Quantitative Analysis of Wetlands at the University of Notre Dame Environmental Research Center

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Abstract

Using a quantitative approach, this study attempted both to discern a correlation between floral composition and chemical parameters in peatlands and to classify peatlands as bogs,fens, or cedar swamps. The study was conducted at the University of Notre Dame Environmental Research Center (UNDERC) in Land o' Lakes, Wisconsin. The study employed eight $100m^2$ sites. Within these sites, the percent cover of plant species, the diameter at breast height of trees, the acidity, and the conductivity of the peatland were recorded. Although data from all of these measurements were included in this study, the study analyzed correlations of only five of the more characteristic peatland plants to acidity and conductivity. Statistical analysis of this data showed that only Thuja *occidentalis* and *Sphagnum* moss were significant in characterizing the sites as bogs, fens, or cedar swamps. A significant correlation was also found for both *Picea mariana* and *Thuja occidentalis* to pH and conductivity gradients. *Sphagnum* moss also correlated significantly to conductivity, but only marginally to the pH gradient. *Chamaedaphne calyculata* marginally correlated to pH, but showed not correlation to conductivity.

Introduction

Scientific analysis of wetlands has been actively undertaken since the early nineteenth century (Naismith 1807, Dau 1823). Because many early studies of wetlands revealed certain plant community gradients corresponding to underlying hydrological and chemical gradients, scientists have long attempted to classify wetlands primarily by plant species. Subsequent classifications which have arisen from these studies have been based on limited data and have ignored other important factors which influence the formation of these gradients (Bridgham et al. 1996). This data has portrayed a rather descriptional approach to the study of wetlands. Recently, wetland ecologists have attempted to redefine these relationships and terminologies by improving their understanding of the underlying science and by developing a universal terminology (Bridgham et al. 1996).

In the modern general sense, a wetland is defined as an ecotone, or transitional area between the terrestrial and aquatic systems in the topography of a region. Three descriptive criteria indicate the presence of a wetland. The most important of these is the presence of water at or near the surface of the soil for at least a portion of the year. Hydric, or reduced soils also denote wetlands. Because hydrophytic vegetation are adapted to life in water-logged conditions, these plants are the third criteria utilized to indicate a wetland.

Historically, wetlands have been subdivided into various categories consisting of swamps, bogs, fens, marshes, moors, and muskegs (Gore 1983). These terms have become problematic, owing to their subjective definitions by various scientists. In response to this dilemma, Gore (1983) and Bridgham (1996) suggest that the terms mire or peatland should be used when referring to a peat-forming wetland without prior knowledge of specific biotic and abiotic factors. Peatlands are present in the location of UNDERC, and will be the focus of this study.

If some of the parameters of a peatland are known, the site may be further classified as a bog or fen. A bog refers to a peatland of low pH and alkalinity and features *Sphagnum* moss as a common plant species. A fen refers, conversely, to a peatland of greater pH and alkalinity, and contains more coniferous and deciduous trees (Bridgham et al. 1996). The most important factor in structuring a peatland is the underlying hydrology of the site (Bridgham et al. 1996). Peatlands may be either ombrotrophic or minerotrophic. Ombrotrophic peatlands, owing to their raised peat dome, receive water primarily through precipitation. This water is typically low in nutrients. Minerotrophic peatlands receive a geogenous water supply which commonly has a higher amount of nutrients. These two hydrologic terms, ombrotrophic and minerotrophic, are commonly thought to determine the division of peatlands into bogs and fens, respectively (Gore 1983). This relationship is also controversial for many wetlands ecologists, including Bridgham (1996), who challenge this ontogenical relationship and find that bogs and fens do not necessarily follow this distinction.

There are many different variables that scientists consider when studying the properties of or classifying a specific wetland. Correlating factors such as pH, alkalinity, and mineral cation concentrations are often indicative of the presence of certain plant communities. For instance, it has been found that in northwestern European mires, sites with rich fen vegetation have a pH in water of over 5.5, while bog water shows a pH below 4.0 (Malmer 1986). In fact, one of the main distinctions today between bogs and fens is acid, mineral-poor soil conditions for the former , and less acid or alkaline mineral-rich conditions for the latter.

Correlating to pH concerns, mineral cation concentrations of such elements as nitrogen, calcium, sodium, and potassium can be studied to reveal how they control the growth of peatland plants. Ca^{2+} specifically is important in many ways in determining the species present in peatlands. Ca^{2+} associates with bicarbonate and forms a buffering system, thereby controlling the pH of many peatlands. In addition, high levels of Ca^{2+} at low pH have been shown to be toxic to several species of Sphagna (Bridgham et al. 1996). Different species in a peatland can be tested in how they respond to cations like $Ca^{2+}$and other specific elements. This can be a valuable indicator as to how these minerals affect the peatland plants, and to what kind of species can be found in certain chemical environments.

In relation to these chemical considerations, hydrology of a peatland is often studied as a determinant in classification. Hydrology is accepted as an important force in controlling the structure and nature of wetlands. The source of water into a peatland regulates its soil and water chemistry. Thus, an increase in minerogenous waters generally corresponds to higher pH, higher cation concentration, higher nutrient availability and better productivity (Bridgham et al. 1996). The main separation between bogs and fens often lies in the origin and chemistry of their respective water supplies. The distinctions between ombrotrophic (rain-fed) bogs, and minerotrophic fens have been noted above. It has been recognized, however, that the distinction between bogs and fens is also often attributed to the presence or absence of certain "fen indicator plants" (Gorham and Janssens 1992). Classifications which are based only on vegetative structure have limited value for wetland ecology (Gore 1983).

Since many different organic and environmental factors can vary independently, close relationships of species to single habitat factors are rather rare.

In fact, most of the data that exists is correlational. There is some connection between mire vegetation and chemical factors. Chemical factors, however, are not always decisive in determining the composition of mire vegetation. Water level, water movement, aeration, peat texture, acidity, and various nutrients affect the success of different mire vegetation (Gorham 1950). All of these factors and their interrelations must be studied to gain a clear picture for classification. Because of this complex coordination of many variables, there are obvious difficulties in setting up strict boundaries for classification of different wetlands.

During the twentieth century there have been many attempts to classify peatlands using chemistry, hydrology, and plant communities as a basis. No strict classification has been achieved, and perhaps the most helpful studies have determined various factors governing plant distribution in specific sites (Gorham, 1950). Detailed and comprehensive research on environmental factors and plant distribution within small areas reveal a great deal more about the relations between plants, chemistry, and hydrology, than do studies based from a wide range of separated communities. UNDERC provides an ideal habitat for this kind of research. In this study, experiments will be performed to collect data on many different variables in certain well defined localities. Plant communities, acidity, and conductivity of peatlands will all be examined in detail, and relations between these variables will be understood in the framework of a single locality.

Materials and Methods

To initiate this study, peatlands were located based on visual observation of typical peatland plant species and hydrology. A total of 8 sites were constructed during the summer. When a peatland was found, a $100m^2$ permanent site was established using 7ft wood stakes with bright orange markings at both the northwest and southeast corners. If the location of the site was not visible from a trail or road, orange flagging was used as markers on trees as a guide to the site. Within each of these $100m^2$ sites, three $4m^2$ plots were randomly established using blue flags. These plots were labeled A, B, C on the flags. The location of the plots within the $100m^2$ site was determined using a random number table (Rohlf and Sokal, Table 10). Numbers from the table were used as distances from the southeast corner of the site to the southeast corner of a $4m^2$ plot. This method performed well excepting that the number 9 could not be utilized because the it would have placed half of the $4m^2$ plot outside of the $100m^2$ site. Although peat core samples were taken from within the $100m^2$ site, care was taken to avoid sampling within the $4m^2$ plots because of the resulting disturbance to the surface vegetation. Acidity and conductivity measurements were taken either in open water in the $100m^2$ site or within the hole created by the peat corer. Conductivity was measured in microsiemens per centimeter and was adjusted to account for the free hydrogen ion concentration in the water.

Plant community and biomass analysis was performed on three different levels. Within the $100m^2$ site, the percent cover and the diameter at breast height (DBH) for all trees of DBH greater than 0.5 cm was recorded. Two of the sites studied were heavily forested cedar swamps. In these sites, DBH was not recorded due to the great number of trees. In each of the $4m^2$ plots, the percent cover of all the plants was recorded. The shrubs in these plots were divided into those greater than 1.4 m and those less than 1.4 m. Due to the difficulty of identifying *Sphagnum* species on location, ten samples of the moss was collected in even increments along the west edge of the plot for later identification in the lab. Occasionally, if the western edge did not possess significant amounts of *Sphagnum* or if a different edge displayed a hummock to hollow gradient, another edge was chosen. The *Sphagnum* samples were smaller than a quarter in diameter and were collected in sandwich bags. Many of the larger plants could be visually determined in the field after reading basic floral guides to peatlands, however, other plants were collected in Ziploc bags for identification in the lab. A voucher sample of each species was also pressed and placed in the Herbarium at Notre Dame. *Sphagnum* species were not pressed, but rather allowed to dry in their natural configuration. They were then carefully placed in envelopes or Ziploc bags for transport back to Notre Dame. Pressings of all the species in the plots were utilized in constructing a teaching collection for future use at UNDERC.

Identification of the *Sphagnum* species proved to be a tedious task until familiarity with a large number of species was garnered. Unfortunately, there was not sufficient time to gain this familiarity before the research began. Familiarity with *Sphagnum* identification was not achieved until roughly half way through the summer. The use of published identification manuals, especially those by Crum and by McQueen, proved instrumental in learning the species of mosses. A list of terms involved with *Sphagnum* identification, constructed by Dr. Bridgham also aided in identification (Table 1).

Identification of other plants was facilitated by waiting to collect them when they were either in flower or fruit. Many of the keys rely on these features to identify the plants. In order to gather the plants in this state, several trips to the site were necessary throughout the course of the summer. Still, by the end of July, not all of the plants in the sites had reached either of these conditions. In general, Voss' work on the flora of Michigan proved useful in identifying plants which were in flower or in seed. N. L. Britton and A. Brown's three volume work was also useful owing to its comprehensive illustrations of all the flora. Other, more specialized works, such as Billington's Shrubs of Michigan, assisted in identifying particular groups of plants. Boughton's field guide sufficed for the identification of ferns and, likewise, Harrington's for the grasses. Wildflowers were identified by the use of Lund's and also Niering and Olmstead's field guides.

All of the sites are located on or near UNDERC property. Site #1, Degobah Fen, is 0.3 miles west of Tenderfoot Creek on the northern side off the loop road. Site #2, Ed's Bog, is on the eastern half on the property. Site #3, Forest Service Bog, is off the southeast corner of the property. Site #4, Sarah's Bog (Vernal Pond #23?), is found on the north side of the south gate entrance road (near the overhead wires), between Forest Service Bog and the Wetlab. Site #5, Cedar Swamp, is found on the Tenderfoot Creek side of the loop road on the eastern half of the property. Site #6, Enchanted Forest, is at the intersection of the loop road and the road to Cranberry Lake on the north side. Site #7, Nih Fen, is at the intersection of the loop road and the road to the gravel pit. It also is found in the north side. Site #8, Druckenbrod's Fen, is found along the road to Cranberry Lake on the southern side.

Results

This study conducted a quantitative analysis of eight peatlands located at the University of Notre Dame Environmental Research Center (UNDERC) in Land o' Lakes, Wisconsin. The eight sites were grouped into three categories (bog, fen and cedar swamp), based on the site vegetation, pH, and conductivity. Sites #3 and #4 were grouped as bogs, while sites #1,2,7, and 8 were defined as fens. Sites #5 and #6 were the only two defined as cedar swamps.

The percentage cover of macrophytes and Sphagnum mosses, the diameter at breast height for trees, and the acidity and conductivity of the eight sites were recorded. Overall, 67 plant species were identified in the eight sites (Table 2), including 10 species of *Sphagnum* (Table 3). The diameter at breast height (DBH) values were recorded for every site except for #5 and #6 owing to the great number of trees (Table 4). The amount of data collected precludes a concise correlational analysis of all species present to these chemical parameters, however, the percentage cover of five of the more distinctive peatland plants will be examined in relationship to these parameters.

A statistical analysis involving both an ANOVA and a regression was conducted on the data. The ANOVA looked for a correlation between the percent cover of each of the five selected plant species to the site type (bog, fen, or cedar swamp). An obvious significant statistical difference was found with the distribution of *Thuja occidentalis* to site type, since *Thuja* was only found within the cedar swamps. A marginal significant difference was discerned with the *Sphagnum* moss percent cover (P=.086), with the greatest difference between bogs and cedar swamps. Neither *Chamaedaphne calyculata, Ledum groenlandicum*, nor *Picea mariana* showed any correlation with their respective percent cover to the site type.

The regression evaluated any possible correlation of the percent cover of the plant species to either the conductivity (corrected) or pH values on a continual scale. For *Picea mariana*, the regression showed a significant correlation to pH (P=.026, R^2=.592) and conductivity (P=.027, R^2= .584) (Figures 1, 2). An even stronger correlation was found for *Thuja occidentalis* to pH (P=.005, R^2=.751) and conductivity (P=.015, R^2=.652) (Figures 3, 4). *Sphagnum* moss also significantly correlated to conductivity (P=.039, R^2=.537), but *Sphagnum* moss displayed marginal correlations to pH (P=.076) (Figures 5, 6). Chamaedaphne calyculata also exhibited only a marginal correlation to pH (P=.08) (Figure 7). However, *Chamaedaphne calyculata* did not show a significant correlation to conductivity (Figure 8). *Ledum groenlandicum* also did not show a significant correlation to either of the chemical parameters (Figure 9,10).

Sphagnum moss species in each of the $4m^2$ subplots were also recorded in Table 4. The species found in this analysis were not correlated to the chemical parameters, however, such an analysis could be conducted with this data.

Discussion

Using a quantitative approach, this study attempted both to discern a relationship between floral composition and chemical parameters in peatlands and to classify peatlands as either bogs or fens. The study was conducted at the University of Notre Dame Environmental Research Center (UNDERC) in Land o' Lakes, Wisconsin. The study employed eight sites. Within these sites, the percent cover of plant species, the acidity, and the conductivity of the peatland were recorded. The study was more quantitative than a descriptional approach to studying wetlands for several reasons. By demarcating a permanent site, the system under analysis was clearly defined. The use of percentage cover estimates, while not as accurate as biomass analysis, provided an approximate amount, as well as presence of plant species. Finally, sampling within the plots was accomplished with the use of a random number table (Rohlf and Sokal, Table 10) which prevented sampling bias on the part of the researcher.

Due to the extensive number of plant species in these sites, correlations between all plant species and these chemical parameters were not investigated. However, five plant species, which were both more visible and indicative of peatlands, were investigated along chemical parameters to determine if a correlation could be drawn. The data for the other plant species in Table 2, for the *Sphagnum* mosses in Table 3, and for the DBH measurements in Table 4 were included for reference for further research on these sites. The question mark symbols on Table 3 correspond to unknown percentage cover estimates from experimental error.

The results of the ANOVA on site type suggest that *Thuja occidentalis* and *Sphagnum* moss are significant in characterizing the site types. However, *Sphagnum* moss is a genus whose individual species often prefer habitats of different pH and conductivity (Crum 1995). A more exacting study of the percent cover of these species would further define the characteristics of the site types. The other three plant species did not serve to characterize the site types.

The significant correlations to pH and conductivity for *Picea mariana* and *Thuja occidentalis* in the regression suggest that these two chemical parameters exert considerable influence on the percent cover of the species. *Sphagnum* moss and *Chamaedaphne calyculata* are also marginally influenced by these parameters. *Ledum groenlandicum*, however, does not appear to be influenced by the gradients of pH and conductivity.

In discussing these relationships, it is important to remember that the relationship may not be a direct correlation between the chemical parameter and the percentage cover of a plant species. Other factors such as shading, peat texture, hydrology, nutrients, herbivory, and precipitation should be analyzed in order to gain a complete understanding of the percentage cover by a particular plant species.

The chemical measurements and the floral composition of these sites provide sufficient data to classify these peatlands as bogs, fens, or cedar swamps. However, an understanding of the hydrology of these peatlands would increase the confidence in these classifications (Gorham 1950). Further study on these sites could determine whether they are minerotrophic or ombrotrophic in origin. This knowledge, coupled with information on nutrient availability, would also provide a more complete foundation on which correlations between plant species could be established.

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commissures—junctions of hyaline and green cells.
cucullate—hood shaped, margins at apex of leaf curled in to form a hood.
fascicles—groups of branches arising from a common point on the stem, with relatively stout spreading branches and slender pendent branches usually closely investing the stem.
fibrils—reinforcing structures that appear as thin spiral or annular lines on hyaline cells (figs. 8-9, 8-10, 8-22, 8-23).
flexuose—wavy, undulate, or slightly bend, curved, or twisted.
gametophores—leafy, haploid stage of plant. The dominant life stage.
hyaline cells—large, broadly rhomboidal cells that lack cytoplasm.
imbricate—leaves appressed and overlapping like shinges on a roof.
involute—margins of leaf rolled inward.
lingulate—tongue-shaped, long with parallel sides and broad apex.
membrane gaps—irregular poforations of the hyaline cells of stem leaves.
membrane pleats—wrinkling of thin walls of hyaline cells of stem leaves.
pores—perforations of regular size and shape in stem leaves. In the branch axis usually restricted end of the protruding neck of retort cells (fig. 8-11).
protonema—normally a small, lobed thallus resulting from germination of the gametophyte spore.
resorption—the absense or disappearance of cell wall material of stem leaf hyaline cells, causing fringing at the leaf margins (figs. 8-12—15), irregular perforation of walls as membrane gaps (fig. 8-29), or wrinkling of thin walls as membrane pleats (fi.g 8-18).
resorption furrow—denticulate border of marginal cells of branch leaves (fi.g 8-46, 8-50, 8-51).
retort cells—large protruding structures sometimes on the outer cortex of the branch axis.
rhizoids—filamentolus extensions of protonema and base of young gametophores, with slanted crosswalls.
secund—turned to one side.
spore—first cell of haploid gametophyte stage.
squarrose—upper portion of leaf bent back towards the base of the leaf in a sharp, right angled bend. Squarrose is present when plant is wet or dry. See "recurved."
stellate—star-shaped. Refers to capitulum in which 5 rays of branches radiate out from center, like spokes on a wheel.
stem—consists of a central parenchyma of pale, isodiametric cells, a woody cylinder or sclerenchyma of long, thick-walled, colored cells, and a cortex of large, empty, thin-walled hyaline cells. The outer cells of the cortex may have one or more surface pores and, in some cases, reinforcing spiral fibrils (fig. 8-7—10) as well.
subsecund—slightly turned to one side, normally referring to leaves.

Table 1: Reference sheet of definitions provided by Dr. Bridgham for use in Sphagnum identification. Definitions are taken from Crum and also McQueen.

	A	B	C	D	E	F	G	H	I
1	% COVER OF FLORA	S1	S2	S3	S4	S5	S6	S7	S8
2		1	2	3	4	5	6	7	8
3	pH	4.7	4.3	3.9	4	5.5	5.9	4.7	4.8
4	Conductivity	40.4	35.3	39.8	35	61	55.5	34.3	39.8
5									
6	100 m2 site								
7	*Alnus rugosa*	0	0	0	0	10	0	0	0
8	*Larix laricina*	2	25	15	5	0	0	0	0
9	*Picea mariana*	5	30	35	15	0	0	0	10
10	*Pinus strobus*	0	0	6	0	0	0	0	0
11	*Thuja occidentalis*	0	0	0	0	75	75	0	0
12									
13	4m2 A								
14	*Acer rubrum*	0	0	0	0	8	0	0	0
15	*Acer spicatum*	0	0	0	0	0	0	0	0
16	*Alnus rugosa*	0	0	0	0	0	20	20	0
17	*Arethusa bulbosa*	0	0	0	0	0	0	0	0
18	*Betula papyrifera*	0	0	0	0	0	0	0	10
19	*Calla palustris*	0	0	0	0	0	0	1	0
20	*Caltha palustris*	0	0	0	0	0	0	0	0
21	*Carex canascens*	0	0	0	?	50	0	0	0
22	*Carex chordorrhiz*	?	0	0	0	0	0	0	0
23	*Carex disperma*	0	0	0	0	0	0	0	0
24	*Carex hystricina*	0	0	0	0	0	0	0	0
25	*Carex limosa*	0	1	0	0	0	0	0	0
26	*Carex sterilis*	0	0	0	0	0	0	0	0
27	*Chamaedaphne calyculata*	50	30	20	0	0	0	5	0
28	*Chiogenes hispidula*	0	10	50	0.5	0	5	0	0
29	*Clintonia borealis*	0	0	0	0	20	0	0	0
30	*Cornus canadensis*	0	0	0	0	2	0	0	0
31	*Cypripedium aeule*	0	0	0	0	0	0	0	0
32	*Drosera rotundifolia*	0	0	0	0	0	0	0	0
33	*Dryopteris cristata*	0	0	0	0	0	0	2	0
34	*Equisetum sylvaticum*	0	0	0	0	15	0	0	0
35	*Eriophorum spissum*	0	0	5	?	0	0	0	0
36	*Galium triflorum*	0	0	0	0	0	1	0	0
37	Graminoid (unidentifiable)	75	15	16	60	50	0	0	15
38	Grass (73) unidentifiable	0	0	0	0	0	0	0	0
39	*Heterocladium dimorphum*	0	0	1	0	0	0	0	0
40	Hydrocotyle Unidentifiable dicot	0	0	0	0	0	1	0	0
41	*Iris versicolor*	0	0	0	0	0	0	0	0
42	*Kalmia polifolia*	0	5	3	0	0	0	0	0
43	*Ledum groenlandicum*	10	15	30	10	0	5	0	0
44	*Linnaea borealis*	0	0	0	0	2	0	0	0
45	*Lycopodium annotum*	0	0	0	0	0	0	0	0

	A	B	C	D	E	F	G	H	I
46	*Lysimachia thrysiflora*	0	0	0	0	0	0	0	0
47	*Maianthenum canadense*	0	15	0	?	0	2	0	50
48	*Menyanthes trifoliata*	0	0	0	0	0	0	0	0
49	*Polytrichum commune*	0	0	0	0	0	0	0	0
50	Moss (S8)	0	0	0	0	0	0	0	5
51	*Nymphaea odonata*	0	0	0	0	0	5	0	0
52	*Onecta sensibilis*	0	0	0	0	5	0	0	0
53	*Osmunda cinnamomea*	0	0	0	0	0	0	0	0
54	*Plantanthera ciliaris*	0	0	0	0	0	0	0	0
55	*Polytrichum sp.*	0	0	0	0	0	0	0	0
56	*Prunus pensylvanica*	0	0	0	0	0	0	0	0
57	*Prunus pumila*	0	0	0	0	0	0	50	0
58	*Prunus virginiana*	0	0	0	0	0	0	10	0
59	*Rhizomnium magnifolium*	0	0	0	0	5	15	0	0
60	*Rubus hispidus*	0	0	0	0	?	10	0	0
61	*Rumex crispus*	0	0	0	0	2	0	0	0
62	*Salix serissima*	0	0	0	0	0	0	0	0
63	*Sarracenia purpurea*	0	0	5	0	0	0	0	0
64	*Scirpus cyperinus*	0	0	0	0	0	0	0	3
65	*Sisyrinchium species*	0	4	0	0	0	0	0	0
66	*Sphagnum*	90	90	80	90	75	75	60	80
67	*Dryopteris spinulosa*	0	0	0	0	0	1	0	0
68	*Thuja occidentalis*	0	0	0	0	0	0	0	0
69	*Trientalis borealis*	0	0	0	0	1	0	0	10
70	*Typha latifolia*	0	0	0	0	0	0	0	0
71	Unknown #4 Unidentifiable (P9)	1	0	0	1	0	0	0	0
72	*Vaccinium macrocarpon*	0	2	1	0.5	0	0	0	0
73	*Vaccinium myrotilloides*	0	0	0	0	0	0	0	0
74	*Viola species*	0	0	0	0	10	5	5	4
75	*Viola nephrophylla*	0	0	0	0	0	0	0	0
76	*Viola renifolia*	0	0	0	0	0	0	0	0
77	*Waldsteinia Fragarioides*	0	0	0	0	0	0	0	0
78	Weed-like unidentifiable (P68)	0	0	0	0	0	0	10	0
79									
80	4m2 B								
81	*Acer rubrum*	0	0	0	0	0	0	0	0
82	*Acer spicatum*	0	0	0	0	0	0	0	0
83	*Alnus rugosa*	0	0	0	0	0	20	50	0
84	*Arethusa bulbosa*	0	0	0	0	0	0	0	0
85	*Betula papyrifera*	0	0	0	0	0	0	0	10
86	*Calla palustris*	0	0	0	0	0	0	10	0
87	*Caltha palustris*	0	0	0	0	0	20	0	0
88	*Carex canascens*	0	0	0	0	0	0	0	0
89	*Carex chordorrhiz*	?	0	0	0	0	0	0	0
90	*Carex disperma*	0	0	0	0	0	10	0	0

	A	B	C	D	E	F	G	H	I
91	*Carex hystricina*	0	0	0	0	0	0	0	0
92	*Carex limosa*	0	0	0	0	0	0	0	0
93	*Carex sterilis*	0	0	0	0	0	0	10	0
94	*Chamaedaphne calyculata*	50	20	10	75	0	0	0	0
95	*Chiogenes hispidula*	0	3	60	0	0	5	0	0
96	*Clintonia borealis*	0	0	0	0	10	4	0	0
97	*Cornus canadensis*	0	0	0	0	0	4	0	0
98	*Cypripedium aeule*	0	0	0	0	0	0	0	0
99	*Drosera rotundifolia*	0	1	0	0	0	0	0	0
100	*Dryopteris cristata*	0	0	0	0	0	0	2	0
101	*Equisetum sylvaticum*	0	0	0	0	10	0	0	0
102	*Eriophorum spissum*	0	0	20	1	0	0	0	0
103	*Galium triflorum*	0	0	0	0	0	0	0	0
104	Graminoid (unidentifiable)	50	20	0	0	40	0	0	75
105	Grass unidentifiable (73)	0	0	0	0	0	0	2	0
106	*Heterocladium dimorphum*	0	0	0	0	0	0	0	0
107	*Iris versicolor*	0	0	0	0	0	0	15	0
108	*Kalmia polifolia*	0	10	4	10	0	0	0	0
109	*Ledum groenlandicum*	15	25	35	0	0	5	5	0
110	*Linnaea borealis*	0	0	0	0	0	2	0	0
111	*Lycopodium annotum*	0	0	0	0	0	0	0	0
112	*Lysimachia thrysiflora*	0	0	0	0	0	0	5	0
113	*Maianthenum canadense*	0	10	0	33	6	0	0	30
114	*Menyanthes trifoliata*	0	0	0	0	0	0	0	0
115	*Polytrichum commune*	0	0	0	0	0	0	0	0
116	*Nymphaea odonata*	0	0	0	0	0	0	0	0
117	*Onecta sensibilis*	0	0	0	0	10	0	0	0
118	*Osmunda cinnamomea*	0	0	0	0	20	0	0	8
119	*Plantanthera ciliaris*	0	0	0	0	0	0	1	0
120	*Polytrichum sp.*	0	0	0	0	0	0	0	0
121	*Prunus pensylvanica*	0	0	0	0	0	0	0	10
122	*Prunus pumila*	0	0	0	0	0	0	0	0
123	*Prunus virginiana*	0	0	0	0	0	0	0	0
124	*Rhizomnium magnifolium*	0	0	0	0	10	0	0	0
125	*Rubus hispidus*	0	0	0	0 ?		0	0	0
126	*Rumex crispus*	0	0	0	0	0	0	0	0
127	*Salix serissima*	0	0	0	0	0	0	0	0
128	*Sarracenia purpurea*	0	1	5	0	0	0	0	0
129	*Scirpus cyperinus*	0	0	0	0	0	0	0	0
130	*Sisyrinchium species*	0	1	0	0	0	0	0	0
131	*Sphagnum*	90	90	90	100	50	80	60	75
132	*Dryopteris spinulosa*	0	0	0	0	0	0	0	0
133	*Thuja occidentalis*	0	0	0	0	0	0	0	0
134	*Trientalis borealis*	0	0	0	0	10	4	0	1
135	*Typha latifolia*	0	0	0	0	0	0	0	1

	A	B	C	D	E	F	G	H	I
136	Unknown #4 unidentifiable (P9)	0	0	0	0	0	0	0	0
137	*Vaccinium macrocarpon*	0	2	0	0	0	0	0	0
138	*Vaccinium myrotilloides*	0	0	2	0	5	10	0	0
139	*Viola species*	0	0	0	0	10	0	2	0
140	*Viola nephrophylla*	0	0	0	0	0	0	0	0
141	*Viola renifolia*	0	0	0	0	0	0	0	0
142	*Waldsteinia Fragarioides*	0	0	0	0	10	10	0	0
143	Weed-like unidentifiable (P68)	0	0	0	0	0	0	5	0
144									
145	4m2 C								
146	*Acer rubrum*	0	0	0	0	5	0	0	0
147	*Acer spicatum*	0	0	0	4	0	0	0	0
148	*Alnus rugosa*	0	0	0	0	0	15	20	0
149	*Arethusa bulbosa*	0	0	0	0	0	0	0	0
150	*Betula papyrifera*	0	0	0	0	0	0	0	0
151	*Calla palustris*	0	0	0	0	0	0	15	0
152	*Caltha palustris*	0	0	0	0	0	5	0	0
153	*Carex canascens*	0	0	0	25	0	0	0	0
154	*Carex chordorrhiz*	0	0	0	0	0	0	0	30
155	*Carex disperma*	0	0	0	0	0	10	0	0
156	*Carex hystricina*	?	0	0	0	0	0	0	0
157	*Carex limosa*	0	0	0	0	0	0	0	0
158	*Carex sterilis*	0	0	0	0	0	0	15	0
159	*Chamaedaphne calyculata*	10	15	35	0	0	0	0	0
160	*Chiogenes hispidula*	0	5	0	0	8	2	0	0
161	*Clintonia borealis*	0	0	0	0	8	3	0	0
162	*Cornus canadensis*	0	0	0	0	0	0	0	0
163	*Cypripedium aeule*	0	0	0	0	0	0	0	0
164	*Drosera rotundifolia*	0	0	2	1	0	0	0	0
165	*Dryopteris cristata*	0	0	0	0	0	0	0	0
166	*Equisetum sylvaticum*	0	0	0	0	0	0	0	0
167	*Eriophorum spissum*	0	0	0	0	0	0	0	0
168	*Galium triflorum*	0	0	0	0	0	0	0	0
169	Graminoid (unidentifiable)	40	20	75	0	20	0	0	20
170	Grass unidentifiable (73)	0	0	0	0	0	0	5	0
171	*Heterocladium dimorphum*	0	0	0	0	0	0	0	0
172	Hydrocotyle unidentifiable dicot	0	0	0	0	0	0	0	0
173	*Iris versicolor*	0	0	0	0	0	0	10	0
174	*Kalmia polifolia*	5	3	6	0	0	0	0	0
175	*Ledum groenlandicum*	5	15	5	3	30	0	50	0
176	*Linnaea borealis*	0	0	0	0	0	0	0	0
177	*Lycopodium annotum*	0	0	0	0	0	0	0	0
178	*Lysimachia thrysiflora*	0	0	0	0	0	0	0	0
179	*Maianthenum canadense*	0	5	0	40	2	2	0	50
180	*Menyanthes trifoliata*	0	5	0	0	0	0	0	0

	A	B	C	D	E	F	G	H	I
181	*Polytrichum commune*	0	0	0	0	0	0	0	0
182	Moss (S8)	0	0	0	0	0	0	0	0
183	*Nymphaea odonata*	0	0	0	0	0	0	0	0
184	*Onecta sensibilis*	0	0	0	0	0	0	0	0
185	*Osmunda cinnamomea*	0	0	0	0	0	0	0	0
186	*Plantanthera ciliaris*	0	0	0	0	0	0	0	0
187	*Polytrichum sp.*	0	0	0	0	0	0	0	0
188	*Prunus pensylvanica*	0	0	0	0	0	0	0	0
189	*Prunus pumila*	0	0	0	0	0	0	0	0
190	*Prunus virginiana*	0	0	0	0	0	0	0	0
191	*Rhizomnium magnifolium*	0	0	0	0	1	5	0	0
192	*Rubus hispidus*	0	0	0	0	0	2	5?	0
193	*Rumex crispus*	0	0	0	0	0	0	0	0
194	*Salix serissima*	0	0	0	0	0	0	0	0
195	*Sarracenia purpurea*	0	0	7	0	0	0	0	0
196	*Sisyrinchium species*	0	0	0	0	0	0	0	0
197	*Scirpus cyperinus*	0	0	0	0	0	0	0	0
198	Sphagnum species	50	90	90	95	80	75	75	75
199	*Dryopteris spinulosa*	0	0	0	0	0	0	0	0
200	*Thuja occidentalis*	0	0	0	0	0	0	0	0
201	*Trientalis borealis*	0	0	0	0	15	0	0	0
202	*Typha latifolia*	0	0	0	0	0	0	0	0
203	Unknown #4 unidentifiable (P9)	0	0	0	0	0	0	0	0
204	*Vaccinium macrocarpon*	0	0	2	0	0	0	0	0
205	*Vaccinium myrotilloides*	0	0	4	0	3	0	0	15?
206	*Viola species*	0	0	0	0	0	0	0	0
207	*Viola nephrophylla*	0	0	0	0	0	0	0	0
208	*Viola renifolia*	0	0	0	0	5	0	0	0
209	*Waldsteinia Fragarioides*	0	0	0	0	5	5	0	0
210	Weed-like unidentifiable (P68)	0	0	0	0	0	0	0	0
211									
212									
213									

Table 2: Percentage cover values for each of the 67 plant species identified in the eight peatland sites. Percentage cover values for the trees were taken as a whole over the 100 m^2 site. Percentage cover values for smaller plants were recorded from measurements in three $4m^2$ subplots (A, B, C). Question mark symbols refer to sites where the percentage cover values are not known due to experimental error.

	A	B	C	D	E
1	Sphagnum Spp	S1	S2	S3	S4
2					
3	4m2 A				
4	1	mag, brev	mag, cus	mag	mag
5	2	brev	mag, cus	mag	mag
6	3	brev	mag	mag,brev	mag
7	4	brev	mag,brev	mag	mag
8	5	brev	mag,brev	mag	mag
9	6	mag, brev	mag, cus	mag	mag
10	7	brev	mag, brev	mag	mag
11	8	mag, brev	mag, brev	mag	mag
12	9	brev	brev, cus	mag	mag
13	10	brev	mag,brev,cus	mag	mag
14					
15	4m2 B				
16	1	mag, brev	cus	mag,ang	mag
17	2	brev	cus	mag	mag
18	3	brev	cus	mag	mag
19	4	mag	cus	mag	mag
20	5	brev	mag,cus	mag	mag,cus
21	6	mag	mag	mag,ang	mag,cus
22	7	brev	mag,cus	mag,ang	mag
23	8	brev	mag	mag,ang	mag
24	9	brev	mag	ang	mag,cus
25	10	brev	mag	brev	mag
26					
27	4m2 C				
28	1	obt	brev	mag,brev	mag,cus
29	2	mag	brev	mag,brev	mag
30	3	brev	brev	brev	mag
31	4	brev	mag,brev	mag	mag,cus
32	5	brev	mag,brev	mag	mag,cus
33	6	brev	mag	mag	mag,cus
34	7	mag	brev	mag	brev
35	8	brev	brev	mag	mag,brev
36	9	brev	brev	mag	brev
37	10	brev	cus	null	brev
38					

	A	B	C	D	E
1	Sphagnum Spp	S5	S6	S7	S8
2					
3	4m2 A				
4	1	null	gir	mag	ten
5	2	ten	gir,mag	mag	gir
6	3	ten,mag	gir	gir,mag	ten
7	4	ten	gir	squ,brev (sub)	brev
8	5	ten,mag	gir	mag	brev
9	6	mag,ten	gir	mag,gir	brev
10	7	ten,mag,wul,gi	gir,ten	mag,gir	brev
11	8	wul,gir	mag,gir	null	brev
12	9	gir	gir	null	brev
13	10	gir,wul	gir,mag	null	brev
14					
15	4m2 B				
16	1	mag,gir	gir,wul	mag,squ	ten,gir
17	2	gir, brev	gir,ten	mag	ten
18	3	mag	gir	mag	ten,brev
19	4	gir	gir,ten	mag	teres
20	5	gri,brev,mag	gir	mag,squ	gir
21	6	gir,mag	gir,wul	mag,squ	gir,teres
22	7	mag	gir	mag	ten
23	8	gir	gir,wul	mag	ten
24	9	gir,mag	gir	mag	null
25	10	null	brev	mag	null
26					
27	4m2 C				
28	1	gir	wul	mag	mag, ten
29	2	brev, mag	gri	mag	mag, ten
30	3	gir,mag	gir	mag	mag
31	4	gir	gir	mag	mag
32	5	gir,mag	gir	mag	mag
33	6	gir,mag	gir	mag	mag
34	7	gir,mag	gir	mag, squ, gir	mag,ten
35	8	null	gir	mag	mag
36	9	mag,ang	gir	mag	ten
37	10	mag	gir	mag	ten

Table 3: Identification of *Sphagnum* moss samples collected within the three $4m^2$ subplots within each of the eight 100 m^2 peatland sites. Competency of *Sphagnum* moss identification was not achieved until approximately Site #5 calling into question the accuracy of earlier identifications.

DBH Measurements	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Larix laricina	1.5	7	5	6	0	0	0	0
	1	7	5					
		6	4					
		6	4					
		5	3.5					
		5	2					
		4	1.5					
		4	1					
		3						
		3						
		3						
		3						
		3						
		2						
		2						
		2						
		2						
		2						
		2						
Picea mariana	4	10	9	5	0	0	0	10
	1.5	8	8	5				7
	1.5	7	7	4				4
		7	7	4				3
		6	7	3				3
		6	7	3				2
		6	6	3				
		2	6	2				
		1	5					
		1	3					
		1	2					
		0.5	2					
		0.5	2					
		0.5	2					
		0.5	2					
		0.5	1					
			0.5					
			0.5					
Pinus strobus	0	0	11	0	0	0	0	0
			2					
			2					
Thuja occidentalis	0	0	0	0	N.A.	N.A.	0	0

Table 4: Diameter at Breast Height (DBH) values for trees located within the eight 100 m^2 sites. Values for the trees in the two cedar swamps (sites 5 and 6) were not determined due to the great number of trees present.

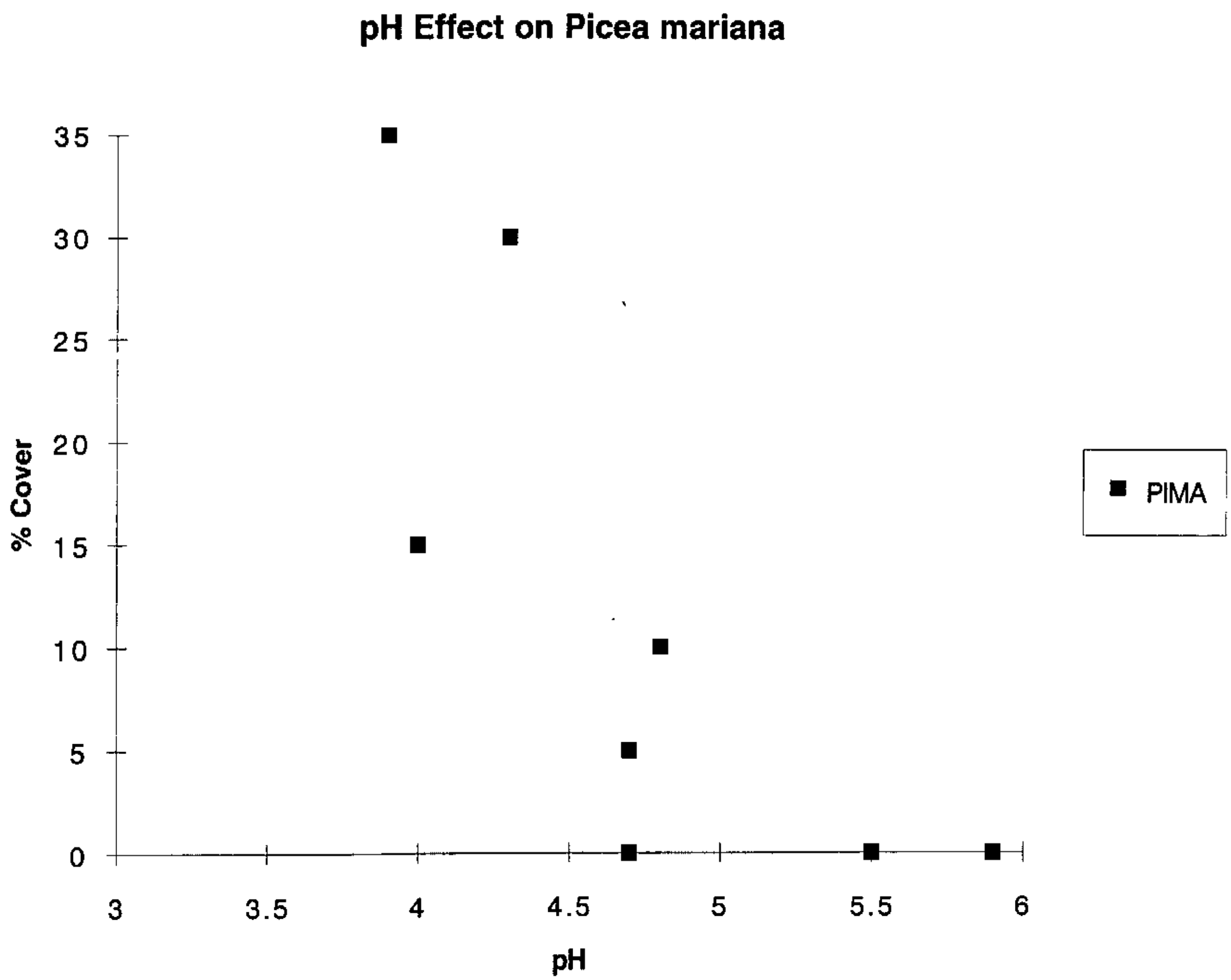

Figure 1: Effect of pH on *Picea mariana* percent cover.

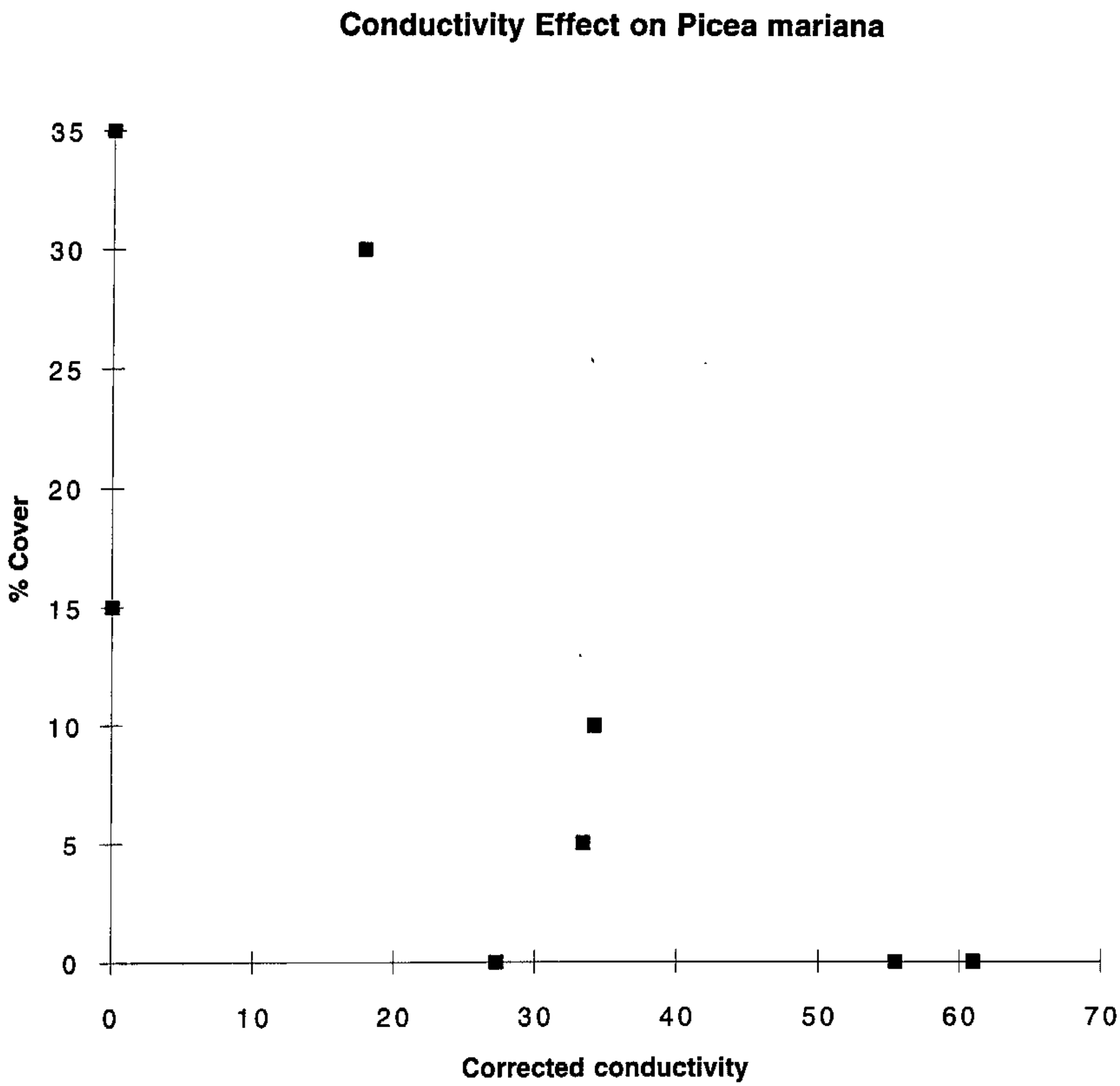

Figure 2: Effect of conductivity (microsiemens per centimeter) on *Picea mariana* percent cover.

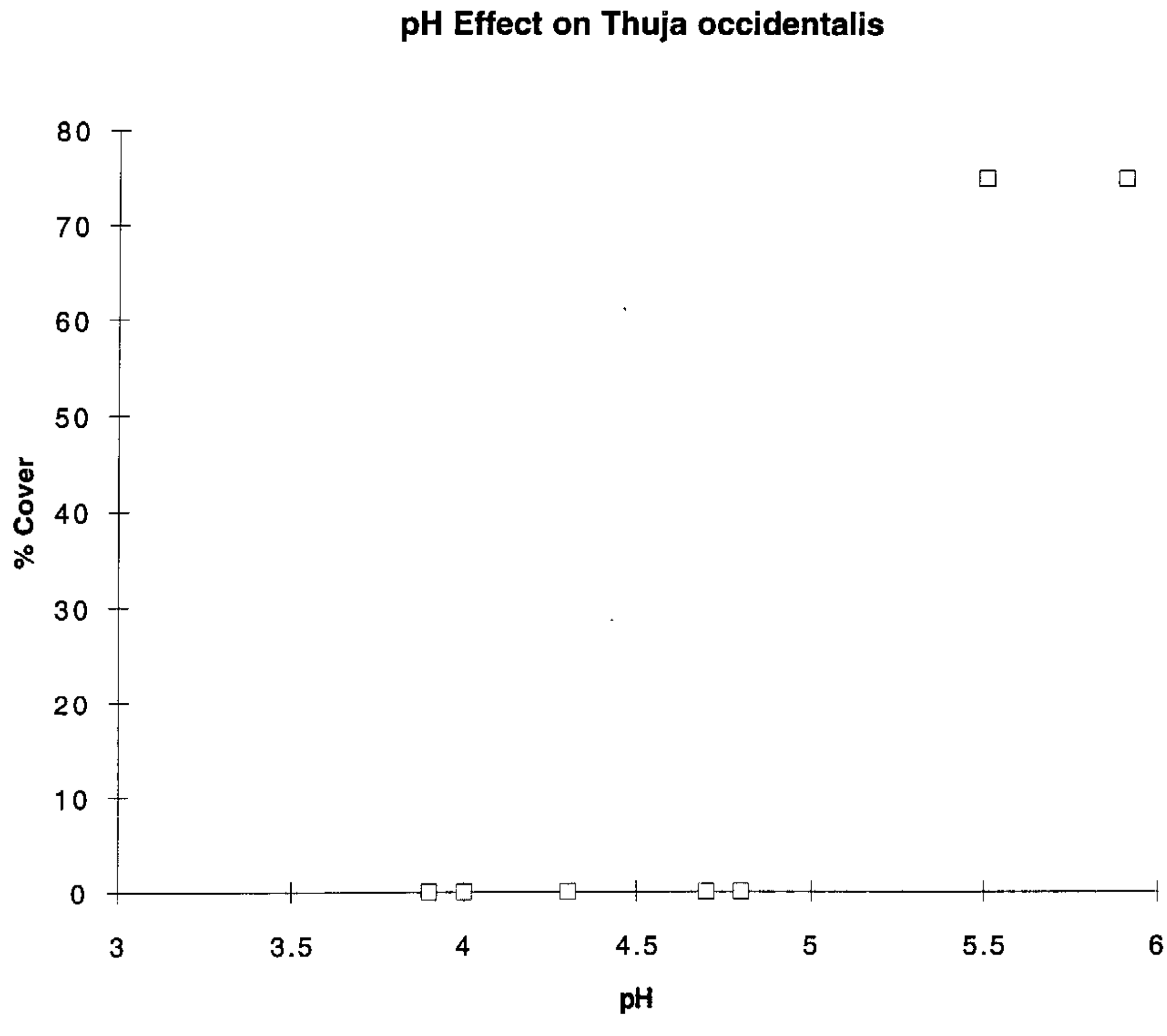

Figure 3: Effect of pH on *Thuja occidentalis* percent cover.

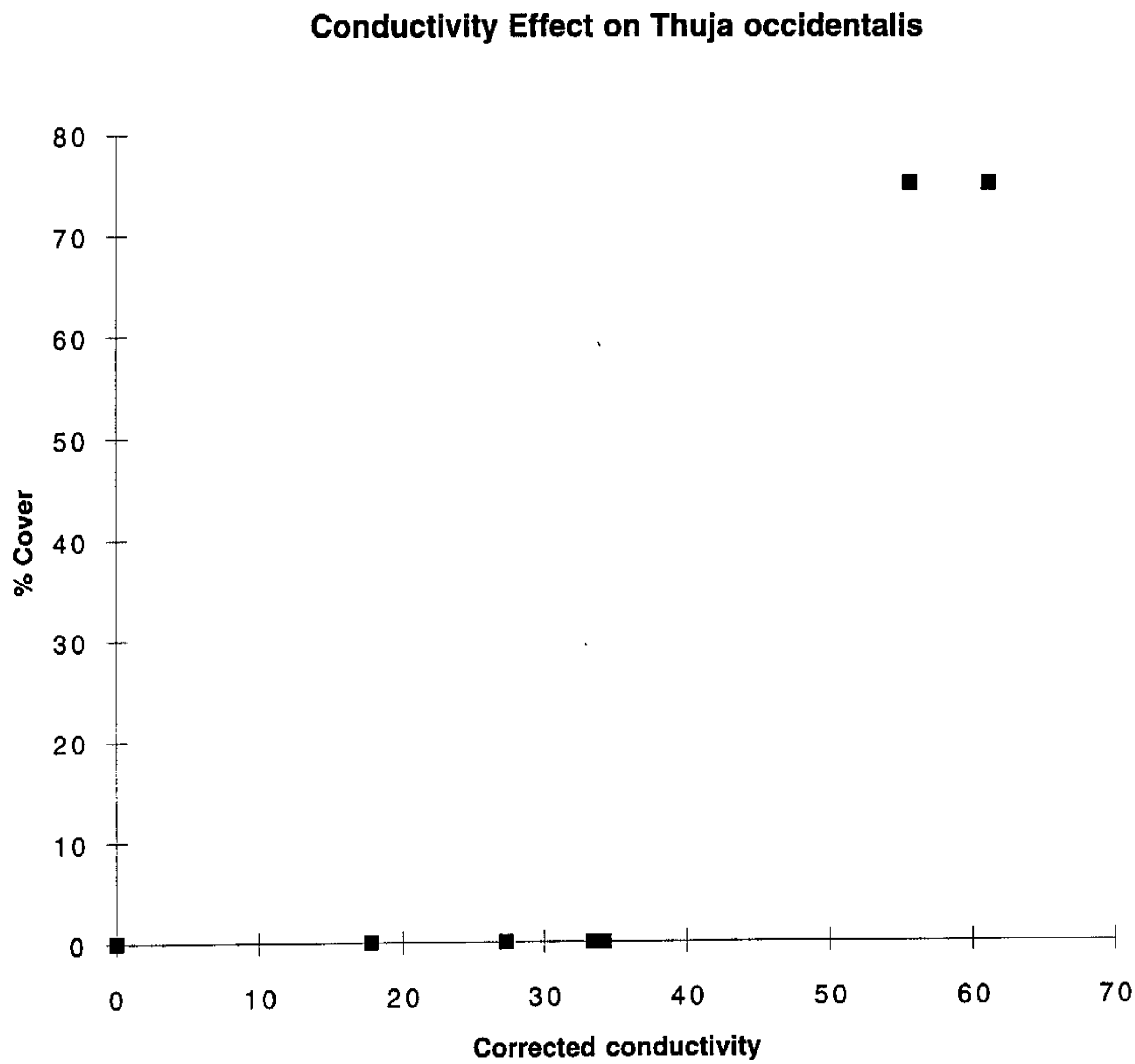

Figure 4: Effect of conductivity (microsiemens per centimeter) on *Thuja occidentalis* percent cover.

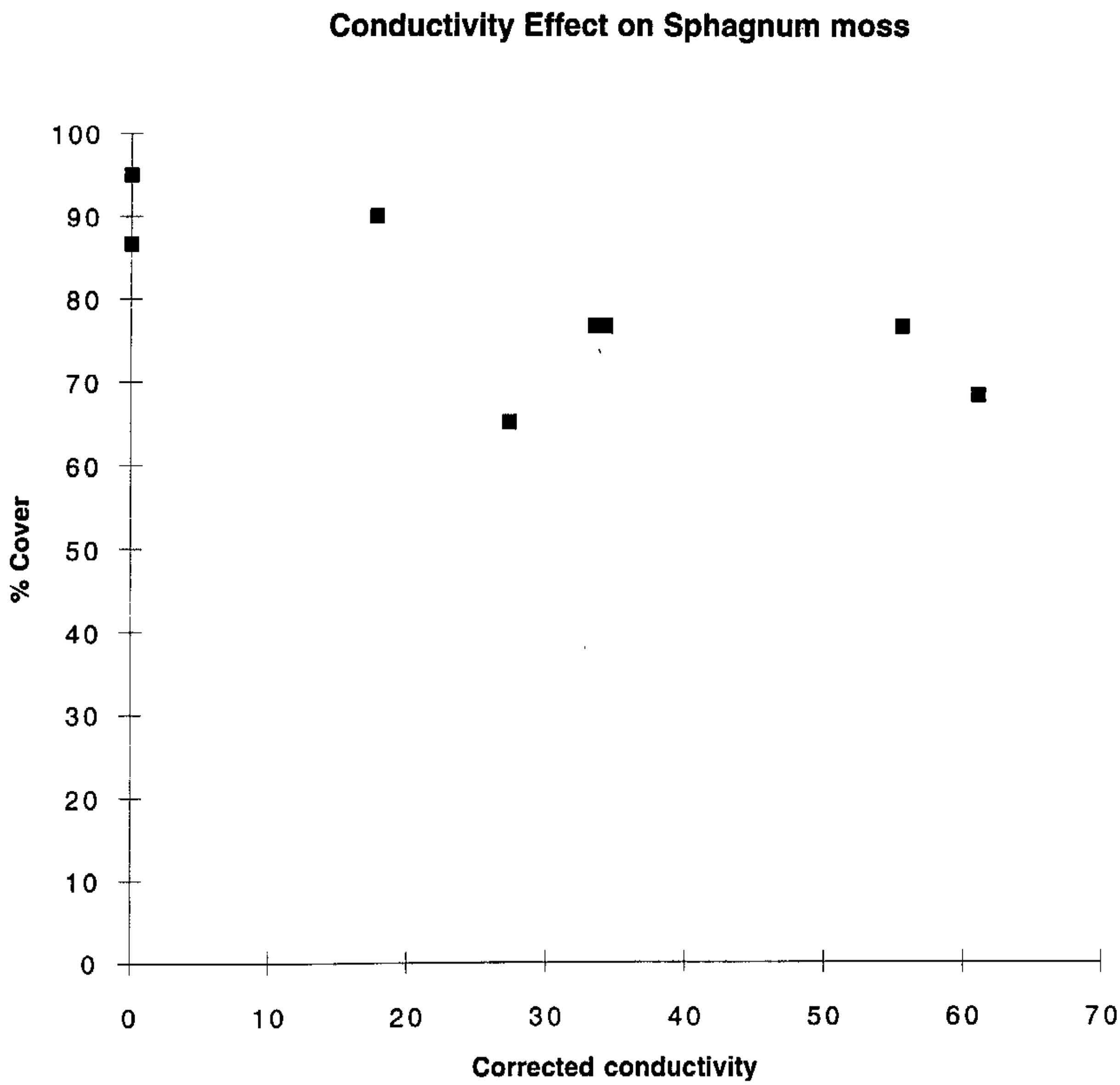

Figure 5: Effect of conductivity (microsiemens per centimeter) on *Sphagnum* moss percent cover.

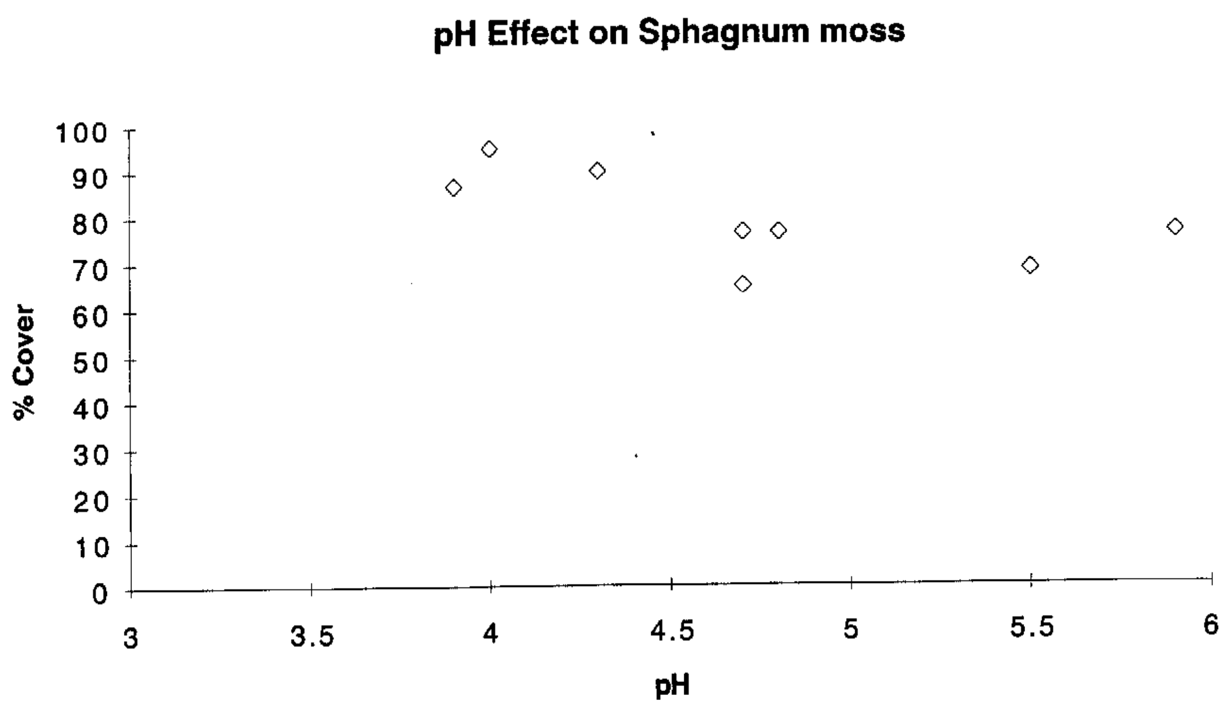

Figure 6: Effect of pH on *Sphagnum* moss percent cover.

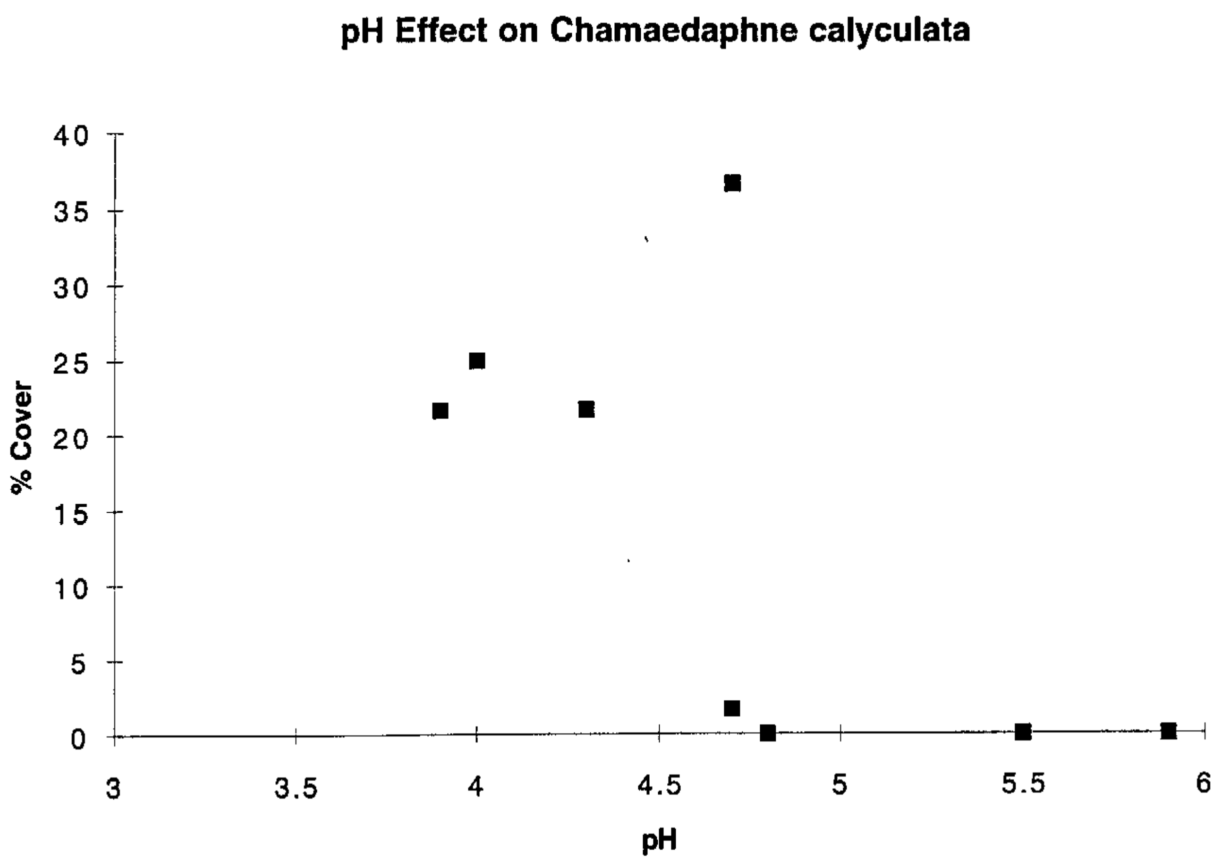

Figure 7: Effect of pH on *Chamaedaphne calyculata* percent cover.

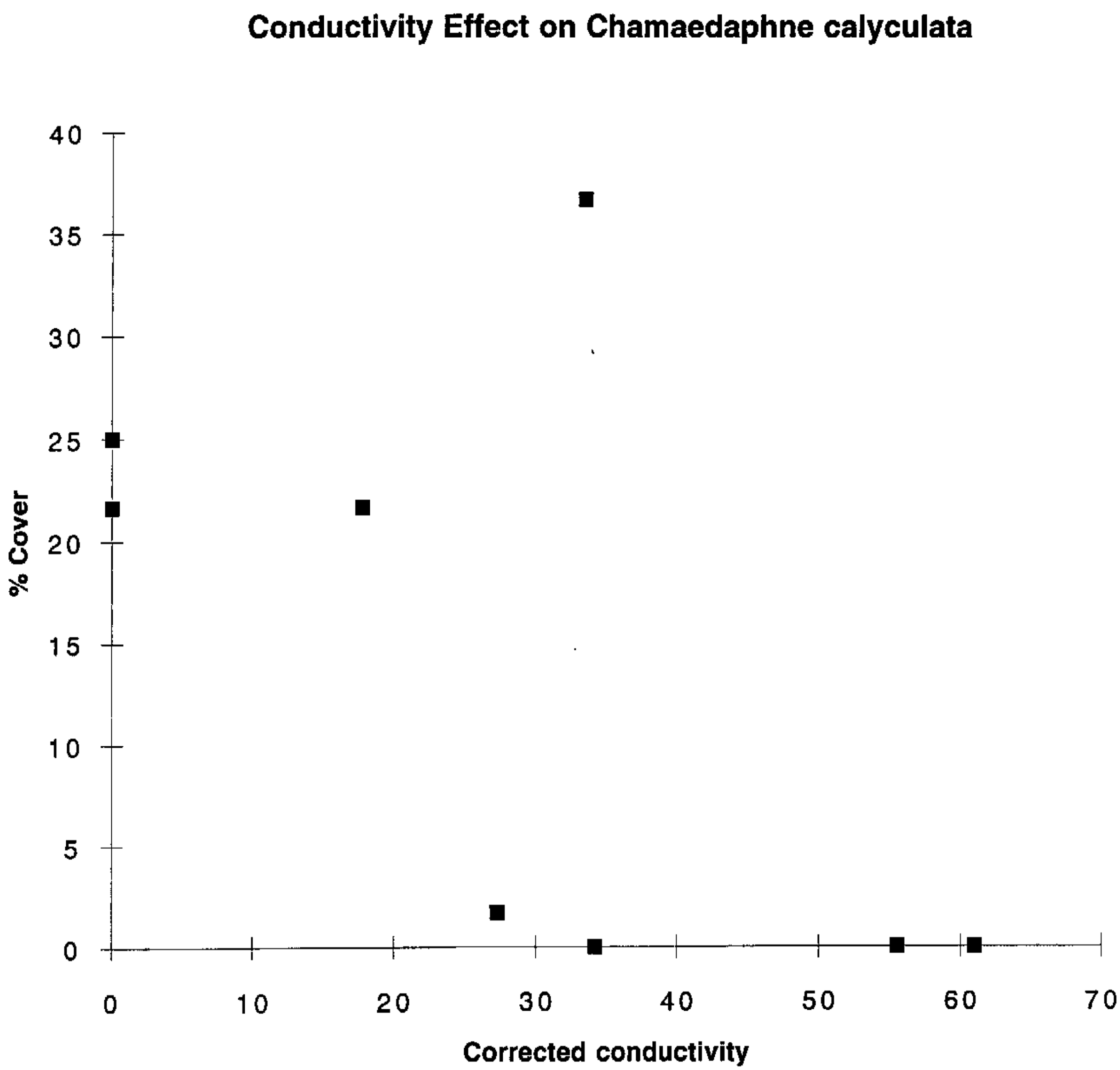

Figure 8: Effect of conductivity (microsiemens per centimeter) on *Chamaedaphne calyculata* percent cover.

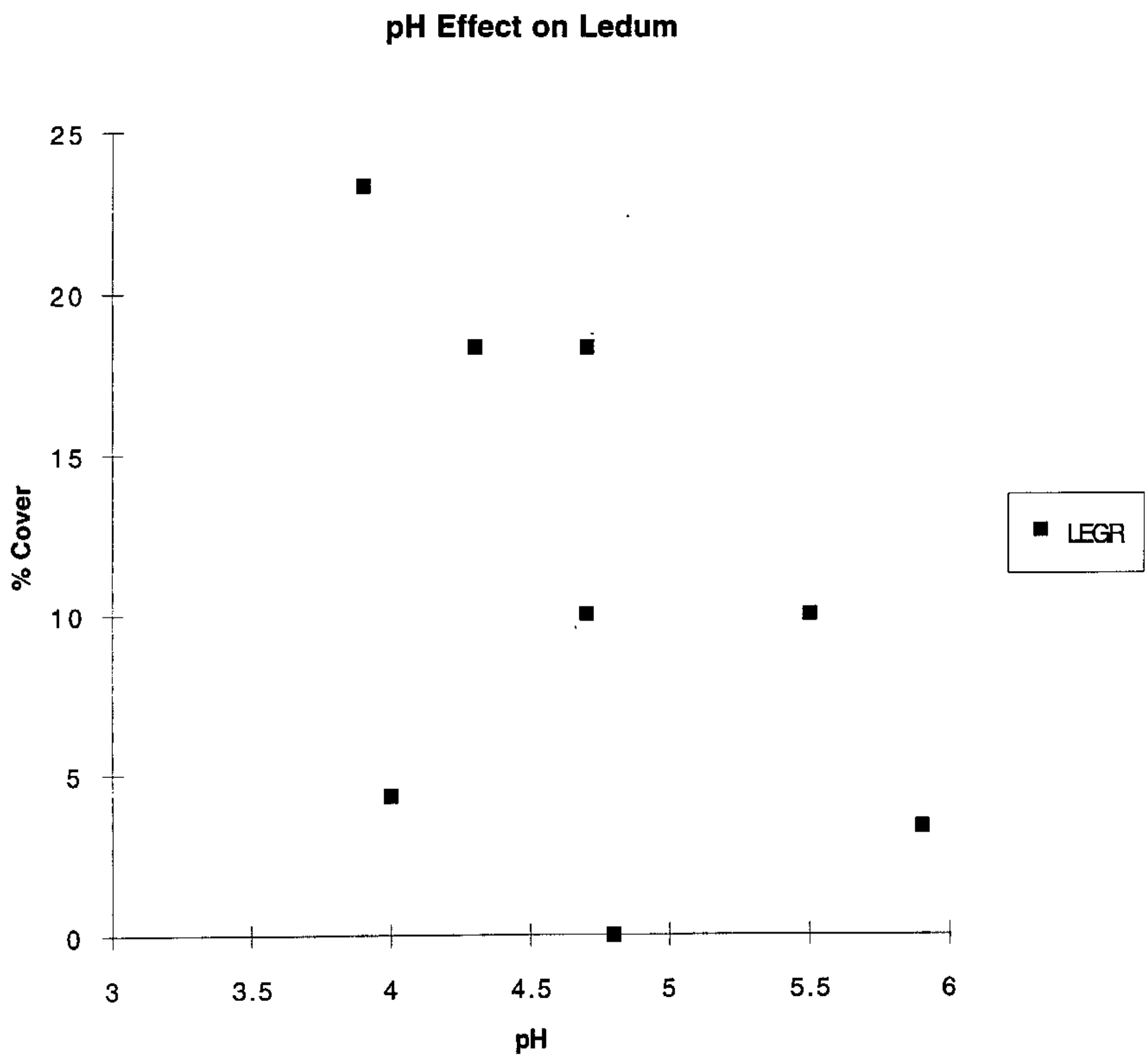

Figure 9: Effect of pH on *Ledum groenlandicum* percent cover.

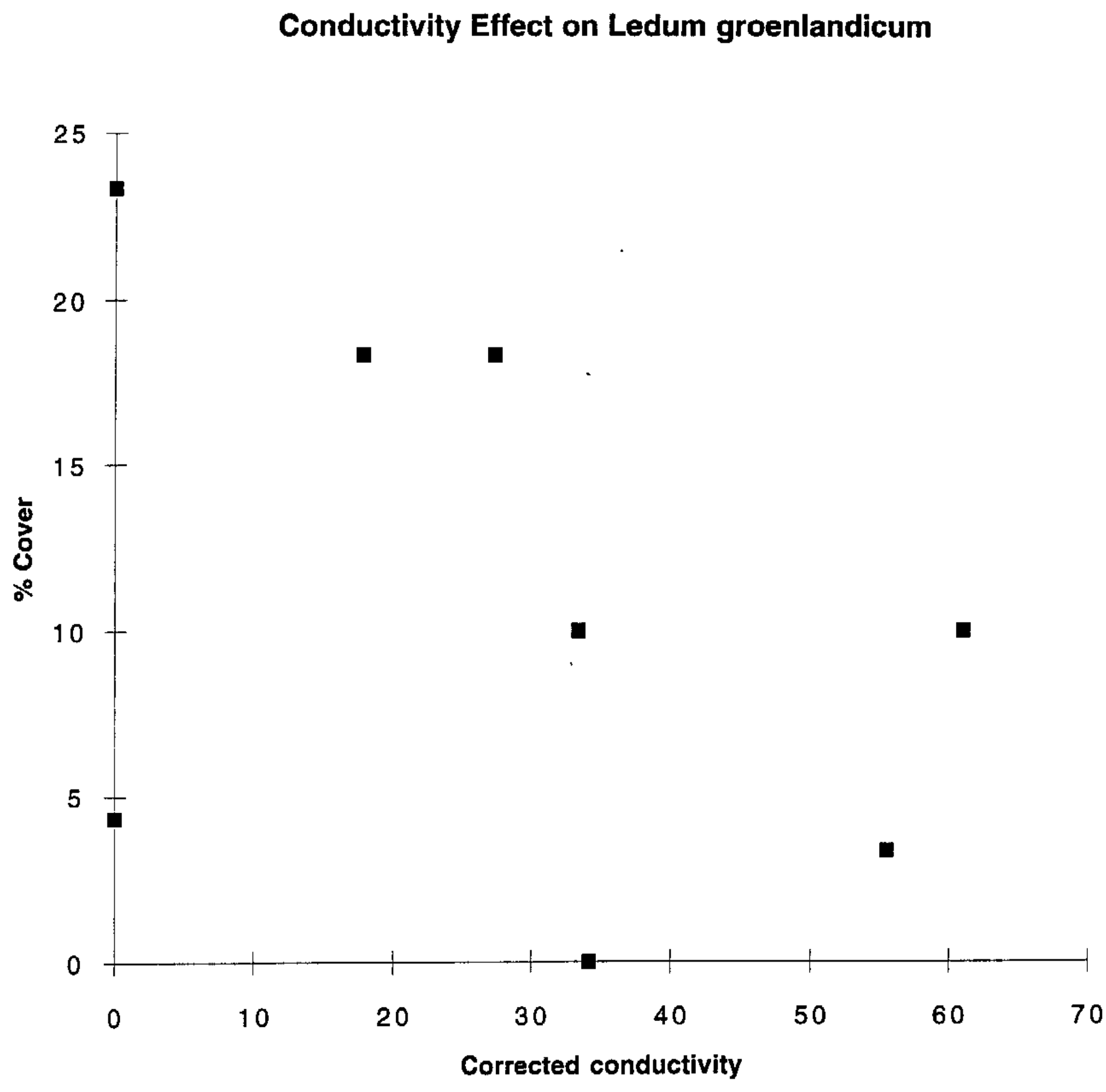

Figure 10: Effect of conductivity (microsiemens per centimeter) on *Ledum groenlandicum* percent cover.