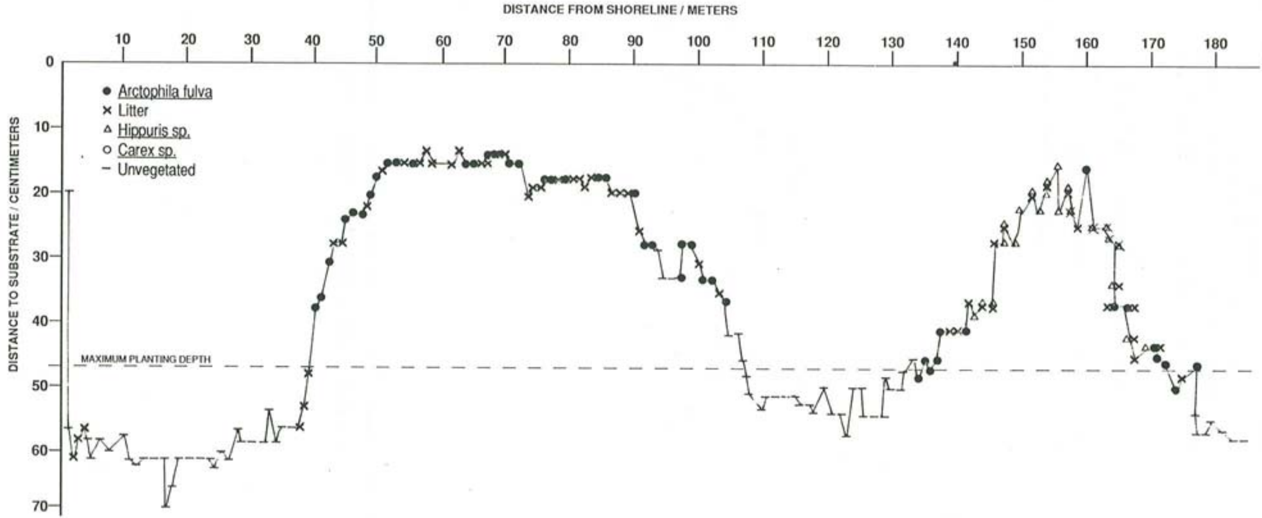


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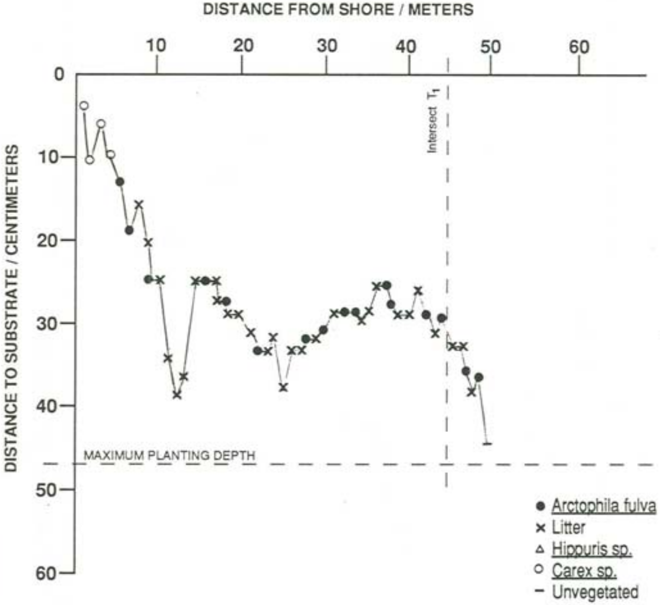
Figure 10

Water depths and species composition at meter intervals on Transect 2 at Nest Lake.



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Goose Lake

Goose Lake, southwest of drill pad 1E is also a large lake with an irregular shoreline. Sampling was limited to the Arctophila communities in the northwestern portion of the lake (Figure 11). These communities are small to moderate in size.

Three transects were established at the Goose Lake study site (Figure 12). Transect 1 ran through a sparse Arctophila community; only a ten percent cover was noted for Arctophila, and no litter was recorded (Table 1).

Nine soil samples were collected from Goose Lake. Soil samples from Transect 1 were slightly more alkaline and more silty than other samples. However, these differences do not seem to be an adequate explanation for the sparse community, especially since nutrient content of these samples is similar to other samples from Goose Lake transects. One possible explanation is that the community is young and in the initial stages of establishment.

Transect 2 was divided into a northern and southern section; the two sections which were separated by a small peninsula. Part of the peninsula was composed of relatively dry tundra and appeared to be a well utilized resting area for shorebirds and waterfowl. Water depths do not appear to be a limiting factor for Arctophila all Goose Lake transects (Figures 11, 13, 14 and 15). Some factor other than water depth must be determining whether or not Arctophila occurs at certain points. All of the water depths measured on these transects were within the range of water depths known to support the growth of Arctophila.

Total cover for Arctophila on both the northern and southern parts of transect 2 was 35 percent; litter cover was 8 and 6 percent respectively, and sedge, Carex sp., had 25 and 5 percent cover respectively.

Soil samples were collected along Transect 2 for chemical and physical analysis. One of these samples (Goose Lake #4) contained a particularly low level of NH_4 and total nitrogen 7.6 ppm; also a soil sample from Transect 3 (Goose Lake #9) contained 1 total nitrogen. These samples contained moderately high levels of organic matter compared to samples taken from Swan Lake which had low nitrogen values and little organic matter. The importance of these differences is unclear since all of the sites support relatively vigorous Arctophila communities.

Soil samples from Transect 3 revealed a wide range of NH4 levels, 84 to 9.1 ppm. Sample Goose Lake #7 contained the highest level of NH4 recorded for any of the samples during the study. This sample also had a high amount of organic matter.

Many Arctophila communities found in shallow water are mixed with sedges or transition into a pure sedge community. Transect 3 at Goose Lake provides an example of such a community (Figure 15). The first species recorded in Transect 3 at Goose Lake was sedge and as water depths increased, more Arctophila was recorded.

Portions of the community sampled on Transect 1 contained a dense mat of roots and rhizomes. This transect sampled one of the shallowest water depths for Arctophila communities of the study; also the highest total cover for Arctophila and Arctophila litter were recorded at this site, 63 and 29 percent respectively.

KRU Arctophila Study - 1985-1989

Figure 11. Goose Lake Study Sites

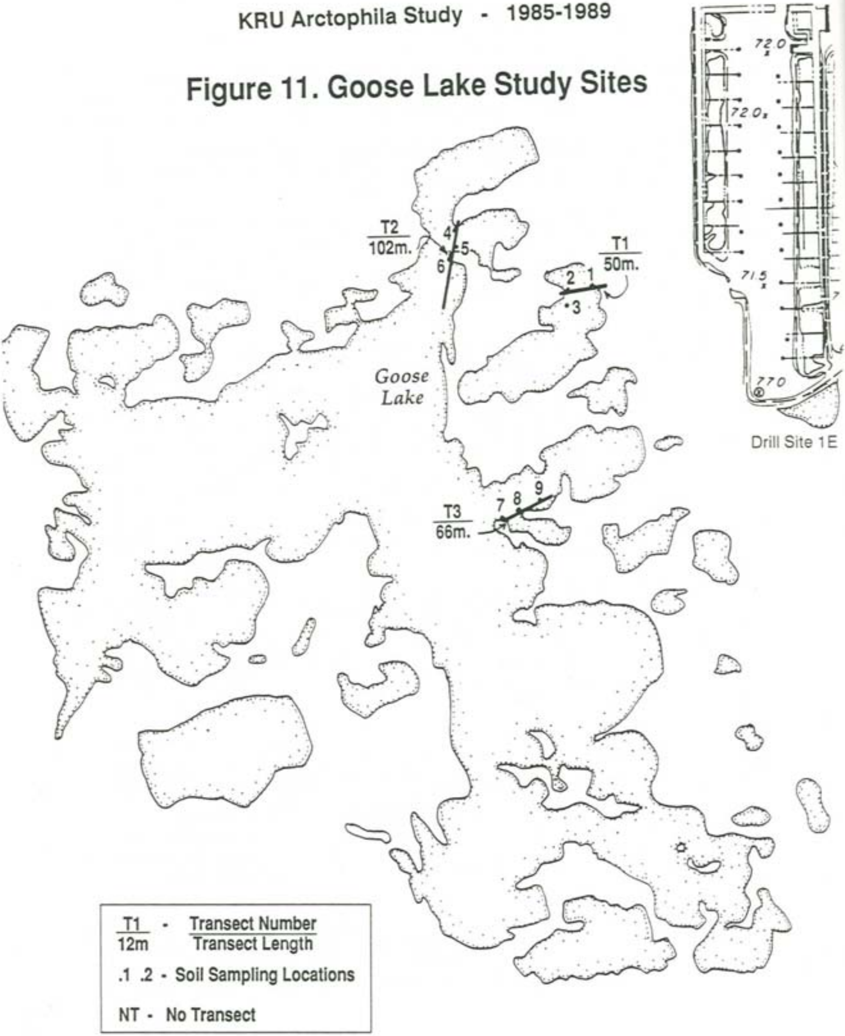
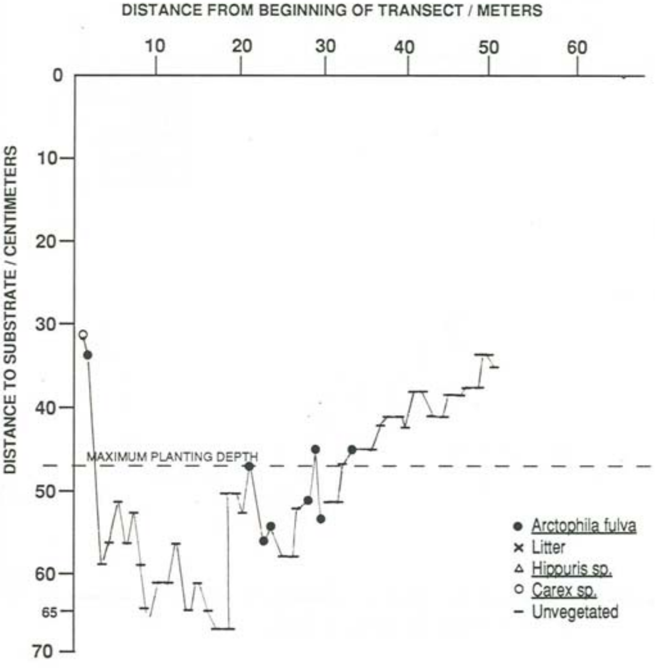


Figure 12

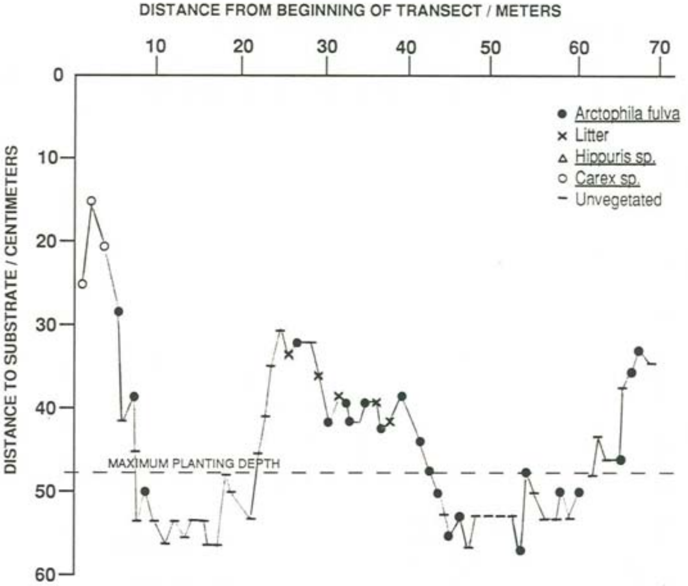
Water depths and species composition at meter intervals on Transect 1 at Goose Lake.



KRU Arctophila Study - 1985 ~ 1989

Figure 13

Water depths and species composition at meter intervals on Transect 2 (southern part) at Goose Lake.



KRU Arctophila Study - 1985 ~ 1989

Figure 14

Water depths and species composition at meter intervals on Transect 2 (northern part) at Goose Lake.

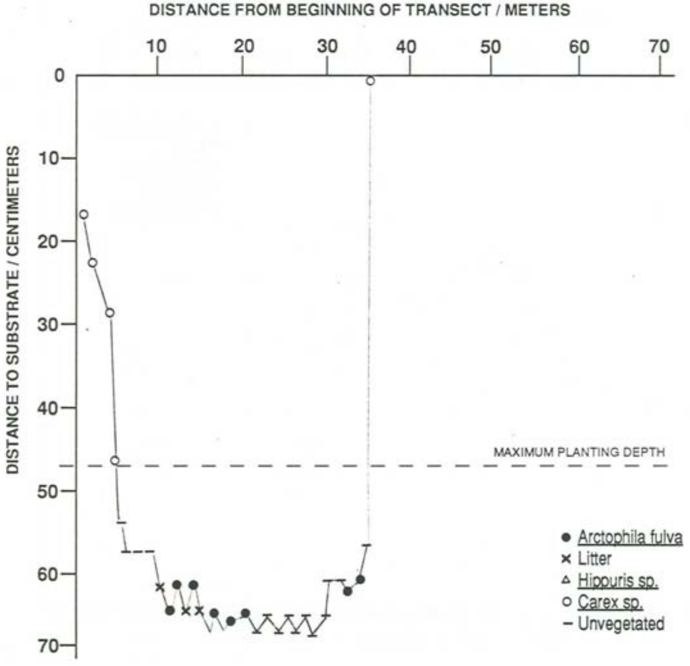
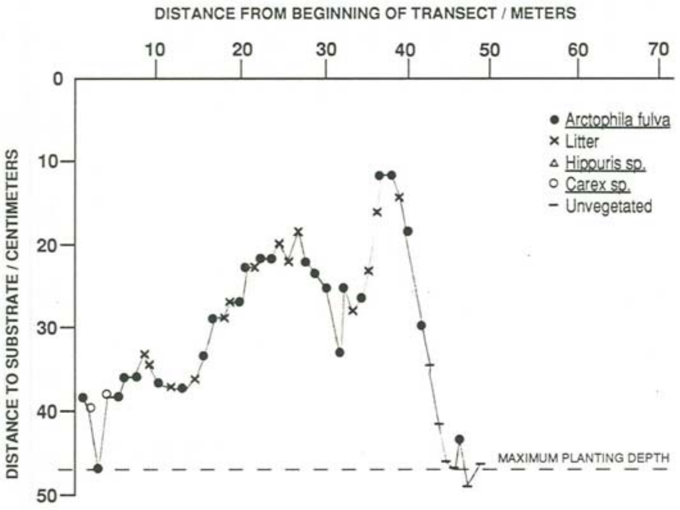


Figure 15

Water depths and species composition at meter intervals on Transect 3 at Goose Lake.



KRU Arctophila Study - 1985-1989

Swan Lake

Swan Lake is a large, elliptically shaped lake with minor variations in the shoreline. The most distinctive feature of the lake is a long, vegetated peninsula parallel with the western shore of the lake (Figure 16). Considerable waterfowl activity was observed in the lake (Figures 17 and 18). Four transects were located in Arctophila communities in the southern part of the lake.

Transect 1 ran for 76 meters from one shoreline to the other across a small bay containing an Arctophila community (Figure 19). Water depths fluctuated from 5 to 39 centimeters. Arctophila was recorded throughout the range of depths along the transect, whereas sedge was recorded only in water 15 to 34 centimeters deep and was found only near the shore. Transect 2 ran perpendicular from the shoreline towards the center of the lake and intersected transect 1. Hippuris sp. was recorded at depths of 12 to 34 centimeters. Water depths on Transect 2 were highly variable (Figure 20). Arctophila was recorded at depths ranging between 14 and 56 centimeters and Hippuris sp. was recorded at depths ranging from 7 to 55 centimeters. Fifty five centimeters is the greatest depth recorded for Hippuris in this study. No sedges were recorded on Transect 2.

Arctophila cover for Transects 1 and 2 was 42 and 45 percent respectively, while litter cover was 34 and 24 percent, and Hippuris sp. was 19 and 29 percent. Sedge cover was 3 percent for both transects. These communities contained more Hippuris sp. than any other communities sampled in this study.

Six soil samples were collected from Swan Lake. These samples contained more sand than those collected from other communities and they contained very little organic matter (Tables 2 and 3). Analysis for both particle size and nutrient content of soil samples collected from Swan Lake, unvegetated areas and potential planting sites (CPF2 Lake, Pipeline Lake and Mine Site D) exhibited similarities. Although these data are limited, these comparisons are encouraging because they suggest that the potential planting sites may contain suitable substrates for the growth and establishment of Arctophila.

Transect 3 ran for 21 meters perpendicular to the shoreline towards the center of the lake. Initially, water depths increased with distance from shoreline, however, six meters from shore the transect crossed a meter-wide mud bar covered by very shallow water (Figure 21). Beyond the mud bar, the water depths again increased steadily to the outer edge of the Arctophila community.

Swan Lake soil sample 1 from Transect 3, contained more silt and organic matter than other soil samples collected from Swan Lake (Tables 2 and 3). The sample was taken from a shallow part of the community with good vegetative cover. It should be noted that the sample point may have been a site where fine mineral particles and detritus were deposited. Deposits of this type may be common in many Arctophila communities. As stated earlier, Arctophila plants reduce wave action which then allows suspended particles to settle (Figure 22), a process which may have formed the mud bar.

Transect 4 was a two-part transect with an eastern and western section. The center point was a mud bar colonized primarily by sedge interspersed with a few Arctophila plants. The eastern part of the transect ran through a sparse Arctophilla community towards the center of the lake. Water depths on the eastern transect increased quickly from the shore to the edge of the community. The water depths on the western transect increased more gradually than on the eastern transect. Carex sp. only occurred in the shallow water along the shoreline (Figure 23).

KRU Arctophila Study - 1985-1989

Figure 16. Swan Lake Study Site

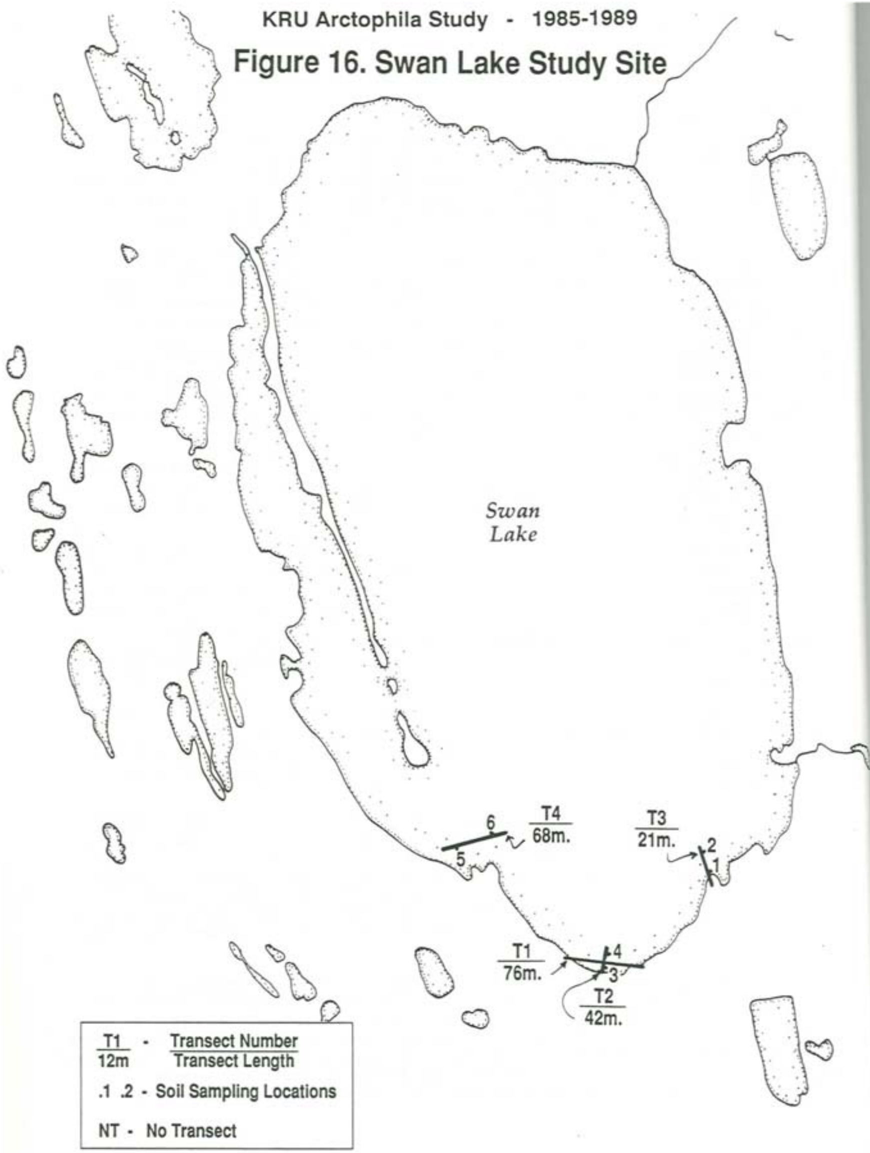
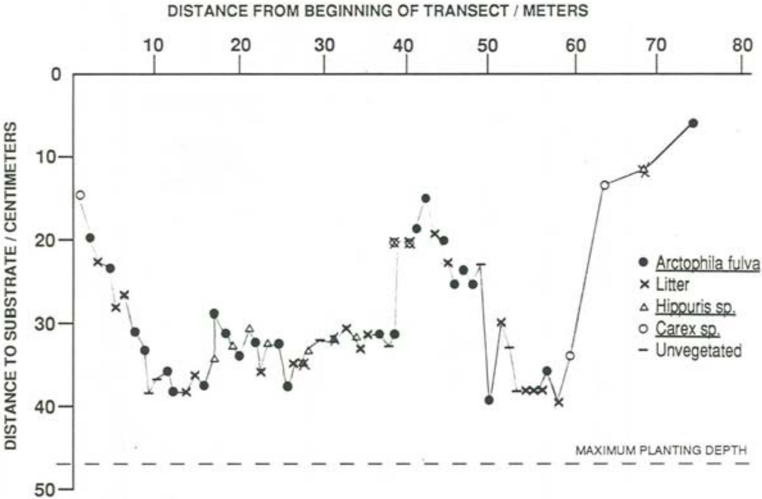


Figure 17. Swans were observed at Swan Lake every year of the study. Three of those years, the swans were rearing young.

Figure 18. Arctophila communities in which waterfowl were observed, contained small areas where the new spring Arctophila growth was found detached from the plant and floating in the water. It is not understood why this occurred since none of the plants appears to have been eaten. This may be the result of feeding on some other organisms found on the plants.

Figure 19

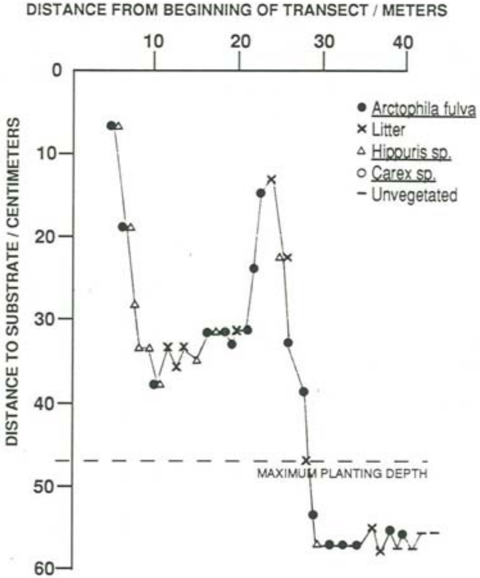
Water depths and species composition at meter intervals on Transect 1 at Swan Lake.



KRU Arctophila Study - 1985 ~ 1989

Figure 20

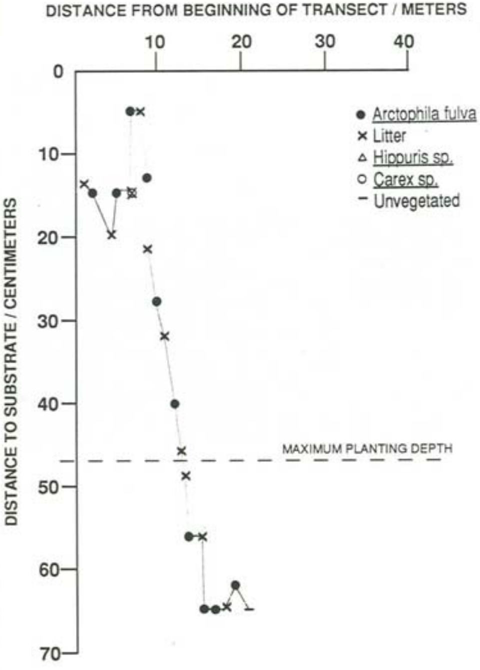
Water depths and species composition at meter intervals on Transect 2 at Swan Lake.



KRU Arctophila Study - 1985-1989

Figure 21

Water depths and species composition at meter intervals on Transect 3 at Swan Lake.

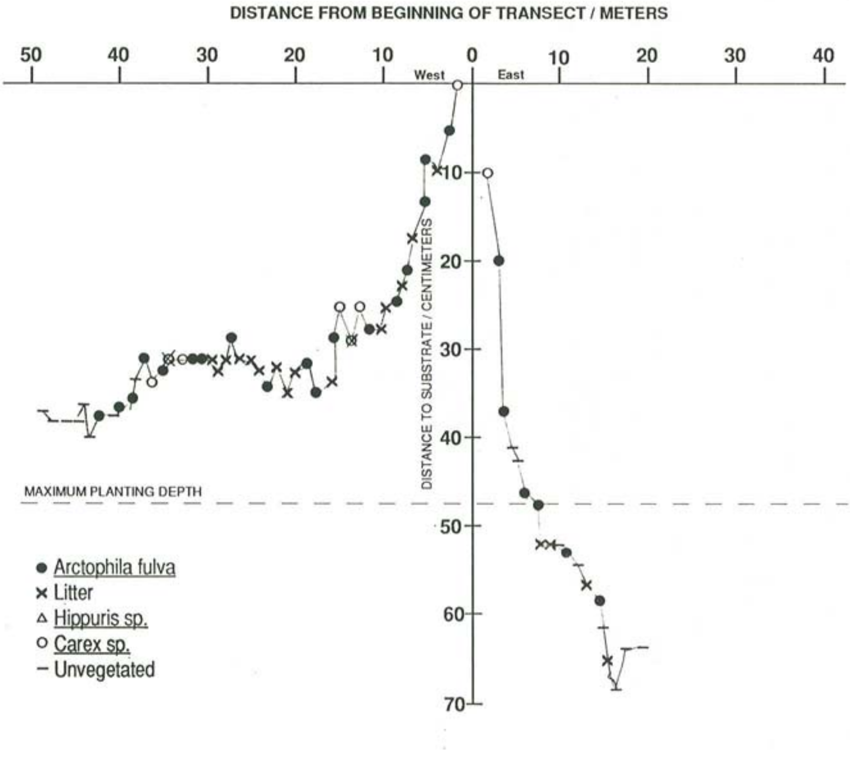


KRU Arctophila Study - 1985-1989

Figure 22. An example of the wave dampening effect of an Arctophila stand.

Figure 23

Water depths and species composition at meter intervals on Transect 4 at Swan Lake.



KRU Arctophila Study - 1985-1989

The western section of Transect 4 had a greater total vegetative cover than the eastern section; Arctophila cover was 38 and 31 percent respectively, litter cover was 38 and 21 percent respectively, and Carex sp. cover was 15 and 5 percent, respectively (Table 1). Shallower and possibly warmer water and protection from some wave action may account for the higher cover measured on the western transect. The analysis of soil samples collected from Transect 4 showed unusual trends (Tables 2 and 3).

In 1986, stem densities were counted in one quarter meter square plots along three of the transects established at Swan Lake in 1985. Densities ranged from 1 to 269 stems per quarter meter square with a mean of 54 stems.

In 1986, stem densities were counted in one quarter meter square plots along Transects 1, 3 and 4 established at Swan Lake in 1985. Densities ranged from 1 to 269 stems per quarter meter square with a mean of 54 stems.

Since the water depth data and density measurements were collected during two different years along the same transect, they should not be directly correlated. A general pattern does emerge, however, and can be seen in the data from Transects 1 and 3; stem densities are highest for areas with water depths ranging from 5 to 20 centimeters (Figures 24, 25 and 26). Data on stem densities found in natural communities will aid the development of planting guidelines and success measurements for large-scale Arctophila plantings.

Figure 24. Transect 1 at Swan Lake measuring stem densities and percent cover of Arctophila and percent cover of other plant species per .25² meter plot.

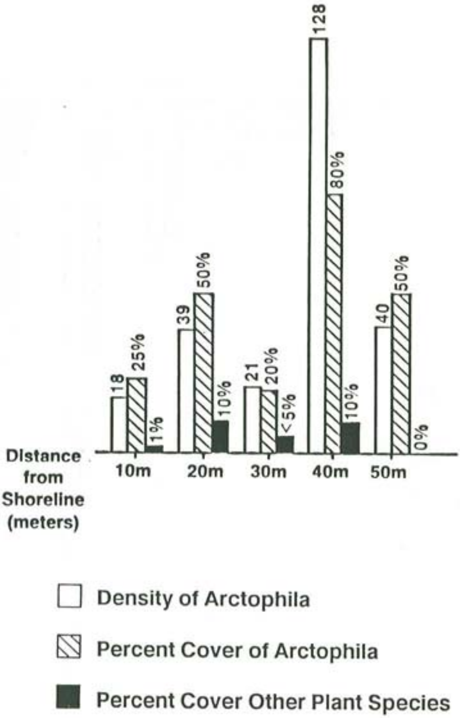


Figure 25. Transect 3 at Swan Lake measuring stem densities and percent cover of other plant species per .25² meter plot.

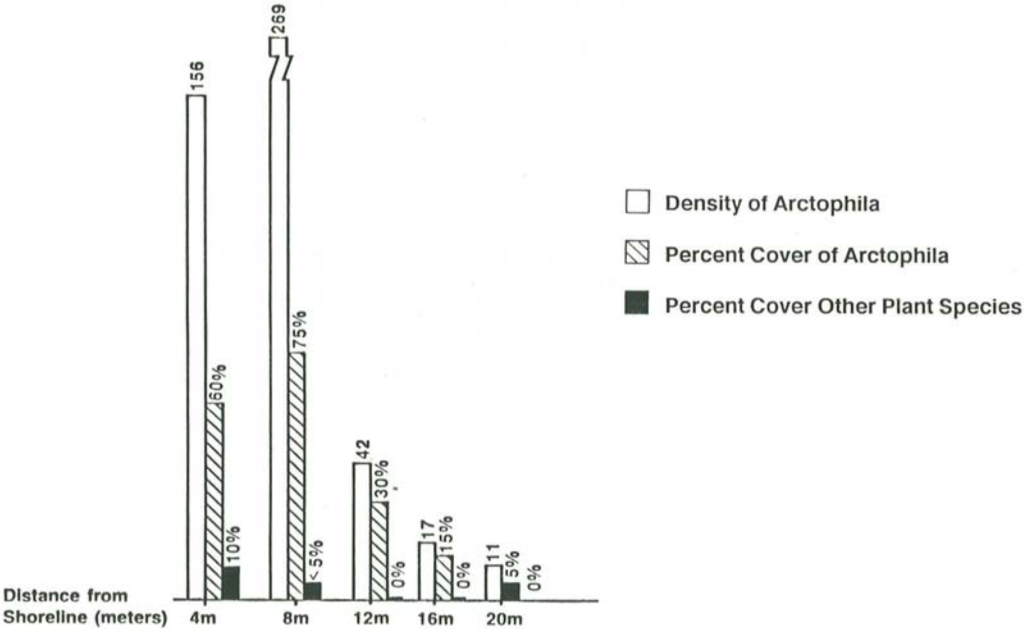
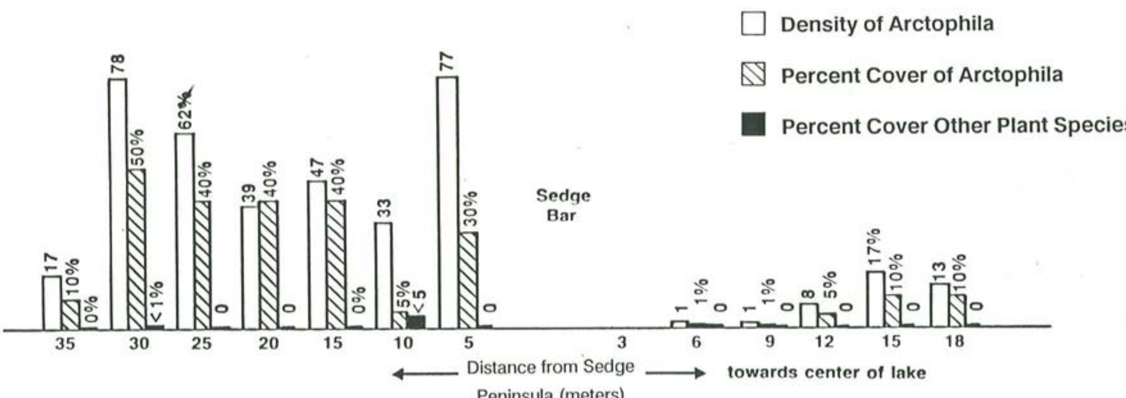


Figure 26. Transect 4 at Swan Lake measuring density and percent cover of Arctophila and percent cover of other species per .25² meter plot.



Water Analysis

Water samples were collected from four areas, two Arctophila communities, Swan Lake and Goose Lake, and two areas representative of potential revegetation sites, CPF2 and Mine Site D. The sites were sampled to determine if any important differences in water quality existed between sites that supported Arctophila communities and potential revegetation sites. The only apparent difference occurred in analysis of the Mine Site D water samples, in which the specific conductance was substantially higher than any of the other samples (Table 4). Although the value of 470 umhos/cm should not present a salinity problem (personal communication, Charles Newling, U. S. Army Corps of Engineers, Waterways Experiment Station).

	Swan Lake Deep	Swan Lake Shallow	Goose Lake Deep	Goose Lake Shallow	Mine Site D Deep	Mine Site D Shallow	CPF2 Lake Deep	CPF2 Lake Shallow
pH (laboratory)	7.68	7.82	7.78	8.10	7.70	7.82	7.98	7.99
Specific conductance (umhos/cm)	295	300	230	220	470	470	145	144
Alkalinity mg/l $CaCO_3$ (to pH 4.5)	116	121	75.6	72.0	77.5	78.1	51.9	51.9
Phosphorus (P) mg/l	0.045	<0.01	0.01*	<0.01	0.055	<0.01	0.01*	<0.01
NO_3-N mg/l	0.2*	0.2*	0.2*	0.4*	5.5	6.1	0.2*	0.3*
NH_4-N mg/l	0.64	0.80	0.67	0.67	0.43	0.31	0.68	0.74
Kjeldahl Nitrogen mg/l	1.90	1.60	1.32	1.25	1.57	1.31	1.28	1.00
Organic Nitrogen mg/l	1.26	0.80	0.65	0.58	1.14	1.00	0.60	0.26
Potassium (K) mg/l	1.01	1.05	0.51	0.58	2.66	2.68	0.51	0.51
Calcium (Ca) mg/l	43.3	42.4	31.4	29.5	42.9	42.8	24.0	24.1
Sodium (Na) mg/l	9.6	4.5	9.0	9.0	23.6	23.9	4.8	4.7
Magnesium (Mg) mg/l	4.4	4.5	3.9	3.8	15.2	15.6	2.2	2.2
Manganese (Mn) mg/l	<0.05	<0.05	<0.05	<0.05	0.08*	0.08*	<0.05	<0.05
Zinc (Zn) mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Iron (Fe) mg/l	0.51	0.43	0.20	0.20	0.61	0.68	0.20	0.20
Copper (Cu) mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

* Indicates values that are at or near the detection limit for the procudure used.

Arctophila Plantings

INTRODUCTION

The first Arctophila transplantings were conducted on a small scale and more out of curiosity than part of an experimental planting. Each year, the plantings became more extensive and were designed to investigate many of the aspects of transplanting Arctophila.

In 1985, a small number of sprigs were planted at two sites with different conditions. A larger scale planting was conducted in 1986 by PMC and ARCO staff. By 1987, it was apparent that a general labor crew was needed to conduct these plantings in order to determine the economic feasibility of a large-scale revegetation project. ARCO contract laborers harvested, prepared and planted the Arctophila sprigs in the spring and fall of 1987. Again in 1988, we utilized a labor crew for planting, but this time the laborers came from the PMC.

The evolution of techniques for Arctophila transplanting occurred on three fronts simultaneously. New planting and harvesting techniques were being developed and a minimum planting unit was being defined.

Each annual planting will be discussed in the following sections.

1985 Planting

Arctophila fulva is strongly rhizomatous and this characteristic makes this species appear to be an excellent candidate for transplanting. Only a few plants were transplanted for this first planting.

Two lakes were selected for the 1985 planting sites. One lake, CPF2 Lake, did not contain Arctophila communities, whereas the second lake, Pipeline Lake, located on Oliktok Point Road, contained numerous Arctophila communities. An unvegetated area adjacent to an Arctophila community at Pipeline Lake, was selected for the planting site.

On July 2, 1985, 25 fresh APU's were planted along the eastern shore of CPF2 Lake and 21 fresh APU's were planted at Pipeline Lake. Also, 19 three-day old APU's were planted adjacent to the fresh plantings at CPF2 Lake.

The planting unit (APU) consisted of a culm and a new shoot (Figures 27 and 28). A potato harvesting fork seemed to be the best tool for harvesting the plants. The fork would rip up an entangled mat of shoots and roots which were then separated into planting units. Preparation of the APUs required twice as much time as the digging process. Therefore, two persons were needed to separate and prepare APUs for each person digging plants. Digging and preparation of 100 planting units took 3/4 of a man-hour.

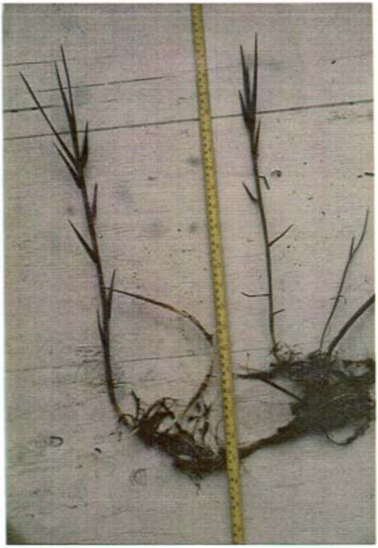


Figure 27. An Arctophila plant. Note rhizome and numerous new shoots. This plant can be separated into at least two Arctophila planting units (APU's).

Figure 28. Close up of the rhizome, new shoot and the root system of an Arctophila plant. This is enough plant material to make one APU.

The trial plantings occurred in water depths of 45 centimeters or less. This depth was chosen because a majority of the Arctophila recorded on the transects, grew within this water depth.

During the growing season, strong winds often occur and create considerable wave action on the lakes. This water movement makes it difficult to plant APUs with the assurance that they will remain in place. To resolve this problem, six-inch jute mesh staples were used to secure the APUs to the lake bottom. The staples appeared to work very well with little or no apparent damage to the plant.

Additional plantings were conducted during August, 1985. Fifty nine APUs were planted with staples at CPF2 Lake. At Pipeline Lake, 26 APUs were planted with staples and 25 were planted without staples.

Approximately ten minutes was needed to plant 45 - 50 APUs for both the spring and fall plantings. We believe this planting rate could also be achieved by laborers if they were planting in similar conditions.

1986 Planting

Instead of using a general laborer planting crew, two ARCO employees helped two PMC staff plant five Arctophila plots (Figure 29). The sprigs were harvested from Swan Lake. Harvesting was difficult because the depth of thaw was shallow and most of the roots were still imbedded in ice. The plants were separated into individual sprigs and placed in plastic sacks for transport to the planting site at CPF2 Lake. The sprigs were planted the same day that they were dug.

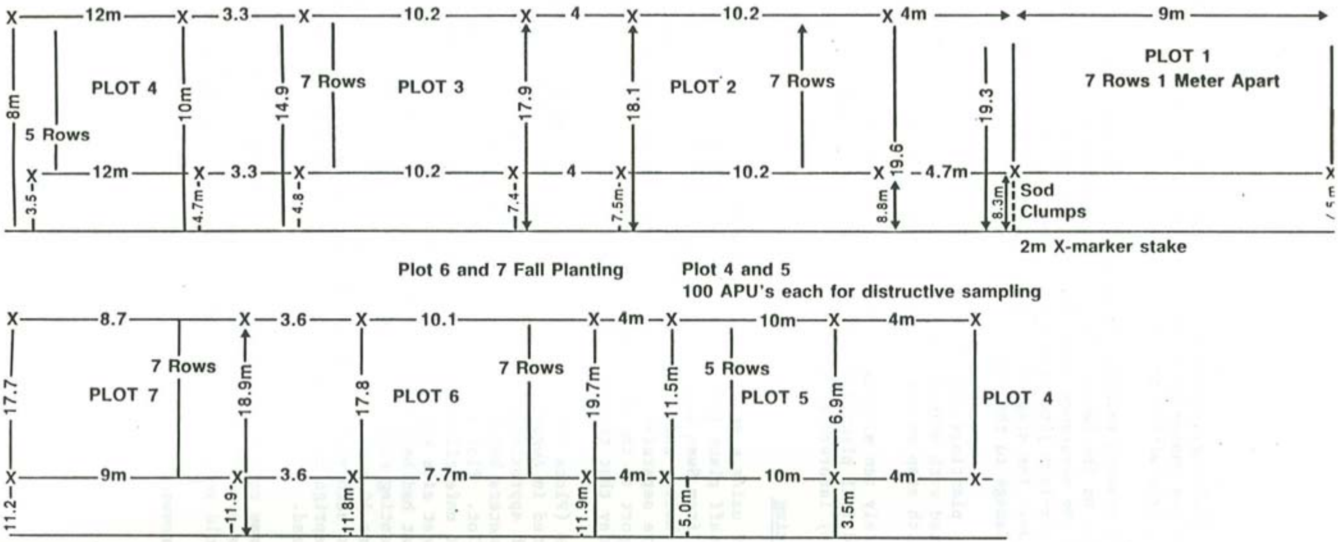
Five plots (Plots 1-5) were planted in the spring and two additional plots were planted in August. Plot size varied, but plantings were made in rows of 20 with approximately one meter between plants in each row, and one and one half meters between rows. Plots 1 and 2 were planted with 140 sprigs in each plot. Plot 2 was fertilized with 21-10-5 Agri-form* tablets; Plot 1 was left unfertilized. No effort was made to match planting water depths with harvest site water depths. However, plot 3 was planted with 140 sprigs that had been harvested from water that was shallower than the water at the planting site. Plots 4 and 5 were planted with 100 sprigs with the intent that 10 sprigs would be dug each year to photo document Arctophila growth for each year of the study. In the fall, plots 6 and 7 were planted with 140 sprigs each, one plot was fertilized and the other was left unfertilized.

Planting was conducted by two teams consisting of two people. One person would take a sprig and lay it on the surface of the water. The other person would secure the sprig to the lake bottom with a six-inch staple.

* No endorsement implied.

Figure 29. Plot Plan for 1986 Arctophila Plantings.

CPF - 2 Lake
Arctophila Plots



If the sprigs were fertilized, a tablet was dropped in the water next to, but not touching, the sprig. The tablet was stepped on so that it would become embedded into the lake bottom and remain in place.

All of the plantings were made at CPF2 Lake which does not contain any Arctophila communities. Time did not allow for the plantings to be replicated in a lake that contained Arctophila communities.

Discussion of 1985 and 1986 Plantings

A greater percentage of the 1985 plantings survived at Pipeline Lake than at CPF2 Lake, but the initial vigor of the plantings appeared to have been greater at CPF2 Lake (Table 5). Several factors may account for differences in survival between the two planting sites; 1) wave energies appeared to be greater at CPF2 Lake than those at Pipeline Lake; 2) differences in the physical and chemical properties of the substrate, including nutrient cycling and nutrient availability; and 3) freeze-thaw patterns in the lake.

Survival of the 1986 plantings over the first growing season ranged from 61 to 66 percent. No important differences were apparent between treatments, although initial observations suggested that vigor may have been slightly higher for those plants that were fertilized. The high mortality that occurred for the plantings removed any possibility to investigate the effects of fertilizer at this site (Table 6).

The greatest mortality appeared to have occurred during the winter or during spring break-up. Wind-generated ice movement during break-up may have uprooted the sprigs.

Evaluation of these plantings became a low priority after 1987, because they exhibited low survival, poor vigor and most importantly, new plantings were established that were more relevant to the study. However, Pipeline Lake was visited in August 1990, the plantings were impossible to identify since natural invasion appeared to be occurring in the vicinity. Whatever the source of Arctophila may have been, none of the stems appeared to be vigorous. They were alive but not thriving.

Table 5. Survival of 1985 Arctophila Plantings. KRU Arctophila Study, 1985 - 1989.

Location	Spring Planting: Fresh APU's	Spring Planting: 3 Day Old APU Planting	Fresh APU's Fall Planting
CPF 2 Lake			
Number Planted	25	19	59
% Survived 8/85 Evaluation	72%	5	just planted
8/86	12	0	27
8/87	0	0	15

No further evaluations.

	Spring Planting	Fall Planting: With Staples	Fall Planting: Without Staples
Pipeline Lake			
Number Planted	21	26	25
% Survived 8/85 Evaluation	100%	just planted	just planted
8/86	52	73[1]	84[1]
8/87	24	62	72

No further evaluations.

No evaluations in 1989.

[1] - None of the plants are vigorous.

Table 6. Survival of 1986 Arctophila Plantings at CPF-2 Lake. KRU Arctophila Study, 1985 - 1989.

	Spring Planting 1986			* Fall Planting 1986
Plot Type	Plot 1 Unfertilized With Staples	Plot 2 Fertilized With Staples	Plot 3 Small APU's From Shallow Water With Staples-Fertilized	Plots 6 and 7 Half Were Fertilized All Stapled
CPF-2 Lake				
No. Planted	140	140	140	280
Percent Survival 8/86	63	66	61	just planted
Percent Survival 6/87	25	25	34	42
Percent Survival 8/87	11	19	12	8

Total number of plantings located 7/88: 7

Total number of plantings located 8/89: 12

* Plots 4 and 5 are not reported here since they were planted for destructive sampling purposes.

1987 and 1988 Plantings

After realizing the disadvantages of planting at CPF-2 Lake, new planting sites were selected for 1987. The sites for the spring planting were two small lakes, Phalarope Lake and Drill Site 2X Lake (Figure 1), which appeared to be less prone to high wave energies and their potentially deleterious effects. These lakes, however, had a more unconsolidated substrate than CPF-2 Lake which made walking difficult.

In 1987, a general labor crew was used to plant Arctophila. The intent was to determine if a crew unfamiliar with the planting technique could be trained to harvest, separate and plant Arctophila effectively.

In July 1987, APUs were harvested with a potato fork and separated into planting units, similar to the methods used in 1985 and 1986. Table 7 indicates that 64-80 APUs per hour could be harvested and prepared by this crew. Planting occurred at a rate of 40-133 APUs per hour.

PMC staff planted 100 APUs along the shore of Mine Site B. Mine Site B is representative of another type of potential planting site.

The spring labor crew harvested Arctophila rather slowly. In order for Arctophila revegetation to be feasible, a more efficient harvest technique needed to be explored. An attempt was made to use a 3-inch, portable water pump. This technique relied on discharge water to flush the substrate from the root mass (Figure 30). Once flushing was complete, clumps of Arctophila were separated from the lake bottom with a potato fork and placed in a tub. These clumps were then planted without any additional separation (Figure 31).

The Arctophila clumps were attached to the substrate with at least two staples and fertilized with two tablets. This harvesting and planting method was used during the fall planting in August 1987.

The fall planting crew consisted of two people. Harvesting Arctophila with the water pump proceeded very well. Ten tubs of Arctophila sprigs were harvested in nine man hours. There was a minimum of 50 clumps per tub (in most cases, there were more) or a minimum of 55 clumps harvested per man hour.

By fall, the substrate at the spring planting sites was too soft and difficult to walk in, so a new lake was selected for the fall plantings. This lake, Rollagon Lake (Figure 1), also contained a soft substrate, but was easier to walk in than the spring planting site. Even so, planting proceeded slowly; 36 clumps per man hour.

Table 7. Spring and Fall Harvesting and Planting Rates for General Labor Crew. KRU Arctophila Study, 1985 - 1989.

Number of APU's/Man Hour[1]

1987	Harvesting	Planting		
		Teams		
Spring Day 1	64	w/staples & fertilizer		105
		w/staples, no fertilizer		88
			Working Separately	Teams
Spring Day 2	80	w/o staples or fertilizer	60	117
		w/o staples w/fertilizer	40	107
		w/staples, no fertilizer	80	120
		w/staples & fertilizer	40	133
		Team		
Fall	≥ 55 clumps	w/staples & fertilizer	36 clumps	
		w/staples, no fertilizer	36 clumps	
1988	**Harvesting**	**Planting**		
		Team		
Fall	70 clumps	w/staples & fertilizer		110

[1]Figures do not include any supervisory time.

Figure 30. A three-inch water pump was used to flush the substrate from the root system of an Arctophila stand.

Figure 31. This clump of shoots, roots and rhizomes is ready for planting. The clump should be secured to the substrate with two staples and then fertilized.

The low planting rate in the fall was unexpected since preliminary tests had indicated that planting clumps should proceed quickly. The variations in planting and harvesting rates during spring and fall, seemed to be related more to the attitude of the laborers than the complexity of the task or the difficulty of walking in the planting area.

The harvesting and planting rates recorded for both the spring and fall labor crews seem to be too low to be cost effective. The crews were composed of summer hires with limited job experience. Productivity should be higher for a professional labor crew supervised by a company foreman.

Despite the low planting rates, transplanting Arctophila clumps appears to have several advantages; 1) large volumes of material can be harvested faster than separating APUs; 2) the clumps are not handled as intensely as an APU, thus reducing the chance of damage to the plant; 3) the clumps should contain more viable plant material which should increase survival and establishment; and 4) the clumps can be spaced further apart than APUs in order to obtain the same cover or density per unit area.

The primary disadvantage of using clumps is that large amounts of plant material are required, thus weight and volume accumulate quickly. Large stacking tubs were used to hold the plant material from the time it was harvested until the time it was planted (the filled tubs also floated so they could be towed alongside the planter). Although the filled tubs were heavy to carry to and from the harvesting and planting sites, the tubs made the volume and weight problem manageable and reduced the damage that could occur to the plants.

The 1987 spring plantings at Phalarope Lake and Drill Site 2X Lake demonstrated the importance of using staples to increase survival (Table 8). Plantings at many sites would not remain in place unless they were attached to the substrate with a staple; this was particularly true at Drill Site 2X.

The clump plantings at Rollagon Lake show a more favorable rate of survival than the APU plantings. By 1989, the long term benefits of fertilizer are also becoming apparent at Rollagon Lake (Table 8).

By the end of 1987, the techniques for transplanting Arctophila were beginning to be defined, but an important question remained: could a general labor crew effectively transplant Arctophila? A permanent or professional labor crew (as opposed to summer hires) with a company foreman overseeing the work would probably be more effective than the crews with which we had been working.

In 1988, the PMC brought four laborers from the PMC staff to Kuparuk to plant Arctophila. The thought was that the time it took this crew to harvest and transplant Arctophila probably would be a fairly accurate indication of the time needed for a large-scale transplant project.

Table 8. Survival of 1987 Arctophila Plantings. KRU Arctophila Study, 1985 - 1989.

Single Sprigs

(Spring Plantings)

	Fertilizer		No Fertilizer	
	No Staples	W/Staples	No Staples	W/Staples
Phalarope Lake				
Number Planted 6/87	200	200	200	200
% Survival 8/87	50	59	46	56
% Survival 8/88	24	45	32	40
% Survival 8/89	29	43	15	31
Drill Site 2X Lake				
Number Planted 6/87		280		280
% Survival 8/87		64		71
% Survival 8/88		22		39
% Survival 8/89		16		23
Mine Site B				
Number Planted 6/87		100		
% Survival 8/87		88		
% Survival 8/88		59		
% Survival 8/89		No data		

Clump Planting

(Fall Planting)

Rollagon Lake				
Number Planted 8/87		200		175
% Survival 8/88		65		54
% Survival 8/89		64		31

A donor community was selected at Swan Lake and the planting site was nearby in a small lake near Drill Site 2D. A machete and potato fork were used to lift the Arctophila off of the lake bottom. The plants were washed free of mud, water was drained off, they were cut into planting units, placed into tubs and hauled to the truck.

A team of two people harvested 2 to 3.6 tubs per hour for an average of 2.8 tubs per hour. Approximately 50 clumps were in each tub, therefore approximately 70 clumps were harvested per man hour (Table 8).

A team of two people planted 2 to 2.6 tubs per hour which averages 2.25 tubs per hour. Therefore, approximately 110 clumps were planted each hour. Planting was conducted from a small raft which allowed the planters to keep from getting stuck in the soft lake bottom. The raft also carried fertilizer and staples. The clumps were towed along in their floating tubs.

One way to make planting more efficient was to keep the planters supplied with plants. Too much time was wasted if the planters had to resupply themselves.

Table 8 compares the harvesting and planting rates for the various years. The only major difference can be found for the planting rate in the fall, 1987, which is considerably lower than the 1988 rate, 36 clumps compared to 110 clumps per man hour, respectively. The harvesting and planting rates for 1988 are consistent with the rates in the spring of 1987.

Considerable frustration was experienced when we first began to work with the labor crews, because the work proceeded so slowly. At first, the crews appeared to lack motivation and at times willingness to work. Now that the harvesting and planting rates have been relatively consistent with all crews, with one exception, we realize that most of the planting sites are simply difficult to work in, and that some laborers responded to the challenge better than others. Planting will occur more quickly at sites with firmer substrates and as planting techniques become more efficient.

The primary advantage of planting clumps appears to not be related to the speed with which the plants are harvested and planted, but related more to the vigor of the planting unit. Also, clumps can be spaced further apart than APU's which allows more area to be planted with the same number of planting units.

The focus of the 1988 plantings was to determine how long it takes a labor crew to harvest and plant Arctophila. The plantings were made around the edge of a large pond adjacent to Drill Site 2D. The exact count of the number of clumps planted was not recorded. Evaluation of the survival of the planting was strictly qualitative based on a photo comparison. Only one winter and one growing season passed from the time of planting until the end of this initial study. Figures 32 and 33 indicate that this planting is performing well.

Figure 32. The planting near Drillsite 2D in August, 1988.

Figure 33. The same planting one year later, August, 1989.

Donor Community Impacts

Considerable effort has been expended to determine the best technique to transplant Arctophila, but the impact of the harvesting activities on the Arctophila community also needs to be determined.

Two 10 square meter plots were set up at Swan Lake before plants were harvested in June, 1987. Cover and density measurements were made prior to harvest and every August after the harvest until the end of the study (Figure 34).

One problem with the comparison of these measurements is that plant cover and density increases substantially from June through August, so the pre-harvest measures are low compared to what the measurements would have been if they had been recorded the August prior to disturbance.

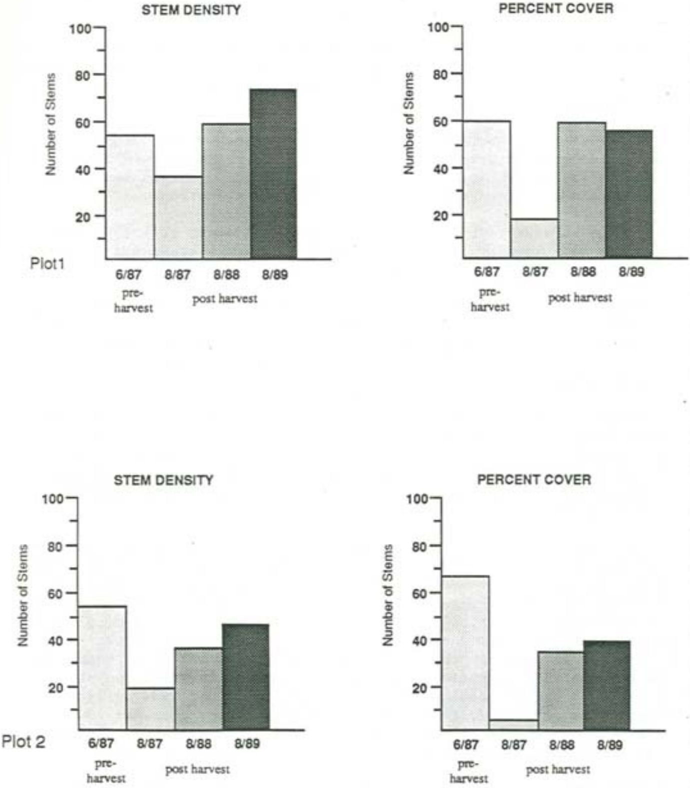
Initially, the harvest reduces the stem density and plant cover, but the data from the two plots at Swan Lake indicate that this stand has recovered quickly. Plot 1 appears to have recovered faster than Plot 2. By 1989, Plot 2 had not recovered to the June preharvest condition, whereas Plot 1 had equalled or exceeded the preharvest condition. Field notes also indicate that the plants were more robust in Plot 1 than in Plot 2. These differences are minor but it is possible that Plot 2 was harvested more intensely than Plot 1, or that the data reflect minor variations in vigor within an Arctophila community.

Six additional plots were established at another harvest site (Movie Lake, see Figure 7) to monitor the recovery of the Arctophila stand after harvest. The data from those plots are presented in Figures 33a and b. Plots 2 and 3 North were the only two plots that represented the harvest site. Arctophila was harvested with the use of the water pump, whereas plants were harvested with a potato fork at Swan Lake.

Comparison of the cover and density values for Plots 2 and 3 North does not indicate that the impact of the harvest was severe, however the Arctophila stand does not appear to be recovering even after two years. Cover and density values have also decreased from August, 1987 until August, 1989 for three of the undisturbed plots. Plot 1 North, another undisturbed plot, had the same cover for the two years, but density had decreased. Presumably, the differences in data for these plots reflect the normal variations that occur in Arctophila commumities. The data are absent for 1988, so what appears to be an overall decline may have begun in either 1989 or 1988. If the community is declining, then it is impossible to say that the lower cover and density values for the harvested plots are a result of the harvest technique or if they reflect a community that is decreasing in vigor.

Results from the plots at Swan Lake suggest that there is little to no negative impact to donor communities from harvesting Arctophila for single sprigs with a potato fork. Additional studies need to be conducted to determine what impacts occur when Arctophila clumps are harvested with a water pump or harvested with a potato fork and machete.

Figure 34 Arctophila Cover & Stem Density from the Swan Lake Harvest Site.



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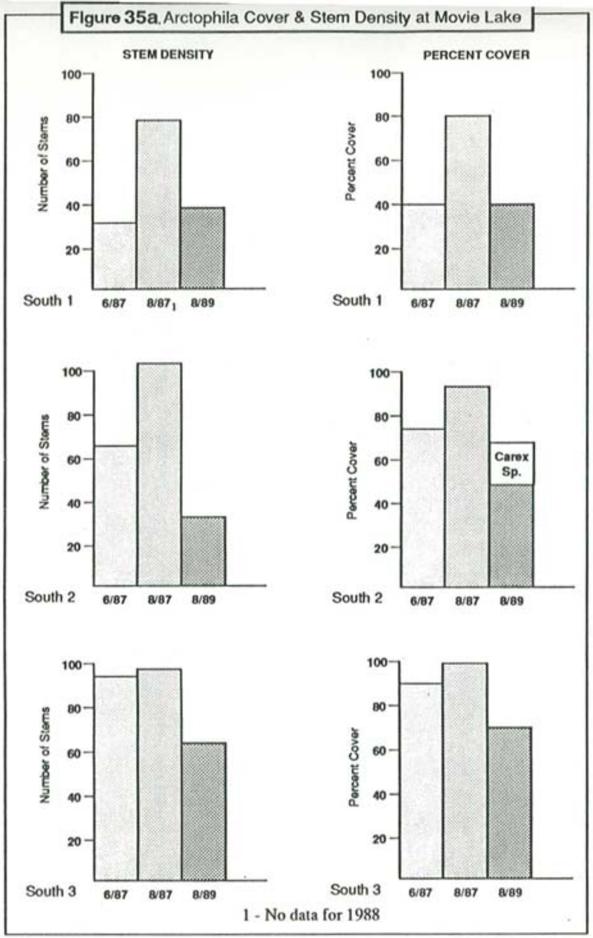

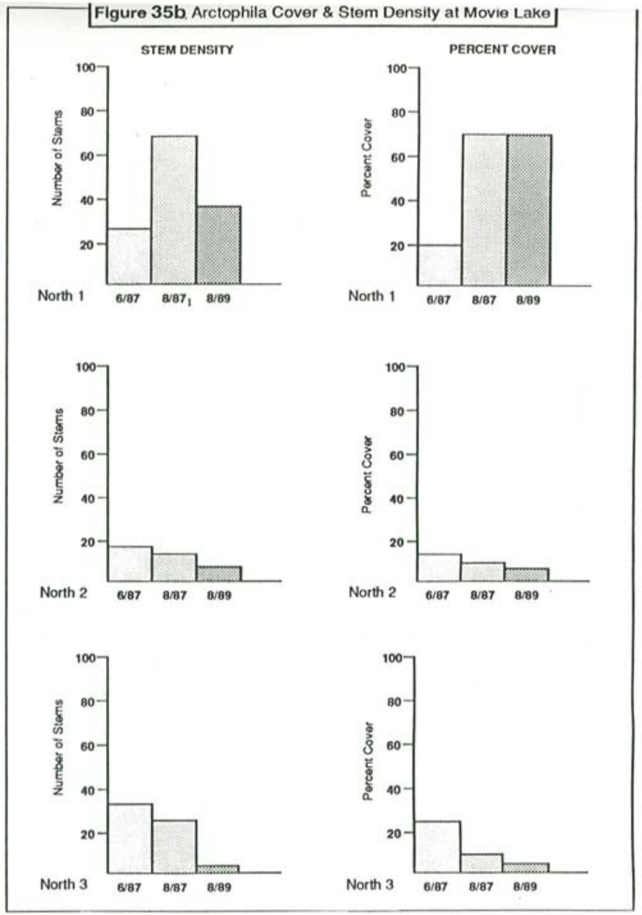

1 - No data for 1988

Summary & Conclusions

Results of the limited baseline ecological studies and transplant experiments indicate that transplanting Arctophila is feasible, however, the economic feasibility of transplanting Arctophila is still uncertain. The following will describe the points that have led to this conclusion.

1) Arctophila grows primarily within a range of water depths that are feasible for planting. Higher stem densities were found in shallower water which has important implications for large-scale planting projects.

2) Some apparently vigorous Arctophila communities grow in relatively nutrient poor conditions such as those found at Swan Lake. The chemical and physical properties found in soil samples collected at Swan Lake were similar to those from proposed planting sites.

3) At present, the preferred method for harvesting Arctophila is by potato fork and machete. Donor communities do not appear to be negatively impacted by this method. Another harvest technique which used a water pump is cumbersome logistically, particularly if a donor community does not occur near the road. Flushing the rooting zone with water appears to be more intrusive to the community than ripping up clumps of plants with a potato fork. A depression in the substrate was created with the water method that was not observed in harvest sites where a potato fork was used. However, it appeared that a more complete harvest could occur with the water method, but this would leave less remnant plant material to support the recovery of the community. Additional work needs to be conducted to determine how harvest sites should be managed and if some harvest techniques have more deleterious effects than others.

4) Most attempts of planting Arctophila with the smaller planting unit, which consisted of a culm, roots and a rhizome, resulted in plantings with low survival and vigor. A larger planting unit, a clump which consistsof several shoots, roots and rhizomes, performed much better. In addition, a clump is more likely to contain other plant species and organisms than an APU which may help to establish an Arctophila community more swiftly. Also, clumps are easier to work with because they require less work to prepare than an APU which requires careful separation.

   The limited investigations conducted so far do not indicate that there is truly an advantage of either an APU or a clump from the standpoint of the speed of harvesting and planting. The primary advantage of the clump, again, appears to be higher survival and vigor which would allow clumps to be planted at a lower density than APUs to provide the same cover per unit area. Additional investigations are necessary to determine if clumps spread more quickly than the APU. However, observations thus far suggest that will be the case.

5) A planting site must be located so that it will not be subject to high wave energies that could wash out new plantings or damage them with ice movement during breakup. The plantings at CPF2 Lake are a good example of plants destroyed by ice movement.

6) Even if a site is selected carefully for minimal wave action, the transplants should be secured to the lake bottom with a jute mesh staple. There have been no indicators in this study to suggest that the staples are deleterious to the transplants, so this security measure seems important to ensure that the transplant remains in place.

7) If possible, a planting site with a firm substrate should be selected since a firm substrate facilitates transplanting. At those sites where the substrate is unconsolidated and difficult to walk in, an inflatable raft should be used for planting.

8) Harvesters and planters seem to work best in teams of two. An additional person expedites the total planting process by keeping the planters supplied with plant material. Both harvesting and planting is a multi-step process. When the plants are harvested they need to be removed from the substrate, divided into clumps, washed free of most of the soil and placed in the tubs. When Arctophila is planted, a clump needs to be placed in the water, stapled into place and fertilized. Both of these processes proceed more efficiently when two people are working together.

   Transplanting Arctophila fulva appears to be a slow and laborious process but feasible from the biological perspective; i.e., it is possible to successfully transplant the species. However, the economic feasibility is uncertain and needs to be determined by the group that is financially responsible for the project. The transplanting studies described in this report hopefully will assist making this determination and will encourage additional studies.

9) The relatively high survival of the fertilized plantings at Rollagon Lake suggest that each transplant should be fertilized. Further studies need to be conducted to determine which formulations would provide the greatest benefit to the transplants.

10) Since Arctophila is an aquatic/emergent species, it may rely on foliar and stem absorption of nutrients. Perhaps, liquid, organic fertilizers should be studied in addition to the solid inorganics presently being studied. Liquid fertilizers would probably be most economically feasible for plantings in small ponds or lakes.

11) A study into the relationship of Arctophila and lake morphology would be of profound interest. Could it be that Arctophila is the basic building block for shoreline encroachment? Is Arctophila the parent material of the "soil" upon which Carex expands? Does the Arctophila litter and detritus produce sufficient insulation to affect the thaw depths on some lake margins? And finally, is Arctophila the initial step in converting an arctic lake into a terrestrial community? The PMC is quite interested in this prospect and feels additional study is warranted in this area.

Other questions need to be investigated that go beyond the techniques of transplanting Arctophila from one location to another. For instance, a measure of success needs to be developed. Does this success standard require that Arctophila fulva is growing over a certain percentage of a planting site after a specified time period, or does this newly created community need to function like an undisturbed community? If the latter success standard is applied, then we must learn how an undisturbed community functions. In either case, additional studies need to be conducted to help define the techniques for achieving these standards.