Case Study of Bog Change on Long Lake in Aitkin County, Minnesota USA

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Abstract

This study examines historical landcover change and growth rate of the bog surrounding Long Lake in Aitkin County, located in Northern Minnesota. Bogs create a unique environment for plants and wildlife alike, which is why it is important to monitor their growth and to keep peatlands intact. This study uses five aerial images covering the period 1939 to 2010. Each image was digitized around areas of open water, bog, and mature bog. The Vector-based Landscape Analysis Tool Extension (V-LATE) was used to examine change over the 71 year time period. V-LATE analyses included area, edge, core area, and diversity. A prediction analysis was also performed to forecast future bog growth. Results showed a large decrease in mature bog in 1982 then an increase for the remainder of the study. An overall bog growth of 9.86 m^2 or 0.0024 acres occurred between 1939 and 2010.

Introduction

Bog wetlands fulfill a crucial role in the world's ecosystems. Global warming, agriculture, urbanization, and industrialization all have effects on the growth rate of bogs (Bragazza, 2008; Rebelo, Finlayson, and Nagabhatla, 2009). According to the Minnesota Department of Natural Resources (MNDNR, 2011), with the exception of Alaska, the state of Minnesota has more peatland than any other state with nearly 6 million acres. For this reason it is especially important to conserve wetlands in order to help with future conservation management efforts.

There are two layers in a bog, the acrotelm and the catotelm. The upper layer, acrotelm, is at the surface and is a thin aerobic layer of the bog, while the catotelm is a thicker anerobic layer below the acrotelm (Clymo, 1984). The decay rates of these layers differ greatly (Yu, Campbell, Vitt, and Apps, 2001). When new litter and peat is introduced to the acrotelm, water and oxygen create a high decay rate. Then in the catotelm, the rate of decay sharply decreases and becomes less dependent on surface conditions (Yu et al., 2001).

According to Clymo (1984), approximately 90% of all matter is decomposed in the acrotelm. However, the other 10% accumulates into the catotelm where decomposition dramatically slows (Clymo, 1984).

Many factors contribute to the growth of a bog such as water table depth, precipitation, temperature, nutrients in the bog, and the animal and plant life on the bog (Clymo, 1984, Yu et al., 2001). These factors lead to an immense variability in growth rates. Due to the inherent intricacy of the interplay between these variables, this study will not consider them. Instead this study will concentrate on aerial bog change. The purpose of this study was to use historical aerial imagery to determine

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changes that occurred in the bog area of Long Lake in Northern Minnesota from 1939 to 2010.

Study Area

Long Lake is located approximately 5 miles south of Palisade, Minnesota and is the home of Long Lake Conservation Center (LLCC) (Figure 1 and 2). The LLCC is an environmental education center which encourages children to become actively involved in the environment. Children of all ages come throughout the school year to learn about the environment, animals and to participate in outdoor activities including a trek through a bog.

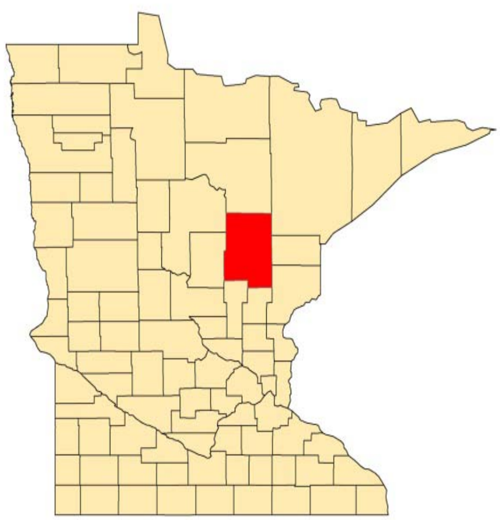

Figure 1. The study area of Long Lake is located in Aitkin County, Minnesota (shown in red).

The bog on Long Lake is located along the eastern shoreline and continues to grow inward. Approximately two-thirds of the lake is only 5-10 feet deep. However the west end of the lake where the LLCC is located has an area 40 feet in depth (Minnesota Department of Natural Resources, 1970). Long Lake is also home to a variety of animals such as beavers, fishers, martens, and otters. One active beaver lodge is located on the east end of the lake. The Long Lake bog contains characteristic bog vegetation such as Black Spruce (*Picea mariana*), Tamarack (*Larix laricina*), Labrador Tea (*Ledum groenlandicum*), Leatherleaf shrubs (*Chamaedaphne calyculata*), Pitcher plants (*Sarracenia purpurea var. purpurea*), and Tussock cottongrass (*Eriophorum vaginatum var. spissum*).

Long Lake was chosen for this study because of its late stage in succession, meaning it is in the process of turning to bog.

Methodology

Data Collection Process

Aerial imagery from 1939 and 1982 was obtained from the MNDNR data deli website. Images from 2003, 2008, and 2010 were obtained through the Minnesota Geospatial Image Service, Web Map Service (LMIC, WMS). All images were one meter resolution and taken in the spring or summer (Figure 3).

Figure 2. Long Lake is approximately 1 mile long with 34 acres of open water and 31 acres of bog, located in Atikin County, Minnesota.

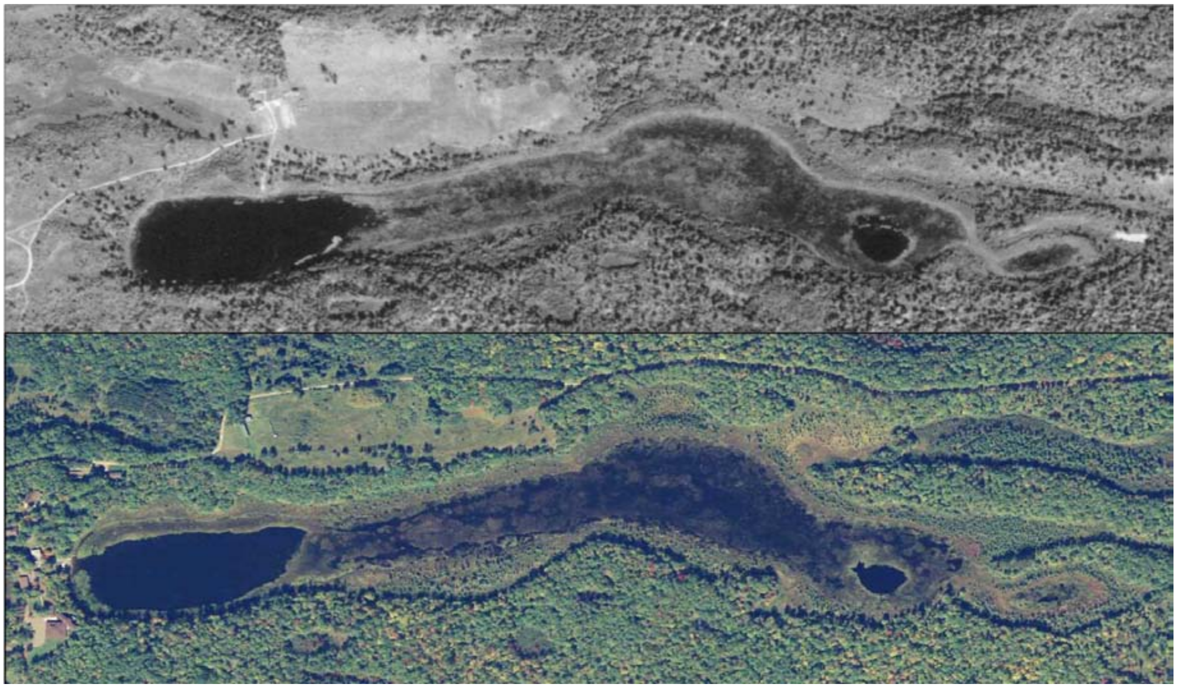

Figure 3. Aerial imagery of Long Lake taken in 1939 (top) and 2003 (bottom).

Data Preparation

Aerial images from 1939 and 1982 were georeferenced using the 2010 imagery as reference. A file geodatabase was created to store the data for the study. Polygon feature classes for each year were created within the geodatabase. To ensure accuracy, all data were projected to the same coordinate system (UTM NAD83).

Spatial Analysis

Each feature class was digitized at a scale of 1:1,500 around areas of the bog for the five years of imagery. A new text attribute field named "TYPE" was created in the attribute table and each polygon was classified as Open Water, Bog, or Mature Bog. Open water consisted of any part of the lake where water was visible. Bog consisted of areas where bog was present with no visible large vegetation. Mature bog contained areas where large vegetation growth on the bog was visible.

Topology was created in ArcCatalog for each feature class. Topology rules ensured no gaps or overlaps were present among polygons.

The Vector-based Landscape Analysis Tool Extension (V-LATE) for ArGIS 10 2.0 was used to obtain data for analysis. V-LATE offers the most common metrics used for ecological studies which cover insightful aspects of the quantitative evaluation of habitat structure (Lang and Langanke, 2005; Langanke, Rossner, Vrscaj, Lang, and Mitchley, 2005). Four analyses (area, edge, core area, and diversity) were performed on each year of aerial imagery with V-LATE. Edge analysis quantified configuration of the landscape while area and diversity analyses quantified the landscape composition. Core area analysis quantified both configuration and composition (McGarigal and Marks, 1995).

Area and perimeter were first calculated with V-LATE for each patch for every feature class, which was added to all attribute tables. The selected class field was set to "TYPE" and all three classes (Open Water, Bog, and Mature Bog) were selected for analysis (Figure 4).

Figure 4. Vector-based Landscape Analysis Tool Extension (V-LATE) was used for analysis of bog change around Long Lake.

Area Analysis

Area analysis calculated the total number of patches (NP), class area in m^2 (CA) mean patch size in m^2 (MPS) and mean patch standard deviation (PSSD). These data were important for the determination of bog growth and to establish when and where areas changed from water to bog or bog into mature bog.

Edge Analysis

Edge analysis is often used for determining relationships between edge and wildlife. No particular wildlife was examined with this study; however it was a functional analysis for comparing configuration of bog landscape. Edge data compares the fragmentation of bog landscape. V-LATE edge analysis calculated mean patch edge (MPE) in meters and edge density (ED) in meters/hectare.

Core Area Analysis

Core area is known as the area within a landscape beyond a particular buffer distance (McGarigal and Marks, 1995). Since V-LATE only performs core area analysis on shapfiles, all feature classes were converted to shapfiles in ArcCatalog. A 10 meter buffer was used for the core area analysis, which calculated total area in m^2 (TA), total core area in m^2 (TCA), core area index by percentage (CAI), number of core areas (NCA), and total class core area in m^2 (TCCA). Core area data provided information on changes in both landscape configuration and composition for each year of study.

Diversity Analysis

Shannon´s Evenness Index (SEI) and proportion were used for comparing diversity of each year of imagery. Evenness is the measured distribution of area among patch classifications located in the Long Lake landscape (McGarigal and Marks, 1995). Proportion provides information on the abundance of each patch type in relation to the total landscape area.

Prediction Analysis

After historical comparisons were completed a prediction analysis model was created to forecast the number of years for Long Lake to become completely covered with bog was calculated by dividing the area of open water in 2010 by the average yearly bog growth.

All V-LATE analyses were exported to .txt files and numbers were copied into an Excel spreadsheet where graphs and tables were created to show changes in the bog over the 71 year time period of this study. In order to easily associate with data, area analysis data were converted into acres using the following conversion.

$1\ m^2 = 0.000247105381467165$ Acres

Results

Spatial Analysis

In all analyses the number of patches (NP) in each classification helped to interpret the data (Table 1). Patches are mosaic, polygons, elements which make up a landscape (McGarigal and Marks, 1995). It was important to note change in patch numbers as it relates to both composition and configuration of the bog. Open Water was not included in the table because there was no change in patch numbers. Each year contained only two open water patches.

Table 1. Number of patches for Bog and Mature Bog in each year of analysis.

Year	Bog (NP)	Mature Bog (NP)
1939	2	10
1982	5	7
2003	10	8
2008	10	8
2010	9	9

Area Analysis

Over the 71 year study period dramatic change occurred in both the acreage of bog and mature bog in Long Lake (Table 2).

The largest change can be seen between 1939 and 1982 when the south side of Long Lake changed from Mature Bog to Bog (Figures 5 and 6). Exact reasons for this change are unknown; however the most likely reason would be from logging sometime in the late 1970s, but no records for this were found.

Over the next 28 years of study, the south side of Long Lake slowly changed back into Mature Bog (Figures 7, 8, and 9).

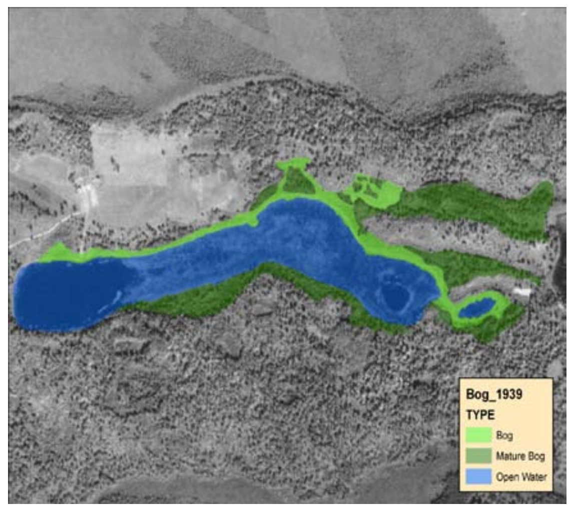

Figure 5. Bog cover on Long Lake in 1939 with a total Mature Bog of 21.80 acres.

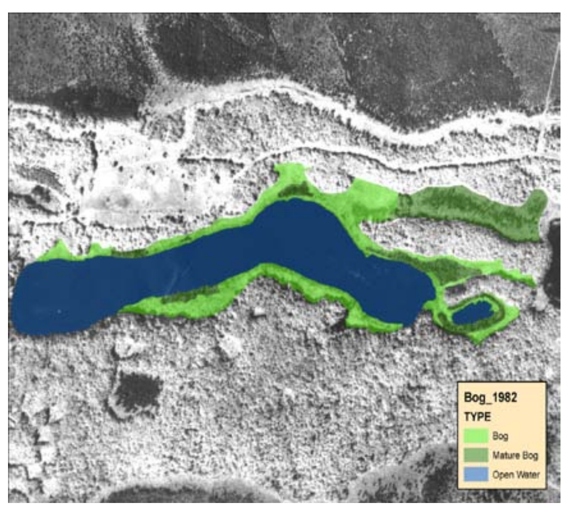

Figure 6. Bog cover on Long Lake in 1982 where Mature Bog decreased 9.87 acres since 1939.

Table 2. Area analysis data for Long Lake Bog and Mature Bog over the 71 year study period.

Area Analysis	1939	1982	2003	2008	2010
Bog CA (acres)	**9.43**	**18.43**	**10.05**	**10.14**	**9.09**
Bog MPS (acres)	4.71	3.69	1.00	1.01	1.01
Bog PSSD (acres)	3.40	3.36	0.74	1.27	1.22
Mature Bog CA (acres)	**21.80**	**11.93**	**19.87**	**20.40**	**22.31**
Mature Bog MPS (acres)	2.18	1.70	2.48	2.55	2.48
Mature Bog PSSD (acres)	2.90	2.20	3.55	3.56	3.59

Core Area Analysis

Total core area was lowest in 2003 (Table 3). Reasons for this can be seen when comparing core area to the numbers of patches (Table 1). In 2003 there was a combined total of 18 bog and mature bog patches, higher than the 12 combined patches in 1982. This resulted in fragmented mature bog area growth which creates smaller patches with less core area. The year 1982 had the highest total core area and it was also the year with the fewest number of patches. With the second highest year for mean patch size (Table 2) 1982 had larger, less fragmented patches.

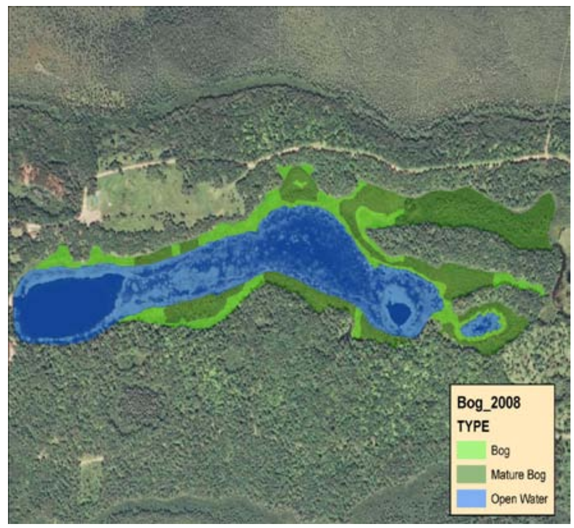

Figure 8. Bog cover on Long Lake in 2008 where Mature Bog area increased 0.53 acres since 2003.

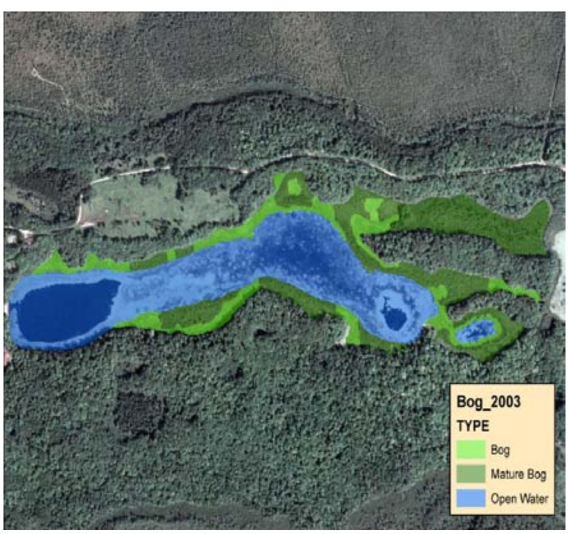

Figure 7. Bog cover on Long Lake in 2003 where Mature Bog area increased 7.94 acres since 1982.

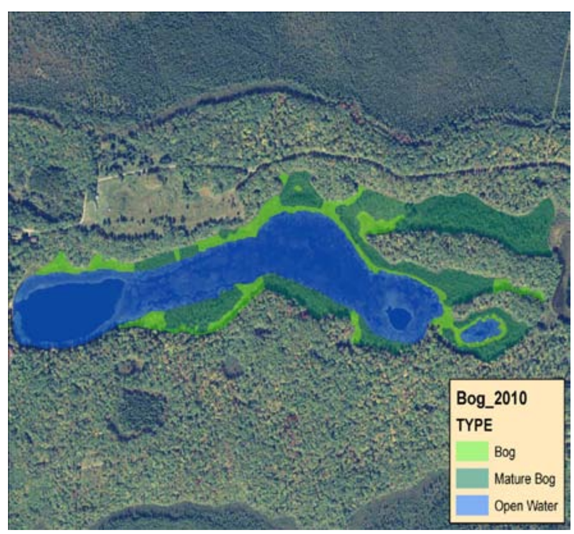

Figure 9. Bog cover on Long Lake in 2010 where Mature Bog area increased 1.91 acres since 2008.

Table 3. Total Core Area for each year of study in the Long Lake bog.

Year	TCA (acres)
1939	39.53
1982	39.75
2003	37.51
2008	38.41
2010	38.12

Edge Analysis

Edge analysis (Table 4) showed 1982 as the year with the highest mean patch edge. Like core area analysis, this is understood when comparing edge with the number of patches. Fewer patches meant patches covered larger areas which resulted in larger patch edge. The least edge occurred in 2003 along with the smallest mean patch edge. When the total patch numbers increased to 18 there were more patches where each covered a smaller area.

Edge density increased each year of the study. In 2003 when MPE decreased, ED still increased. This was possible because 2003 was also the year with the lowest total bog (Table 2). This could have been due to higher water levels in the imagery or clarity of the 2003 image.

Diversity Analysis

Proportions for each classification in each year of imagery were compared as a way to observe change in the Long Lake bog. Major change occurs in 1982 when bog proportion greatly increased and mature bog decreased, all other years were relatively similar in each classification (Table 5).

As the Shannon's Evenness Index (SEI) nears one, landscape diversity becomes perfectly even. Each year has a similar SEI value so bog diversity had changed minimally over the 71 year period (Table 6).

Table 4. Edge Density and Mean Patch Edge for each year of study.

Year	ED (m/ha)	MPE (m)
1939	479.54	916.94
1982	490.82	938.93
2003	521.19	689.65
2008	526.7	703.7
2010	529.44	704.09

Table 5. Proportions of classifications for each year.

Year	Bog	Mature Bog	Open Water
1939	14.25	32.95	52.8
1982	**27.85**	**18.03**	**54.13**
2003	15.36	30.38	54.26
2008	15.35	30.9	53.75
2010	13.82	33.95	52.23

Table 6. Shannon's Evenness Index for each year of study.

Year	SEI
1939	0.893
1982	0.908
2003	0.893
2008	0.896
2010	0.892

Prediction Analysis

Average yearly growth was measured by subtracting the total bog area (bog + mature bog) in 1939 from the total bog area in 2010 and then divided it by the total number of years of study. This led to the following calculation:

(31.40 acres -31.23 acres) / 71 years = .0024 acres/ year

Assuming conditions remain in the

future as they have for the past 71 years, an estimate of the amount of time for Long Lake to become a fully formed bog can be calculated by dividing the total area of open water in 2010 by the average yearly bog growth, as seen below. Likely, Long Lake will be a bog lake for years to come.

34.33 acres / .0024 acres/= 14,304 years

Conclusions

This study conducted an analysis of bog change on Long Lake in Aitkin County, Minnesota over a period of 71 years. The study used historical aerial imagery to analyze area, edge, core area, and diversity with the Vector-based Landscape Analysis Tool Extension (V-LATE). A prediction analysis was also conducted to estimate future bog life.

Findings revealed a loss of mature bog area between 1939 and 1982. Mature bog area then increased in 2003, 2008, and 2010. Since both diversity and area analyses quantify landscape composition, the 1982 difference in proportion was also seen in the area analysis when more bog area was present than mature bog area. Reason for the decrease in bog in 1982 could have been caused from logging or animal damage. A total increase of 0.17 acres was found over the 71 year period of study. Assuming conditions remain as at the present, prediction analysis estimated it would take at least 14,303 years for Long Lake to mature into a complete bog landscape.

Limitations of this research include resolution of images and interpretation of researcher. Data were based on the digitization and interpretation skills of researcher.

Future research could focus on more precise measurement techniques of the Long Lake bog growth. Further monitoring of the Long Lake bog as well as bogs in general would provide excellent educational data for students.

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