
Brad Toms
Mersey Tobeatic Research Institute
9 Mt. Merritt Road
Kempt, Nova Scotia
Contents
List of Tables ........................................................................................................................................... 2
List of Figures ............................................................................................................................................... 3
BACKGROUND ........................................................................................................................................... 4
Purpose ...................................................................................................................................................... 4
Methods ...................................................................................................................................................... 4
Habitat classification ................................................................................................................................. 4
Gull colony .................................................................................................................................................. 7
Bog width .................................................................................................................................................. 7
Lagg vegetation .......................................................................................................................................... 7
Area of occupation ..................................................................................................................................... 7
Results ....................................................................................................................................................... 7
Habitat Classification ............................................................................................................................... 7
Bog Width .................................................................................................................................................. 12
Gull Colony ................................................................................................................................................ 18
Lagg Analysis .......................................................................................................................................... 18
Area of occupation ..................................................................................................................................... 21
Discussion ............................................................................................................................................... 22
Works Cited .............................................................................................................................................. 22

List of Tables
Table 1: Selected aerial photo details....................................................................................................... 5
Table 2: Ratios of open and forested habitats in Big Meadow Bog 1955-2015 using Maximum Likelihood Classification. *2001 and 2015 images contained reflection in forested habitats resulting imprecise results using supervised points and Unsupervised ISO Clusters ................................................................. 9

List of Figures

Figure 1: Mask polygon overlaid on the 1955 aerial photo ................................................................. 6

Figure 2: Ratio of open and forest habitats using Maximum Likelihood Classification by polygons (Model 1), 1955-2015 ................................................................................................................. 10

Figure 3: Ratio of open and forest habitats using Maximum Likelihood Classification by points (Model 2), 1955-2015 ................................................................................................................. 11

Figure 4: Ratio of open and forest habitats using Maximum Likelihood Classification by ISO Clusters (Model 3), 1955-2015 ................................................................................................................. 11

Figure 5: Transect lengths 1945-2015. Transects begin (1) in the south and continue every 100m north on the UTM grid .................................................................................................................. 12

Figure 6: Mean Transect Length 1945-2015. n= 12 for each mean value ............................................. 13

Figure 7: Supervised Maximum Likelihood habitat classification by polygons (Model 1) 1955-2015 .... 14

Figure 8: Supervised Maximum Likelihood habitat classification by points (Model 2) 1955-2015 .......... 15

Figure 9: Unsupervised Maximum Likelihood habitat classification by ISO Clusters (Model 3) 1955-2015 16

Figure 10: Suspected location of Herring Gull colony 1978-2015 based on vegetation impacts .......... 17

Figure 11: Polygon of Lagg Zone (hatched area) used in analysis .................................................... 18

Figure 12: Ratio of forest to open area in lagg zone around Big Meadow Bog ................................... 19

Figure 13: Supervised Maximum Likelihood habitat classification by polygons (Model 1) for Lagg Zone 1955-2015 (red=open, green=forest) .................................................................................. 20

Figure 14: Area of occupation in 2012 (Green), 2013 (Yellow) and 2015 (Red) in Big Meadow 1 ....... 21
BACKGROUND

Brier Island Nova Scotia is situated at the end of the Digby Neck in the Southwest of the province. It is separated from Long Island by a narrow channel (Grand Passage). Long Island is further separated from the mainland (Digby Neck) by another channel (Petit Passage). This has meant that for much of its post-glaciation history it has been separated from the rest of the Mainland. Brier Island has likely been inhabited for millennia by Mi’kmaq cultures; and since 1769, by post European settlement mainly in the town of Westport. The island underwent significant land use changes during and after European settlement.

Big Meadow Bog, on Brier Island, is habitat for the endangered Eastern Mountain Avens (Geum peckii). It occurs only on Brier Island and Harris Lake in Nova Scotia and the White Mountains in New Hampshire. The Eastern Mountain Avens currently faces a cascade of connected threats in Big Meadow Bog (Environment Canada, 2010). The bog originally contained a mix of raised bog and fen characteristics and was used by island residents for foraging and hunting and recreation (Toms & LaRue, 2012). In 1958 and 1959 several ditches were excavated in an attempt to convert the bog into agricultural land. It was subsequently tilled several times but the venture never thrived and was soon abandoned (Toms & LaRue, 2012). After the ditch digging, changes to the local ecosystem have been slow but currently appear to be accelerating and interacting in previously unanticipated ways. The drying of the bog has allowed the formation of very large Herring Gull colony (Larus argentatus smithsonianus) which has persisted (either continuously or sporadically) since the mid 1970’s (Toms & LaRue, 2012). This has led to an increase in nutrients in the bog substrate and a change in the vegetation community. The bog ecosystem has changed from native bog species with a dominance of sphagnum sp to one dominated by ruderal native species, exotic invasive species and woody vegetation where sphagnum and native bog species are increasingly rare. In the lagg portion of the bog native vegetation has remained somewhat intact compared to the rest of the wetland.

In 2012 work began to investigate the scale and extent of impacts to Eastern Mountain Avens populations and develop long term monitoring protocols (Toms & LaRue, 2012). The documented impacts from that year prompted the initiation of a large scale multi-partner project to ultimately restore the ecology of the bog and gradually eliminate threats to Eastern Mountain Avens.

Purpose

The goal of this project is to document the extent of changes to the vegetation community by analysing existing aerial photography that exists from 1928-2015.

Methods

Habitat classification

Aerial photos were obtained by an in-kind donation by Nova Scotia Department of Natural Resources. Photos were obtained for the years, 1928, 1945, 1955, 1967, 1978, 1988, 2001, 2011. A further aerial
photo was obtained from the Nature Conservancy of Canada for the year 2015. A summary of the photo characteristics found in the National Aerial Photo Library (NAPL, 2015, 2015) can be found in table 1.

Table 1: Selected aerial photo details.

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Other aerial photos were available in the National Aerial Photo Library but were not used due to their large scale and temporal proximity to other photos (1987, 1993, and 1998). Two photos (1928 and 1945) were not used. The 1928 photo was slightly out of focus and of a low resolution. The 1945 image had water damage that was scanned into the digital version and an alternate photo from that year was out of focus. A flight report was not available online for 2011.

All photos were processed using a method set out by the United States Geological Service for analysing salt marshes as a guide (US Geological Service Western Ecological Research Station, 2011). All analyses were completed using ArcGIS 9.3 and ArcGIS 10 with the Spatial Analyst add-on. The recommended program, ERDAS Imagine, was not used for some steps because of the cost limitations of the project. The equivalent processes in ArcGIS were used in their place.

The photos were masked with a polygon using the Extract by Mask tool in Spatial Analyst. The mask area was determined by making a rough outline of the Big Meadow Bog using the 1955 photo to ensure that it reflected a pre-impact state (Figure 1). It was further modified in the southeast corner to accommodate the 1988 photo that was cut off in that area. This was preferable to introducing bias by creating a mosaic of the photo with another from that year to fill in the missing area. The area of the bog in question drains directly into Big Pond or just the end of the drainage ditch and likely doesn’t affect the results of this study.
The images were resampled at a 0.5m² resolution (cell size 1.64041) using cubic convolution. Polygons of open water were drawn for each image and erased from the raster in order to eliminate any confusion of forest and water by the model.

The prepared images were analysed using three methods. An unsupervised classification and a supervised classification were executed using ArcGIS 9.3. Supervised classifications involve the user defining training points to the tools that are then extrapolated to the rest of the image (Model 2). Without “on the ground” vegetation plots this method introduces the bias of the user expecting that they can interpret the vegetation types. Unsupervised classification (program defined categories) removes bias but increases the risk that two habitat types with similar colour signatures will be determined as equal by the tools.

Training points were established (>50 per category) for Forest and Open vegetation types for each aerial photo. Signature files were created using the Create Signature tool. The Maximum Likelihood Classification tool (with a reject fraction of zero) was used with the signature file to classify the image.

For the unsupervised classification the ISOCluster (Model 3) tool was used to create signature files with 10 classifications and then processed using the Maximum Likelihood Classification tool with a reject fraction of zero. The user then determined whether each of the 10 categories represented Forest or Open vegetation types by comparing them with the image.

Limitations of the supervised classification method in ArcGIS resulted in the use of a supervised classification using ArcGIS 10 (Model 1). The supervised classifications in ArcGIS 9.3 use training points
while ArcGIS 10 uses training polygons to classify habitats. In some photos (particularly 2001 and 2015) a very bright reflectivity of forest vegetation caused the model (using points in 9.3) to confuse bright spots in old forest vegetation as the same type as bare soil. Using polygons of the forest and open areas in the supervised classification reduces this error by drastically increasing the area sampled and accounts for the overall composition of the vegetation types rather than single points.

Gull colony

The location of the Herring Gull colony using vegetation classification was also outlined by manually drawing polygons around impacted areas where there were ruderal species of vegetation and obvious trails and clearings that the gulls maintain while occupying the site.

Bog width

As a supplement to the habitat classification, bog width was measured. A sampling grid was established using Hawth's Tools with East-West lines established every 100m. The distance from the east edge of the bog to the west edge of the bog was then measured along these lines for each aerial photograph.

Lagg vegetation

In order to investigate whether the lagg zone might be impacted differently than the bog as a whole, a separate analysis was completed. A polygon was created by snapping to the mask polygons of the vegetation analysis and by drawing new lines that followed the man made ditches on the East side of the bog and by following the footpath along the west site of the bog (Figure 11). Model 1 (Maximum Likelihood polygons) rasters were cut extracted to the lagg polygon.

Area of occupation

On the ground observers suspected a spatial loss of Avens habitat from 2012-2015. Census data was used to calculate an “area of occupation” for Geum Peckii in order to determine if such a loss empirically occurred. GPS positions of count data collected by Toms and LaRue (2012), MTRI (2013) an MTRI 2015 for Big Meadow Bog (BM1) and Runway Bog BM3 (b) were brought into a shapefile. The Buffer tool was used to create a 4 meter buffer around each GPS point to account for GPS error and the buffers were dissolved where they overlapped (). The area of the resulting polygon was then measured using the Calculate Geometry tool resulting in an area in square meters.

Counts of BM1 all occurred using multiple observers travelling in parallel lines and marking counted areas with flags as they went. Counts of BM3b were all conducted by the same single observer in all years using the same method but without flagged lines.

Results

Habitat Classification

Overall, all three results showed a decline in open habitats and an increase in forest habitats (Table 2). Supervised points (Model 2) and Unsupervised ISO clusters (Model 3) produced results that often
misidentified habitats and were affected by reflection of forest vegetation in some photos. Supervised Maximum Likelihood Classification (Model 1) by polygons seemed to solve this issue by considering the overall composition of the photo rather than individual points. Increases in open habitats in 1967 and 1978 could be attributed to previously wet areas drying up after draining and being classified as open habitat rather than being deleted from the photo. Model 1 showed that open habitats and forest habitats have changed from a 63/37 split to nearly an even 50/50 split (Table 2)(Figure 2). In the context of a 71.67Ha sampling area this translates to a loss of open area of 9.57Ha (45.15Ha-35.58Ha).

Results from Model 2 and Model 3 are presented illustratively even though their results were dubious. Visual representations can be seen in Figures 7, 8 and 9.
Table 2: Ratios of open and forested habitats in Big Meadow Bog 1955-2015 using Maximum Likelihood Classification. *2001 and 2015 images contained reflection in forested habitats resulting imprecise results using supervised points and Unsupervised ISO Clusters

<table>
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Figure 2: Ratio of open and forest habitats using Maximum Likelihood Classification by polygons (Model 1), 1955-2015.
Figure 3: Ratio of open and forest habitats using Maximum Likelihood Classification by points (Model 2), 1955-2015.

Figure 4: Ratio of open and forest habitats using Maximum Likelihood Classification by ISO Clusters (Model 3), 1955-2015.
**Bog Width**

No bog width transects showed an overall increase in length from 1945-2015 and all showed an overall decrease in length (Figure 5). The mean width for each year trended clearly shorter with a strong linear correlation (r=0.904) (Figure 6).

![Figure 5: Transect lengths 1945-2015. Transects begin (1) in the south and continue every 100m north on the UTM grid.](image)
Figure 6: Mean Transect Length 1945-2015. n = 12 for each mean value.
Figure 7: Supervised Maximum Likelihood habitat classification by polygons (Model 1) 1955-2015
Figure 8: Supervised Maximum Likelihood habitat classification by points (Model 2) 1955-2015
Figure 9: Unsupervised Maximum Likelihood habitat classification by ISOClusters (Model 3) 1955-2015
Figure 10: Suspected location of Herring Gull colony 1978-2015 based on vegetation impacts
Gull Colony

Analysis of vegetation impacts from 1978 revealed a northward migration of the gull colony and corresponding changes in vegetation (Figure 10). Most concerning is the increase in the vegetation impacts observed on the ground and by aerial photo from 2011 to 2015 in Big Meadow 1 area that contains a large number of Eastern Mountain Avens.

Lagg Analysis

The lagg zone had a greater increase in forested area from 1955 to present compared to the entire bog (Figure 12). Similarities between 1955 values and 2015 values can be explained by a spatial shift in vegetation (more area interpreted open in NW and more interpreted as forest in the SE) as well as increased open where forest was cleared for the runway. There was also a shift from large contiguous open areas to many smaller openings (Figure 13).

Figure 11: Polygon of Lagg Zone (hatched area) used in analysis
Figure 12: Ratio of forest to open area in lagg zone around Big Meadow Bog
Figure 13: Supervised Maximum Likelihood habitat classification by polygons (Model 1) for Lagg Zone 1955-2015 (red=open, green=forest)
Area of occupation

Area of occupation for various years can be seen in Figure 14. Spatial loss occurred due to changes in substrate from Sphagnum moss and shrubs to grasses, impatiens and mucky soil and due to nesting Herring Gulls moving into the area. Area of occupation in BM1 was: 4399m² in 2012, 4541m² in 2013, and 3483m² in 2015. As a comparison Runway Bog (BM3b) was also measured resulting in areas of occupation of: 2073 m² in 2012, 2038 m² in 2013, and 2197 m² in 2015.

Figure 14: Area of occupation in 2012 (Green), 2013 (Yellow) and 2015 (Red) in Big Meadow 1
Discussion

Supervised Maximum Likelihood Classification using polygons proved to be the superior method for properly classifying aerial photos. There has been a clear decrease in bog width as well as a decrease in the ratio of open habitat to forested habitat. The lagg zone has been had a greater change than the bog as a whole. The area of occupation in BM1 has decreased significantly from 2013-2015 (1058m$^2$ (23%)). While BM3 reflects a small increase (6%) due to increased knowledge of the site and finding new occupied area.

The restoration of the bog to its former hydrology in order to cease or reverse these trends likely can’t come too soon.

Works Cited


