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Cameras, Satellites, and Surveys: A Multi-Platform Approach to Monitoring Lake Conservation Behavior

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EXCECUTIVE SUMMARY

Shoreline buffers are essential to maintaining lake water quality and there are numerous methods for their assessment. There is uncertainty in the benefits and drawbacks of different shoreline buffer assessment methods. In this study I explore three methods of remotely assessing shoreline buffers in the Belgrade Lakes Region of Maine: household surveys, geotagged shoreline photos, and satellite imagery. By comparing these three methods I will evaluate their accuracy and applicable scale when used to assess the presence and quality of shoreline buffers.

I used both parametric and non-parametric analysis to (1) evaluate the relative accuracy of 154 household surveys in identifying buffer presence or quality, (2) compare experts in their evaluation of 98 geotagged photos of buffers, (3) assess the accuracy of approximately 450 million square meters of classified Geoeye-1 imagery, and (4) compare the three buffer assessment methods across lakes and demographic factors. Relative to an expert assessment, shoreline residents similarly identified the presence of buffers but significantly differently estimated their extent and quality. Experts differed in how they assessed the extent and quality of buffers. Classified satellite imagery did not significantly predict an expert assessment of buffer presence or quality. While not significant, inter-lake comparison found that North Pond residents assess buffers slightly differently than Great Pond or East Pond residents.

These findings suggest that household surveys and geotagged shoreline photos are valuable tools for evaluating shoreline buffers. Satellite imagery is informative at a lake or watershed scale, but has limitations at a lot scale. Continued lake stewardship education efforts are important and should be supplemented, not replaced, by remote assessment methods.

ACKNOWLEDGEMENTS

I owe a great thanks to all the individuals who helped me throughout my research and writing. Without you this study could not have happened. Specifically, I would like to thank the residents of Great, North, and East Ponds who filled out household surveys and in a very real sense made this study possible. Pete Kallin, Dan Buckley, and Maggie Shannon, you provided invaluable input and guidance throughout my study for which I am enormously grateful. Your dedication to the Belgrade Lakes community is inspiring. The Maine Congress of Lakes Associations, the Belgrade Regional Conservation Alliance, and the Maine Department of Environmental Protection contribute a tremendous amount, such as the inspiration behind LakeSmart and geotagged shoreline photos, to conservation and research on the Belgrade Lakes. For that, and their support of my research, I owe them great thanks.

Many of my sources of data, such as the household surveys, the shoreline photos, and the lot layer, would not have existed where it not for the hard work of Colby students, past and present. Sophie, for the household surveys, inspiration, and friendship, I thank you. Ian, my Olin research friend, driving companion, and Moose aficionado, I thank you for your work on the lot and land cover data. Josie and Kat, I thank you for the hundreds (if not thousands) of geotagged shoreline images.

To my readers, Russ and Whitney, thank you for your input. You helped me clarify my message and hopefully make my thesis more useful for those who read it. Thank you. Manny and Travis, without your unfailing willingness to answer my convoluted and frequent questions, I would not have been able to do much of my research. You are both incredibly patient and kind, thank you. Gail and Lia, thank you for letting me procrastinate by bothering you. I very much enjoyed our frequent hallway chats. Last, but certainly not least, Philip, I owe you a tremendous thanks. Because of your gentle guidance and wisdom I have had a terrific four years at Colby. I thank you for your help on this project, and much more. Thank you.

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INTRODUCTION

Lakes are an important social, ecological, and economic resource. The nearly 6,000 lakes in Maine provide a majority of the state's drinking water, numerous recreational opportunities, and habitat for a diverse array of flora and fauna (Michael et al. 1996). Collectively, Maine lakes contribute $3.5 billion annually to Maine's economy (Williams and Hill 2009, MDEP 2011). Despite their importance, nearly 10% of lake acres assessed by the Maine Department of Environmental Protection (MDEP) are impaired, meaning they do not meet state water quality standards (MDEP 2010).

Human activity along lake shorelines, such as residential development, is strongly linked to lake water quality through its negative effects on nutrient loading, woody debris, aquatic vegetation, and macrophyte populations, among a host of other factors (Radomski and Goeman 2001, Baker et al. 2008, Strayer and Findlay 2010). Installation or enhancement of vegetated buffers between shoreline houses or agriculture and the shoreline can help improve water quality by mitigating the negative effects of shoreline activity (B. M. Vought at al. 1995, Hardesty and Kuhns 1998).

Monitoring conservation behavior to assess the effectiveness of particular conservation practices is important to evaluate and improve conservation efforts (Yoccoz et al. 2001, Mascia et al. 2003). In the realm of lake conservation, monitoring lake water quality and its related components, such as effectiveness of shoreline buffers, is essential to improving lake water quality and encouraging beneficial stewardship practices.

To evaluate shoreline buffers and encourage lake residents to improve their buffer design, MDEP uses the LakeSmart program. LakeSmart evaluates, among other things, the presence and quality of shoreline buffers (Welch and Smith 2008, MDEP 2010B). Assessing remote methods for buffer evaluation may enable more frequent and accurate monitoring while lowering costs and increasing knowledge for policy creation. Remote sensing has similarly been used to evaluate urban growth and general land cover change (Xiuwan 2002, Jain and Jain 2006, Van Delm and Gulinck 2011). Of the various remote evaluation methods, I used three: household surveys, geotagged shoreline photos, and satellite imagery.

The Belgrade Lakes are a chain of seven lakes in Central Maine that, like lakes throughout the state, are a valuable resource to the surrounding environment and people.

However, human activity on these lakes has contributed to declines in their water quality over the past decade, highlighting the importance of evaluating and improving buffers (MDEP 2010).

Household surveys and satellite imagery have been used to evaluate perceptions of water quality and shoreline development, respectively (Brody et al. 2005, Stedman and Hammer 2006). Geotagged photos are a promising new data source but have been investigated primarily for mining social knowledge, classifying events, landmark recognition, and photo (non-geotagged) location (Joshi at al. 2010, Yuan et al. 2010, Zheng at al. 2011). Based on a literature review, there is an apparent dearth of literature on the use of geotagged photos in the field of conservation. However, there are recent examples of their use for biological research. For example, geotagged photos in concert with Geographic Information System (GIS) technology and online mapping services, such as Google Earth, have been used to provide geovisualization aspects to research, such as primate identification and mapping (Elmwood 2008, Jong and Butynski 2010).

The purpose of this study is to evaluate the accuracy and scale with which household surveys, geotagged shoreline photos, and satellite imagery can be used to evaluate shoreline buffer presence and quality. I studied 154 of nearly 1,500 shoreline lots on three of the Belgrade Lakes: Great Pond, North Pond, and East Pond. For this study I defined buffer quality in terms of percent of buffer vegetated along shoreline, buffer's estimated ability to reduce runoff, and tiers of vegetation within buffer. I assessed accuracy through comparison of the evaluation methods to one another using spatial and statistical analyses. In doing so I not only assess the functionality of buffer assessment methods, but also create an evaluation framework for comparison of assessment methods.

This study is organized as follows. I first describe the methods I used to evaluate the accuracy and applicable scale of household surveys, geotagged shoreline photos, and satellite imagery as shoreline buffer evaluation methods. I then present the findings from spatial and statistical analyses of the three buffer evaluation methods. Last, I discuss and summarize my findings and offer future recommendations concerning shoreline buffer evaluation and research.

METHODOLOGY

I collected three types of data pertaining to the Belgrade Lakes and shoreline buffers for this study: survey data, shoreline photo data, and spatial data (Figure 1). In continuation of Sophie Sarkar and Philip Nyhus's (of the Colby Environmental Studies Program) 2011 research, I focused specifically on Great Pond, North Pond, and East Pond while collecting data. For a complete list of GIS data sources see Table 1.

Table 1. GIS data sources pertaining to the Belgrade Lakes region of Maine, land use, and shoreline buffers.

Variable	Description	Source
Administrative boundaries	State, county, and town boundaries	Maine Office of GIS (www.maine.gov/megis/)
Elevation	10m DEM	USGS National Elevation Dataset (ned.usgs.gov/)
LakeSmart Awards	Awards and recognitions as of 2011	BRCA (www.belgradelakes.org/)
Land cover 1	Land cover digitized using NAIP imagery by Colby ES494 students 2009-2011	Colby Environmental Studies Program (www.colby.edu/environ)
Land cover 2	Maine Land Cover Map 2004 (30m Landsat imagery)	Maine Office of GIS (www.maine.gov/megis/)
Lot boundaries	Tax lots digitized by Colby ES494 students and Ian McCullough 2008-2010	Colby Environmental Studies Program (www.colby.edu/environ)
Satellite imagery	Geoeye-1(4m) imagery taken May through Sept. 2009-2010 (covering ~731,000,000 m^2)	Geoeye (www.geoeye.com/CorpSite/)
Shoreline Photos	Photos of shoreline residences	Lab of W. King, Colby College (web.colby.edu/epscor/shoreline-photos/)

To evaluate the accuracy and appropriate scale of use for household surveys, geotagged shoreline photos, and satellite imagery, I used three methods to process the collected data: geotagged photo location and evaluation, satellite image processing, and statistical analysis. A general description of each methodological step follows.

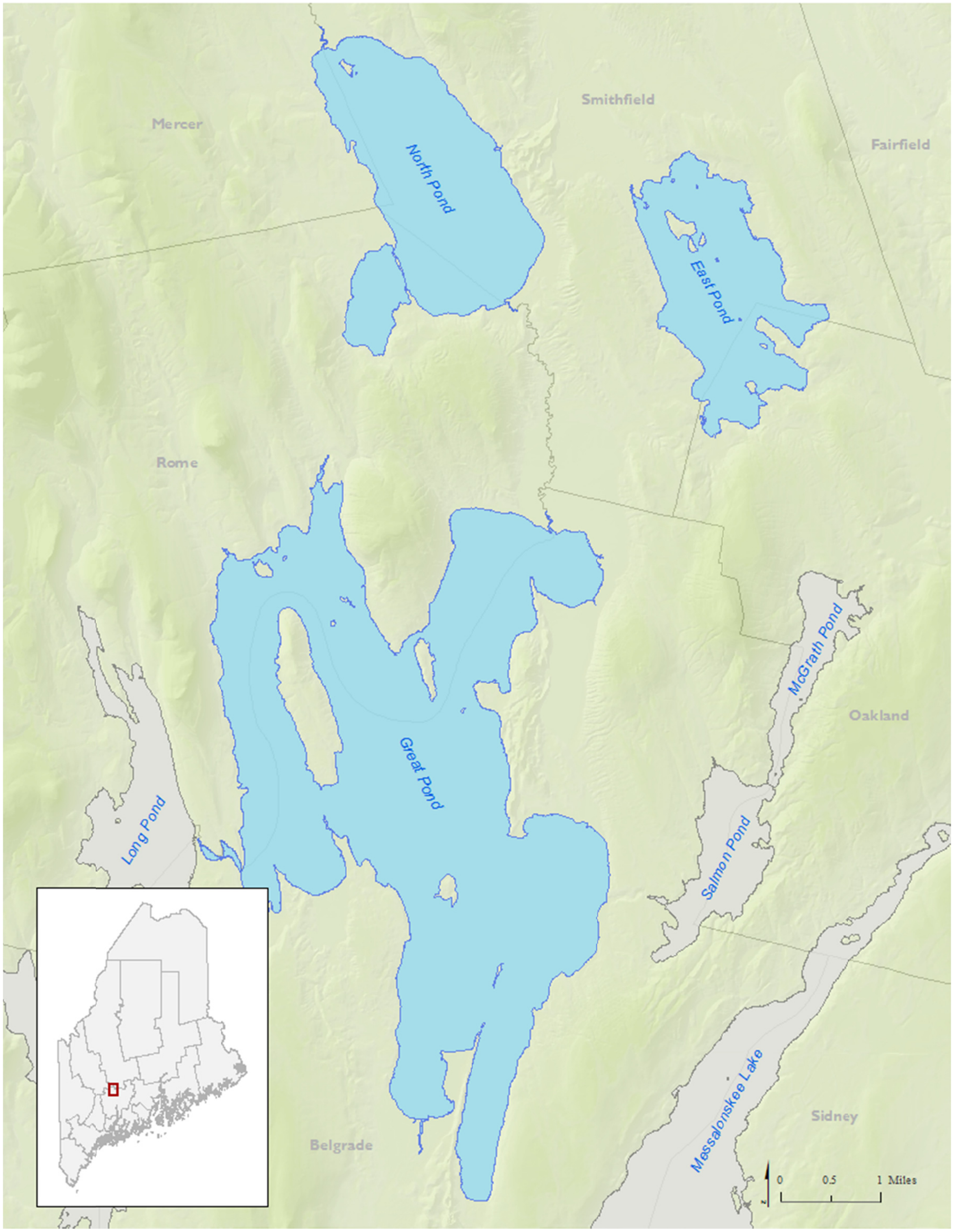


Figure 1. Three study lakes: Great Pond, North Pond, and East Pond in the Belgrade Lakes region of Maine (Maine Office of GIS 2010, USGS 2011).

Shoreline Photo Location and Evaluation

Household Survey

During the summer of 2011 Sophie Sarkar and Philip Nyhus of the Colby Environmental Studies Program surveyed shoreline residents of Great Pond, North Pond, and East Pond (Appendix A). The purpose of this survey was to evaluate shoreline conservation practices and aesthetic values while also collecting contingent valuation and demographic data. The questions within this survey pertaining to shoreline buffers were created with the LakeSmart evaluation criteria in mind (Appendix C). Sarkar and Nyhus sent a total of 550 surveys to shoreline residents: 200 to Great Pond, 169 to North Pond, and 181 to East Pond. Of the 550, 50 were returned to sender due to incorrect addresses and 172 surveys were returned complete (34% response rate).

Household Survey Location

I used two references to geolocate the household surveys and link them to lots. The first was a lot layer digitized by ES494 (Environmental Studies Science Capstone) students between 2008 and 2010 (Figure 2). The second was a simple address lookup using Bing maps. Often I needed both references to locate the survey house in question. Once I had located the survey residence, I used the Google Earth database of geotagged shoreline photography collected and created by Josephine Thiele, Katherine Murray, and Whitney King, to find the corresponding shoreline photo. Each shoreline photo had complete geographic coordinates, date and time taken, exposure and aperture settings, and compass heading.

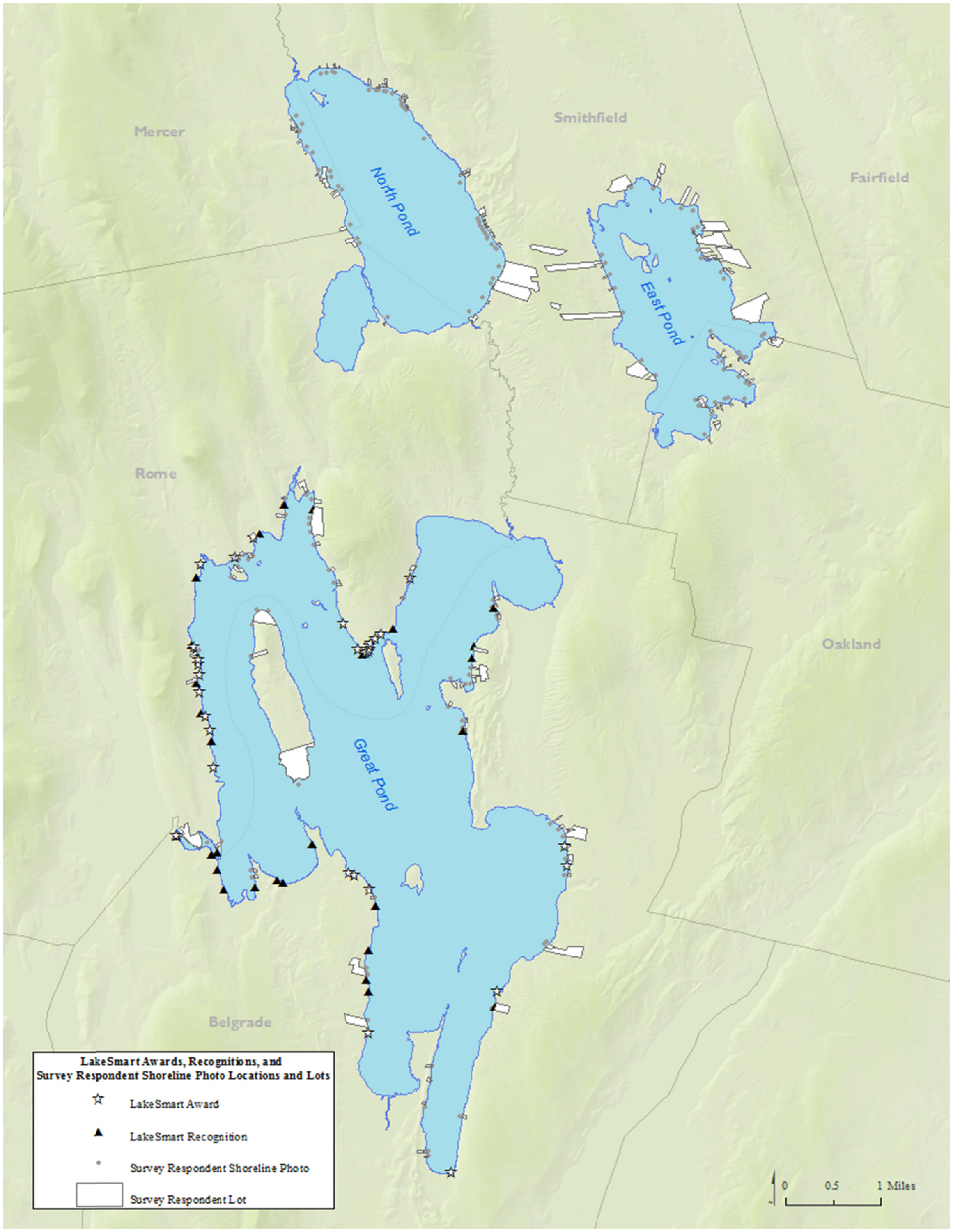


Figure 2. Distribution of LakeSmart awards, recognitions, and shoreline photos matched to lots and household surveys on Great Pond, North Pond, and East Pond (BRCA 2011).

I rated the match of the shoreline photo to the survey residence on a certainty scale of one through three. One represented a match that was tenuous due to a missing street name from the address (or missing map and lot numbers). Two represented a certainty of match that was relatively strong but complicated by a missing house number from the address or difficulty placing the address using Bing. Three represented a match that was strong and seemingly without issue although there was still the possibility that placement of the street address by Google or Bing may not match the lot database perfectly.

I also located the shoreline photos of the houses on either side of the survey residence using the Google Earth shoreline photo database. In some cases, I found no house adjacent to the survey residence (within four or five photos). When this occurred, I used the photo directly adjacent.

After geographically locating the household survey responses, I eliminated 18 surveys because either the surveyed property was not on the shoreline, had incomplete information, or could not be geolocated. The resulting sample size of 154 surveys accounts for approximately 90% of all the completed surveys. Of the 154 selected surveys, 64 were from Great Pond (91.4% of completed surveys), 50 from North Pond (94.3% of completed surveys), and 40 from East Pond (81.6% of completed surveys).

The incomplete nature of the satellite imagery (see Image Processing section below) meant that I had land cover data for even fewer of the shoreline residences. I was able to process land cover data for 52 (81.2%) of Great Pond lots, 34 (68.0%) of North Pond lots and 40 (100% of selected surveys) of East Pond lots.

Evaluation of Shoreline Photos

To compare resident evaluations of shoreline conservation practices to expert assessment, I sent a shoreline photo survey to three trained LakeSmart evaluators (for more about the evaluators see the Expert Shoreline Photo Evaluation Overview below). Within each survey I included a number of the geographically located shoreline photos. For each photo, I asked the experts to answer the same shoreline buffer evaluation prompts based on LakeSmart evaluation criteria that the Sarkar and Nyhus survey asked of the residents (Appendix A). I did omit question 15b; "On average, how wide (from the

shore to your yard) is the buffer directly in front of your house?" because of the difficulty the experts might have answering such a question using only a photograph.

I sent the three experts the same 20 shoreline properties (randomly selected from the 154 selected surveyed residences). This was intended to provide an intercoder reliability measure of 20 shoreline properties. For each expert's survey I placed the first half of the 20 intercoder properties at the beginning of the survey and the second half at the end of the survey. I sent one surveyor an additional 20 randomly selected properties because the expert had a limited amount of time for evaluation. I sent an additional 58 properties to the other two experts. See Appendix B for a final version of the survey sent to experts.

Image Processing

I processed only the Geoeye-1 satellite images, acquired in 2010, that covered Great Pond, North Pond, and East Pond (Figure 4). For ease of reference, I labeled the five images Multi (short for multiband) 1 through 5 (Figure 4). The satellite images entitled Multi 4 and Multi 5 do not contain portions of Great Pond, East Pond, or North Pond useful for this study's analysis so I did not process them, although I do refer to them in Table 2 and Figures 2 and 3. Using ArcGIS 10.0, I performed a three step process to classify the satellite images: a manual cloud extraction, a supervised classification, and a georectification (Figure 3). A more detailed description of each analysis step follows.

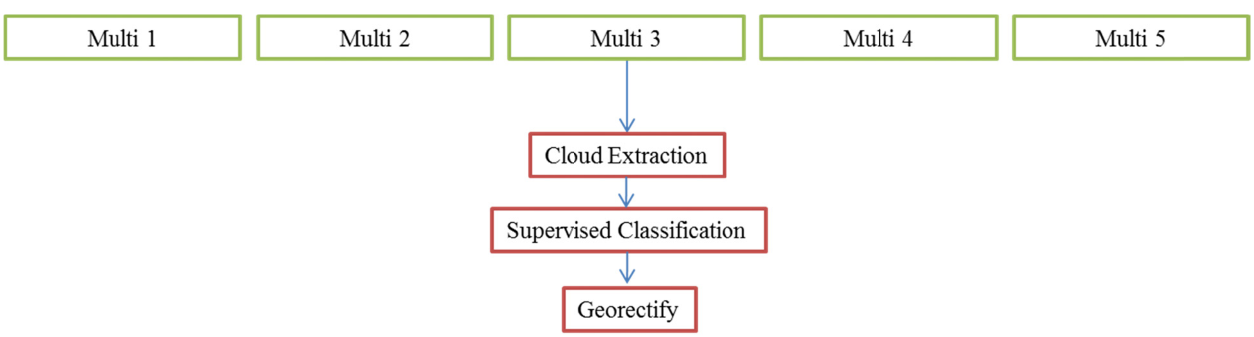


Figure 3. A visual depiction of the model used to process and classify the Geoeye-1 satellite imagery using ArcGIS 10.0.

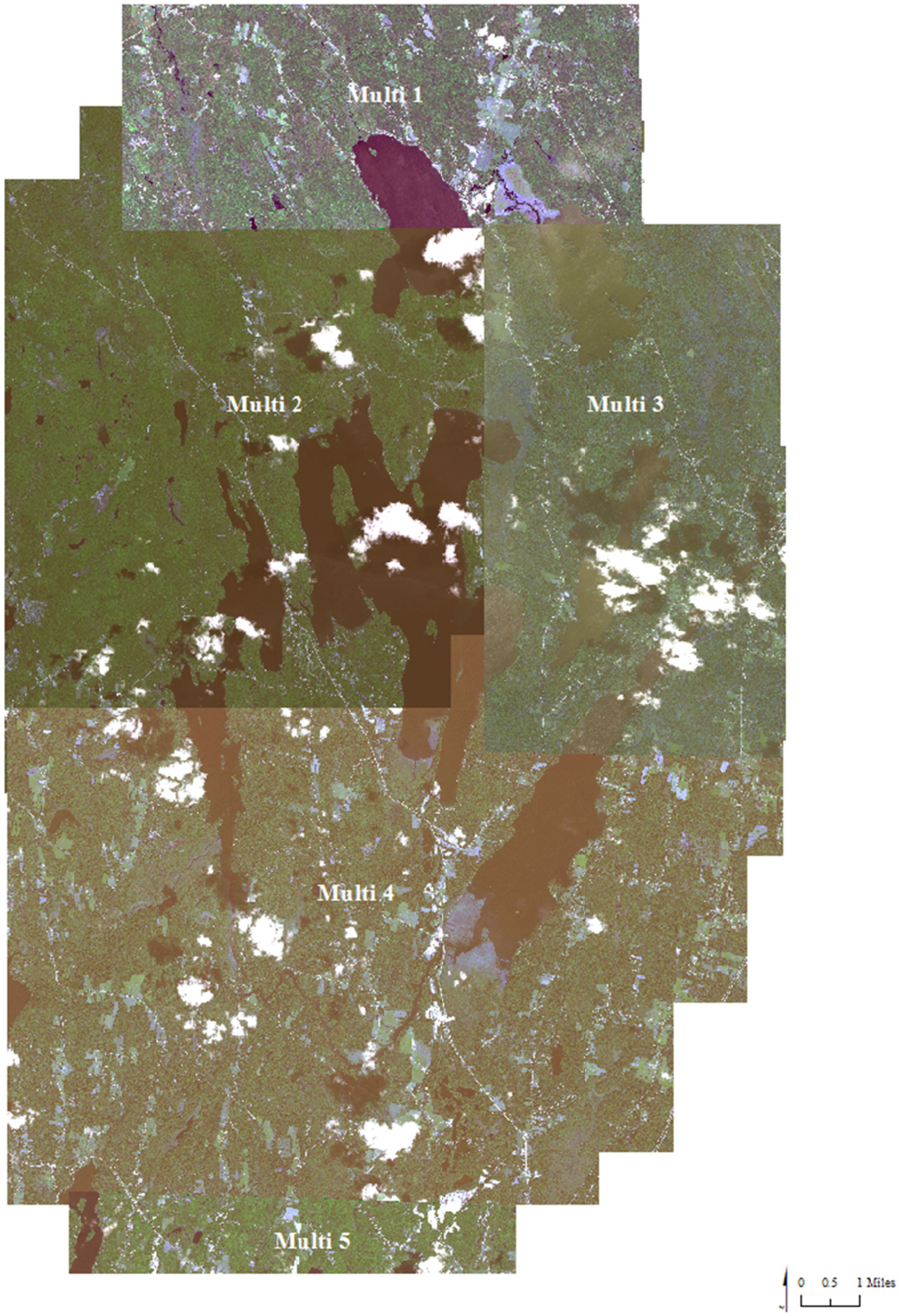


Figure 4. Geoeye-1 satellite imagery of the Belgrade Lakes region of Maine used for classification and spatial analysis of shoreline buffers (Geoeye 2010).

Cloud Extraction

Approximately 4.1% of the area of the Multi 2, 3, and 4 satellite images was covered by clouds (Multi 1 had no cloud cover). To remove clouds, I manually identified and extracted the clouds from the satellite images. Because only four images needed processing, manual identification and extraction was the fastest and most accurate cloud removal procedure (Wang et al. 1999, Dare 2005). Three steps defined the extraction process: creation of polygons over areas of cloud cover, division of satellite images into separate color bands for extraction, and compilation of bands after cloud extraction.

Supervised Classification

I classified the four satellite images separately because each image had different cloud, haze, and light conditions resulting from the various capture dates (Table 2; Furby and Campbell 2001). For the same reason, I chose not to merge any two images needed to cover an entire lake although no single image contains one lake in its entirety (Figure 3). As a result, I did not produce land cover data for all of Great, North, or East Ponds. See Figures 5, 6, and 7 for an example of the land cover data surrounding Great, North, and East Ponds after classification.

Table 2. Geoeye-1 satellite imagery information including date range (D, M, Y), cloud cover, and upper left coordinates for Geoeye -1 satellite imagery (Geoeye 2010).

Image	**Image Date(s)**	**Cloud cover (%)**	**UL Latitude (DD)**	**UL Longitude (DD)**
Multi 1	05.28.2010-07.27.2010	0	44.6788667905	-69.7660609353
Multi 2	05.28.2010-07.27.2010	7	44.6536132321	-69.7649716581
Multi 3	09.18.2010-09.29.2010	6	44.6244032525	-69.7151959511
Multi 4	09.18.2010-09.29.2010	2	44.5222089483	-69.7146995058
Multi 5	06.08.2009	1	44.3823635469	-69.8057340491

I used the standard supervised maximum likelihood classification scheme within ArcGIS 10.0 to classify the imagery. To best identify the foliage spectral response within the imagery, I used the blue (450-519 µm), red (655-690 µm), and near infrared (780-920

μm) bands. The maximum likelihood classification tool uses both the variances and covariances of the class signatures to assign a class represented in the signature file, or training area, for each cell (Lu and Weng 2007, ArcGIS Resource Center 2011, Ayhan and Kansa 2012).

I created the training areas (areas in which land use is manually identified) needed for the maximum likelihood classification based on 2009 National Agriculture Imagery Program (NAIP) imagery and 60 ground truth points Ian McCullough and I collected during the summer of 2010. The training areas included over 900,000 pixels in the Multi 2 image, 100,000 pixels in the Multi 1 image, and nearly 300,000 pixels in the Multi 3 image across all six land cover classes: grass, mixed forest, road/impervious, house, water/shadow, and wetland/grass (Table 3).

Table 3. Pixel count and percentage by class for satellite image training areas created within Geoeye-1 satellite imagery.

	Multi 2 (Great Pond)		Multi 1 (North Pond)		Multi3 (East Pond)	
Class Name	**Pixel Count**	**Total Class Area (%)**	**Pixel Count**	**Total Class Area (%)**	**Pixel Count**	**Total Class Area (%)**
Grass	8,779	0.2	18,376	0.7	8,234	0.7
House	573	0.0	183	0.1	514	0.0
Mixed Forest	53,143	0.1	11,888	0.1	39,812	0.2
Road/Impervious	807	0.3	405	0.1	715	0.7
Water/Shadow	848,933	8.4	40,309	2.8	231,535	5.9
Wetland/Grass	1,965	0.1	33,830	2.2	16,745	0.4
Total	914,200	1.4	104,991	0.5	297,555	1.1

Georectification

I used 2009 NAIP imagery downloaded from the Maine Office of GIS as a spatial reference for the Belgrade Lakes to standardize the various data layers for this project. Using the NAIP imagery Peter Smithy and I digitized the lake shoreline boundaries at a scale of 1:2000, edited shoreline lot layers, and georectified the classified imagery (Figure 5, 6, and 7).

Post Processing Analysis

For analysis purposes, I evaluated both entire lot land use and just the shoreline (250 ft) portion of the lot. I compared the classified imagery to two other land cover data

sources to assess the accuracy of the land cover classification scheme I created. For comparison I used the ES494 2010 land cover data layer manually digitized on a visual scale by ES494 students using 2009 NAIP imagery and the 2004 Maine Land Cover Map (MELCD) classified using an automated scheme on an individual pixel scale. Comparison of the three land cover data sets is difficult because the classification categories do not coincide perfectly.

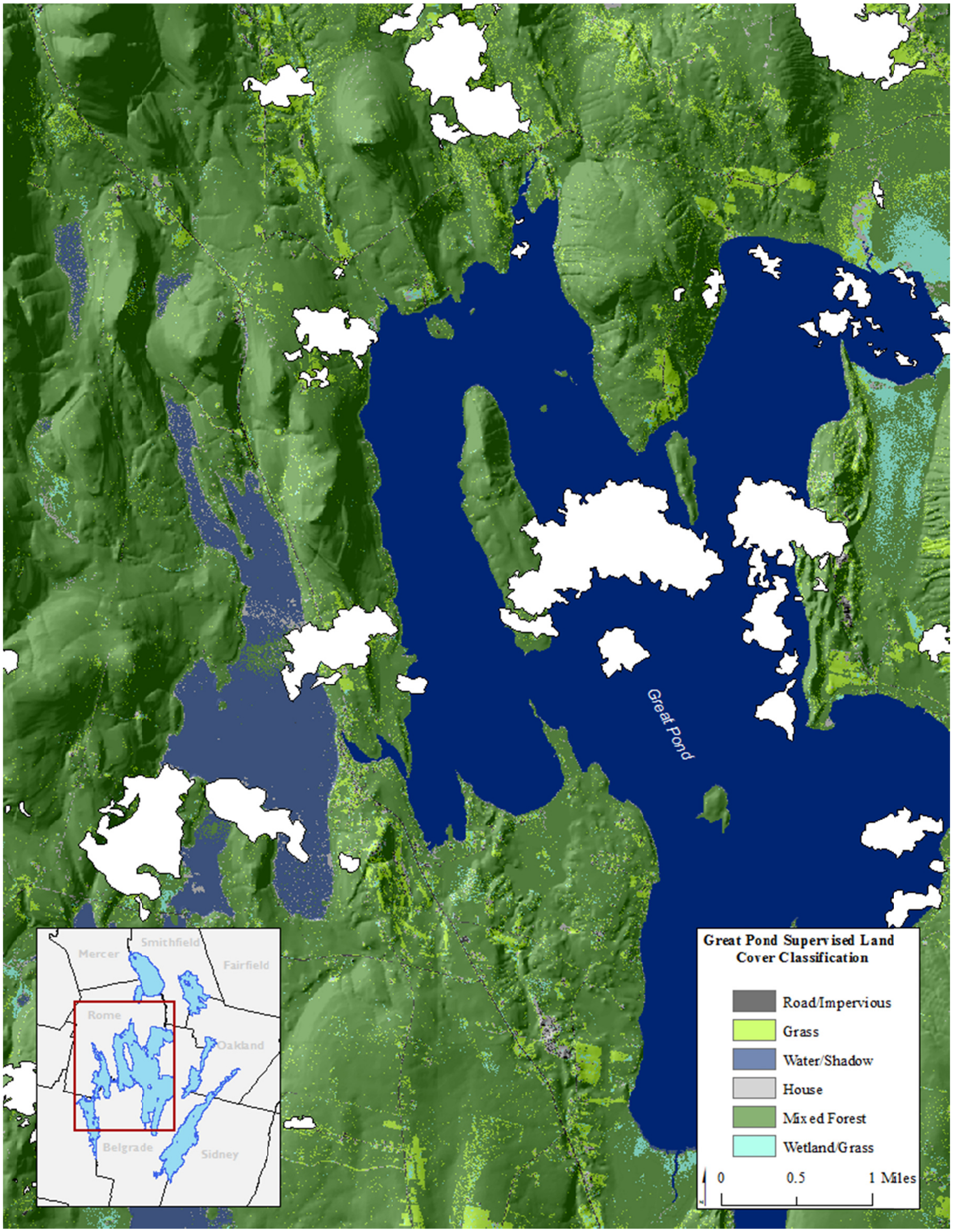


Figure 5. Great Pond supervised land cover classification of Geoeye-1 satellite imagery, created using ArcGIS 10.0.

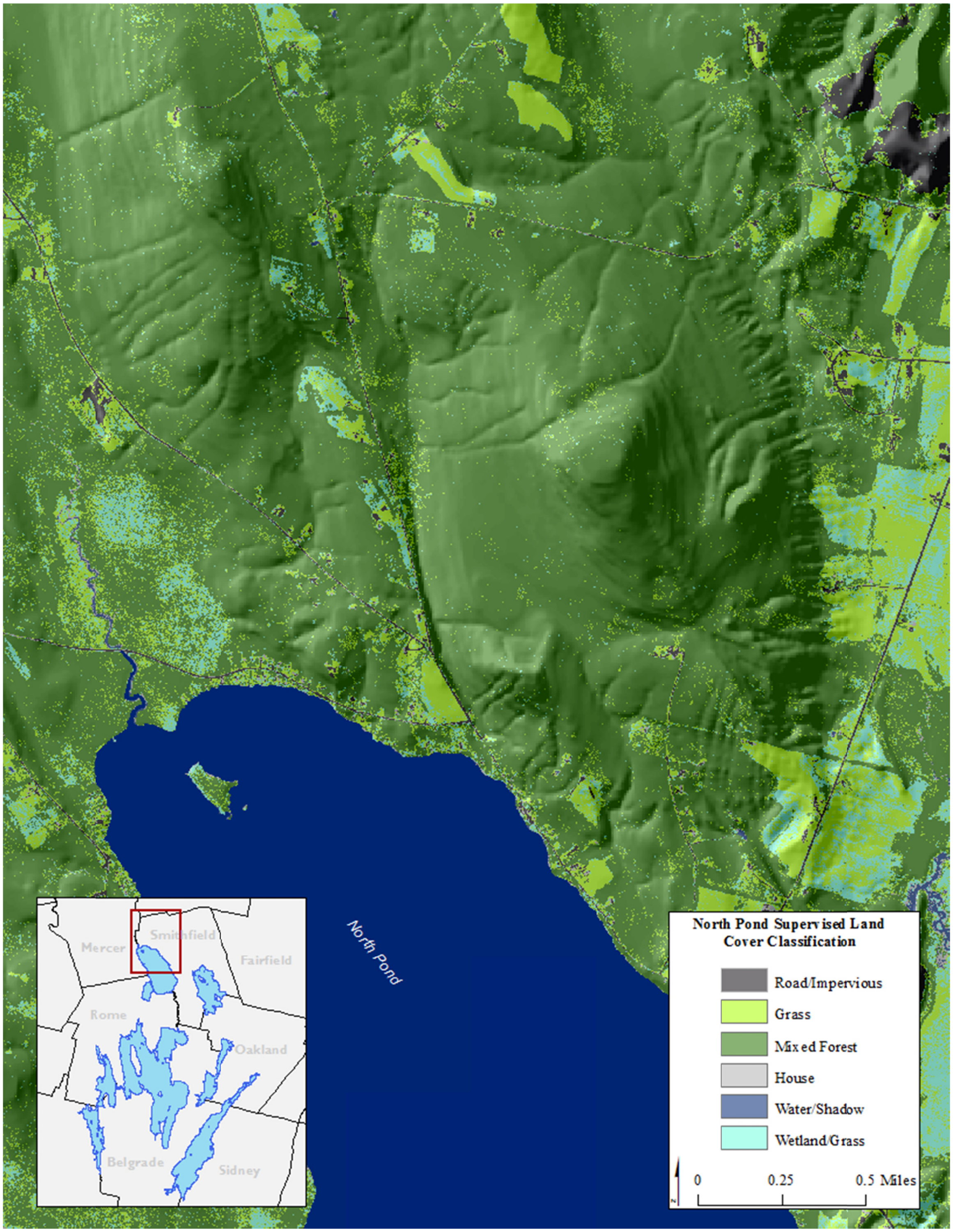


Figure 6. North Pond supervised land cover classification of Geoeye-1 satellite imagery, created using ArcGIS 10.0.

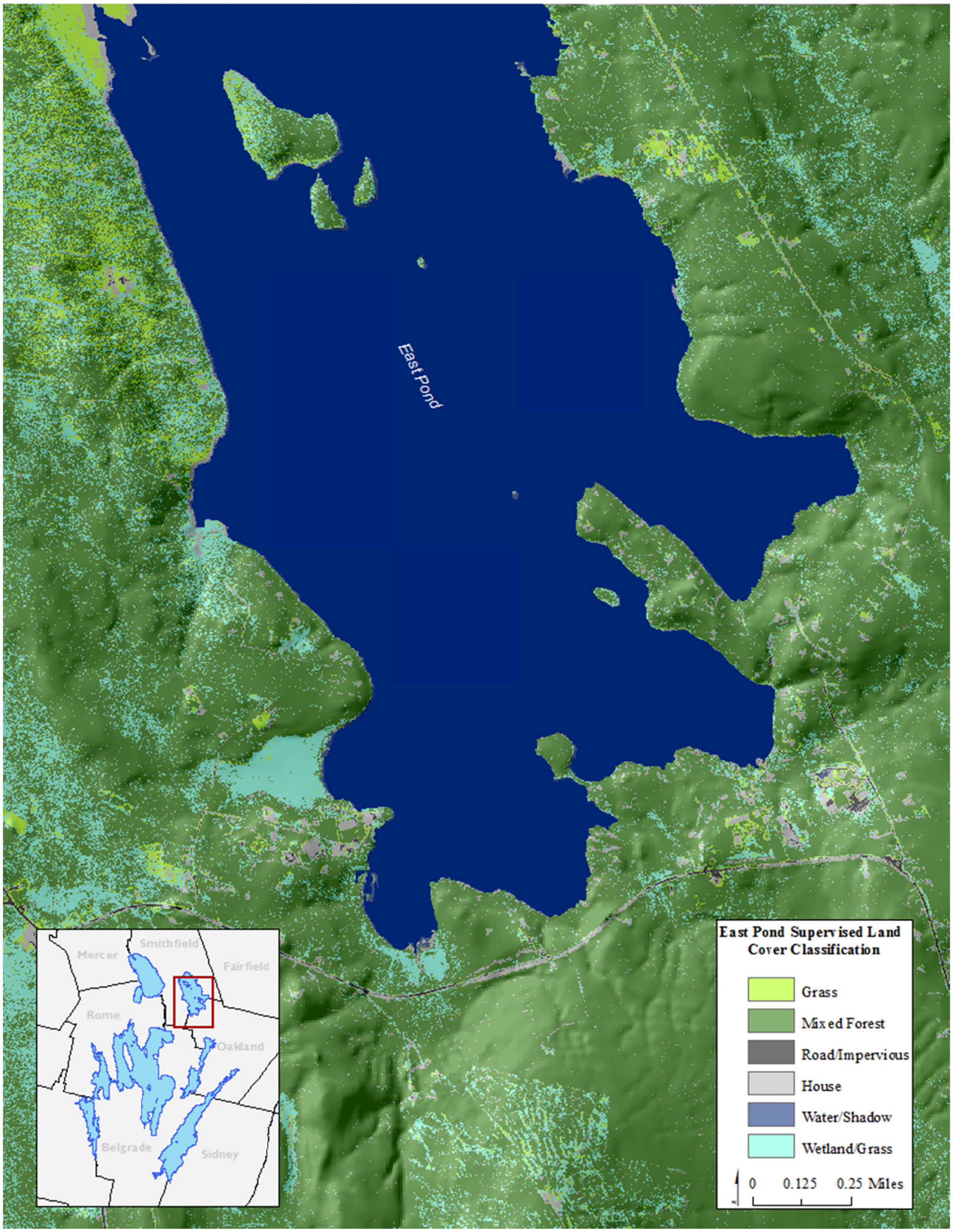


Figure 7. East Pond supervised land cover classification of Geoeye-1 satellite imagery, created using ArcGIS 10.0.

Statistical Analysis

In addition to visual inspection of the data, I performed all statistical analysis using the STATA 12.0 statistical package. For comparison of expert evaluation and resident evaluation, I created difference values by subtracting from the experts estimates the resident estimates (e.g., difference value = expert evaluation value – resident evaluation value). For percent of buffer vegetated the difference value was in terms of percentage points (e.g., there was a difference of 20 percentage points) because the original evaluation was in terms of percentage (0-100). For both the buffer quality ranking and tiers of vegetation the difference value was in terms of rank values (e.g., there was a difference of 2 rank values) because the original evaluation was in terms of rank values (1-5).

I used a t-test to compare household and expert data because the data representing the difference between the household surveys and expert surveys were normally distributed. I used an ANOVA model to compare an expert evaluation of percent of buffer vegetated across lakes because the data were continuous. I used a Kruskal-Wallis test to compare the expert buffer quality rating and vegetation layers across lakes because both sets of data were ordinal (UCLA 2012).

To compare the satellite data to an expert evaluation of presence of buffer and tree canopy, I used a Wilcoxon-Mann-Whitney test. Lastly, I used a simple linear regression to compare the satellite data to an expert evaluation of percent of shoreline vegetated and a Kruskal-Wallis test to compare satellite data and an expert buffer rating.

For more information on the statistical tests I used for analysis see the University of California Los Angeles's webpage on STATA and statistical analysis: http://www.ats.ucla.edu/stat/stata/).

RESULTS

The results proceed as follows: an overview of the household survey buffer evaluation, an overview of expert shoreline photo buffer evaluation, a comparison of household and expert buffer evaluation, an overview of satellite buffer evaluation, and lastly, a comparison of satellite and expert buffer evaluation.

Household Survey Buffer Evaluation Overview

Across the three lakes, most respondents, 55 (>70%), reported having a buffer. North Pond stands out as having the largest number of respondents 13 (26.0%) who identified not having a buffer, followed by East Pond and Great Pond (Table 4).

Table 4. Number and percentage of respondents on Great Pond, North Pond, and East Pond identifying the presence (yes/no) of a buffer.

	Great Pond		North Pond		East Pond*	
Buffer Present	N	%	N	%	N	%
Yes	55	85.9	37	74.0	31	79.5
No	9	14.1	13	26.0	8	20.5

(*) One East Pond respondent did not report either having or not having a buffer.

Of the Great Pond respondents who identified having a buffer, 43 (86.0%) reported having a buffer that was good, very good, or excellent "in terms of potential for reducing stormwater run-off" (Appendix C). Comparatively, 25 (71.4%) of North Pond respondents reported having a good, very good, or excellent buffer. East Pond respondents more closely followed the Great Pond distribution with 25 (89.3%) reporting a good, very good, or excellent buffer with more reporting very good or excellent buffers, 10 (35.7%) for both, than good buffers (Figure 8).

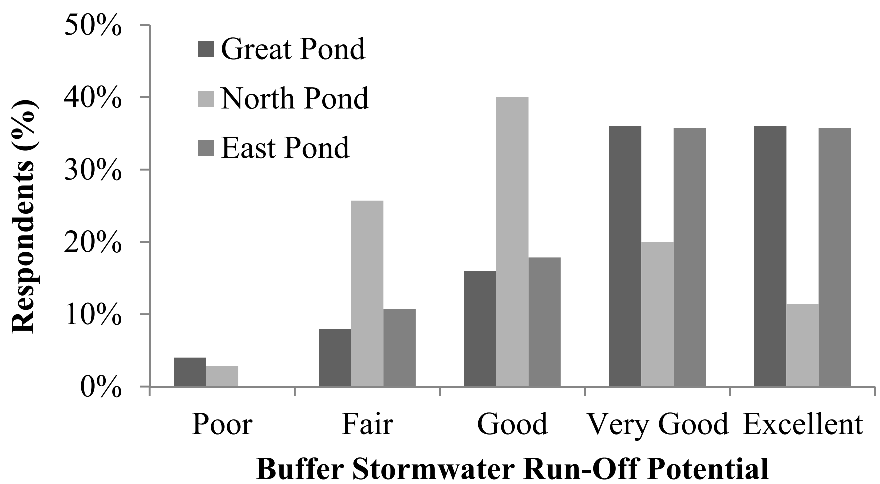


Figure 8. Respondents' buffer rankings (poor-excellent) for Great Pond, North Pond, and East Pond.

A relatively small percentage 11 (17.5%) of Great Pond respondents reported having two thirds or less of their entire shoreline vegetated (Figure 9). Of the remaining

respondents 45 (71.4%) reported having at least 80% of their entire shoreline vegetated. Relatively more, 17 (35.4%), North Pond residents reported having 66% or less of their entire buffer vegetated. A little more than half of respondents 25 (52.1%) reported having at least 80% of their entire shoreline vegetated. Falling between Great Pond and North Pond, 11 (30.0%) of East Pond respondents reported having 66% or less of their entire buffer vegetated with 26 (65.0%) reporting 80% or more of their entire buffer vegetated.

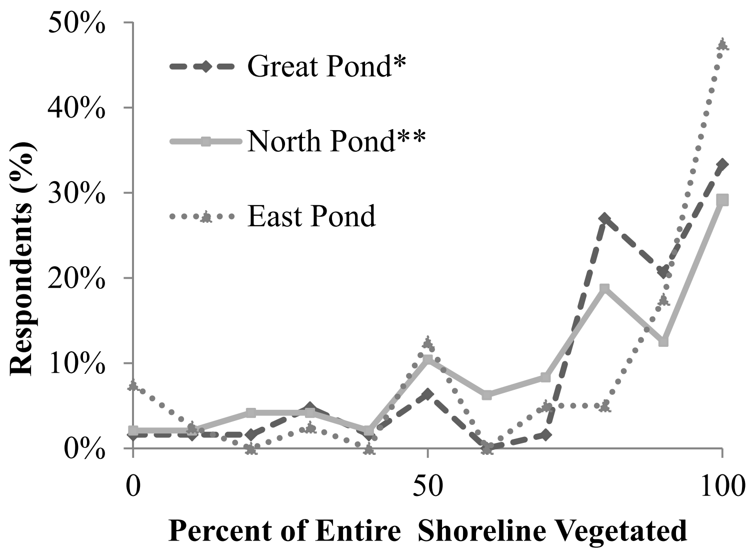


Figure 9. Respondents' evaluation of percent of entire shoreline vegetated on Great Pond, North Pond, and East Pond.
(*) One Great Pond and (**) two North Pond respondents did not evaluate the extent of their entire buffer.

A majority, 38 (59.4%), of Great Pond respondents reported having at least three tiers of vegetation in their buffer (Figure 10). Substantially fewer respondents, 11 (17.2%) reported having zero tiers of vegetation. Compared to Great Pond, fewer respondents, 15 (30.0%), of North Pond reported having at least three tiers of vegetation while 16 (32%) reported having zero tiers of vegetation. Similarly, 15 (37.5%) East Pond respondents reported having three tiers while 11 (27.2%) reported having zero tiers.

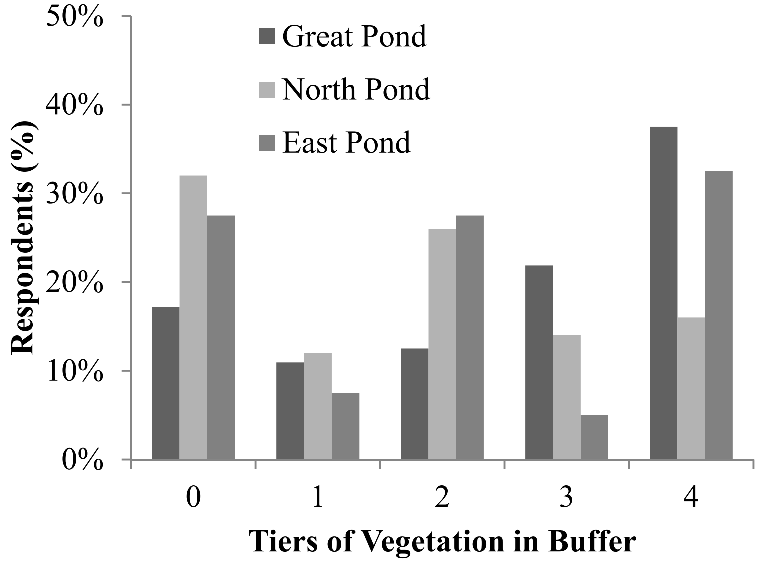
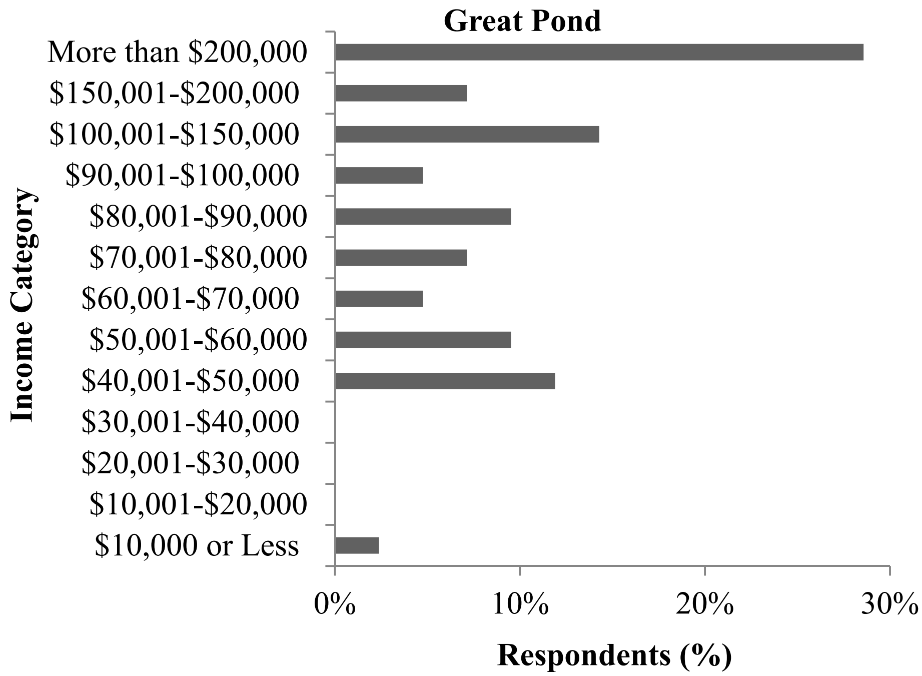
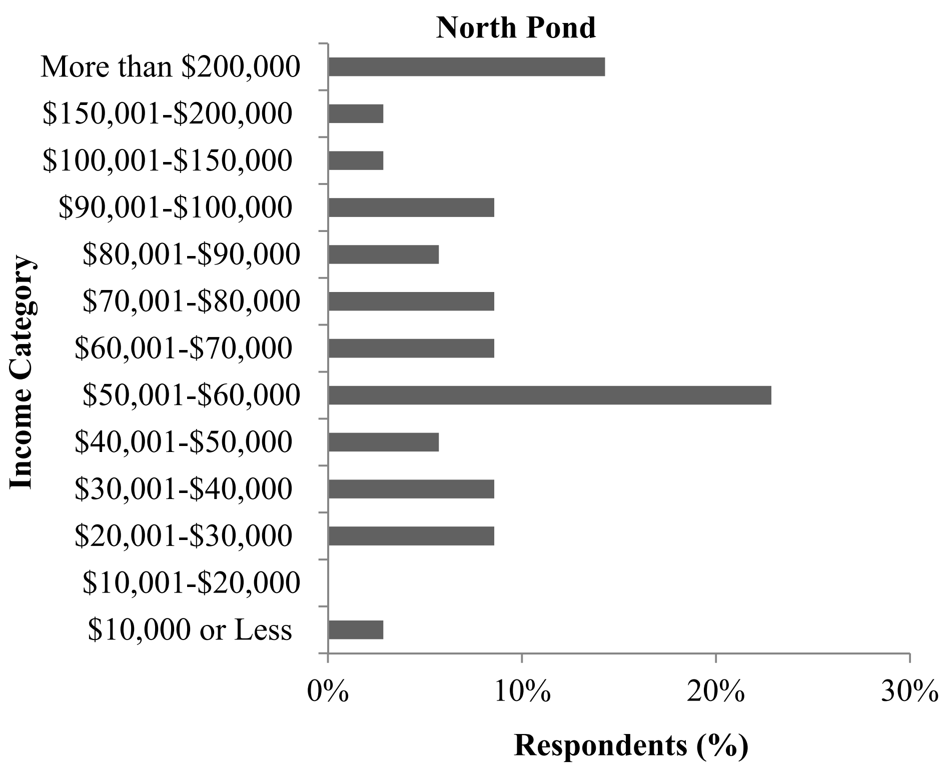


Figure 10. Respondents' evaluations of tiers of vegetation in buffer on Great Pond, North Pond, and East Pond.

Lake association membership across lakes did not vary substantially. Approximately 85.5% of Great Pond respondents are lake association members while 87.0% and 88.0% are on North and East Ponds (respectively). A substantial portion of residents on all three lakes were not members of an environmental organization. More specifically 70.9%, 91.3%, and 76.2% of Great, North, and East Pond respondents were not members of an environmental organization. Income distribution, however, did vary substantially from lake to lake (Figure 11). Compared to Great Pond and East Pond with 50.0% of respondents reporting an income of at least $100,000 per year, only 20.0% of North Pond respondents reported the same amount (Figure 8). Conversely, more North Pond respondents (37.1%) noted making between $30,000 and $60,000 than Great or East Ponds (21.4% and 13.8% respectively).


Great Pond
More than $200,000
$150,001-$200,000
$100,001-$150,000
$90,001-$100,000
$80,001-$90,000
$70,001-$80,000
$60,001-$70,000
$50,001-$60,000
$40,001-$50,000
$30,001-$40,000
$20,001-$30,000
$10,001-$20,000
$10,000 or Less
Income Category
0%
10%
20%
30%
Respondents (%)


North Pond
More than $200,000
$150,001-$200,000
$100,001-$150,000
$90,001-$100,000
$80,001-$90,000
$70,001-$80,000
$60,001-$70,000
$50,001-$60,000
$40,001-$50,000
$30,001-$40,000
$20,001-$30,000
$10,001-$20,000
$10,000 or Less
Income Category
0%
10%
20%
30%
Respondents (%)

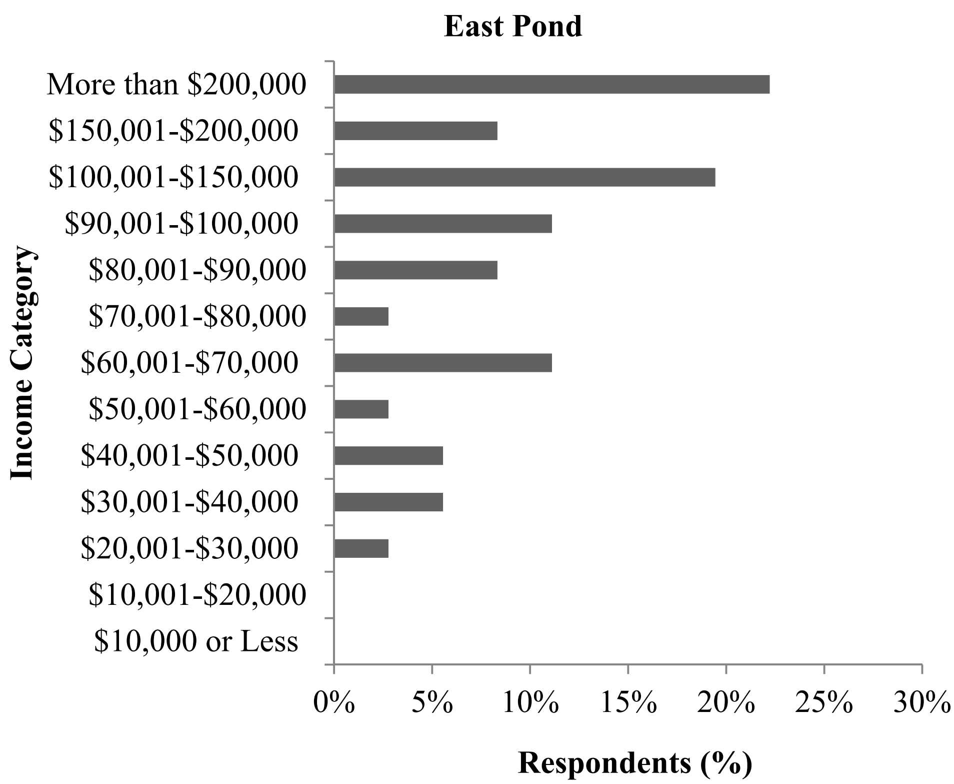


Figure 11. Distribution of income across lakes, Great Pond N = 42, North Pond N = 35, East Pond N = 36.

Expert Shoreline Photo Buffer Evaluation Overview

One of the experts to whom I sent 78 surveys did not send back a completed survey in time for the writing of this study. As a result, 98 distinct photos (accounting for 63.6% of the selected resident surveys) were evaluated by two experts certified as LakeSmart evaluators. Of the two experts who returned completed surveys, one is a wetland scientist with over 20 years of watershed management while the other is a professor of biology.

Although 20 shoreline photos were repeated between the experts, one expert omitted two photo evaluations. Of the 18 identical photo evaluations the experts differed substantially. Half (50.0%) of estimates for percent of entire shoreline vegetated were at least 20% different in terms of percentage points. A scatter plot comparing the expert estimates of percent of entire shoreline vegetated suggests that while there was a general trend of agreement at the low and high ends of the spectrum, there was inconsistency in the rest of the data (Figure 12).

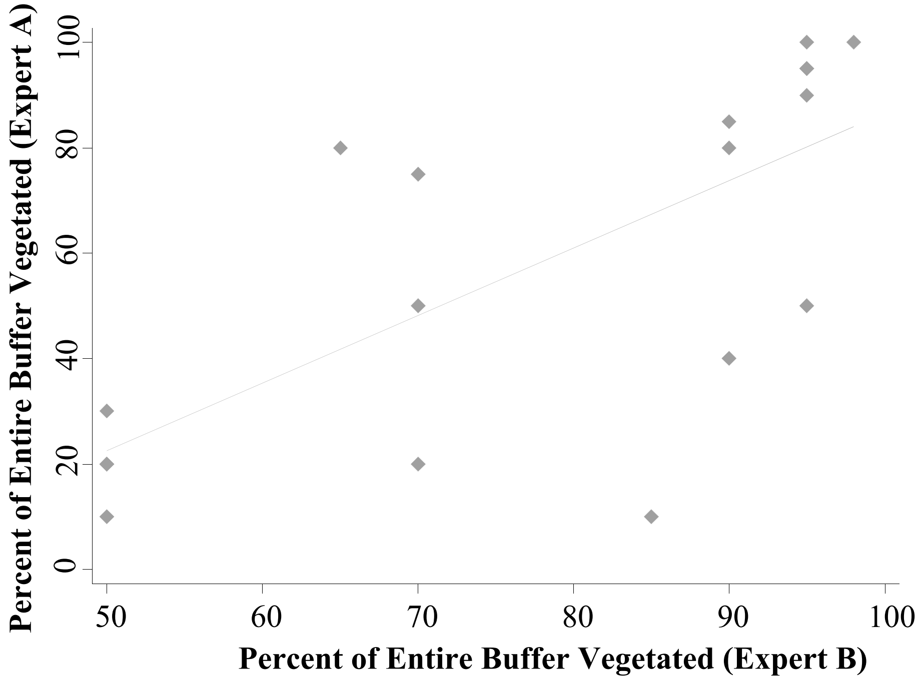


Figure 12. Comparison of expert (A and B) estimates of percent of entire buffer vegetated, N = 18.

Similarly, 44.4% estimates for shoreline directly in front of the house were at least 20% different in terms of percentage points. Comparing the distribution of difference between expert estimates of percent of entire shoreline vegetated and percent of shoreline in front of house vegetated reveals that while the experts differed for both measures (a substantial portion of the points have a difference value not equal to zero), they differed similarly in their rating of entire shoreline and shoreline in front of the house (the scatter plot follows a nearly linear relationship with a correlation coefficient of 0.89) (Figure 13). This suggests that estimates for entire shoreline vegetated and shoreline in front of the house vegetated are similar. As a result, I will refer to only estimates of the entire buffer in the analysis that follows.

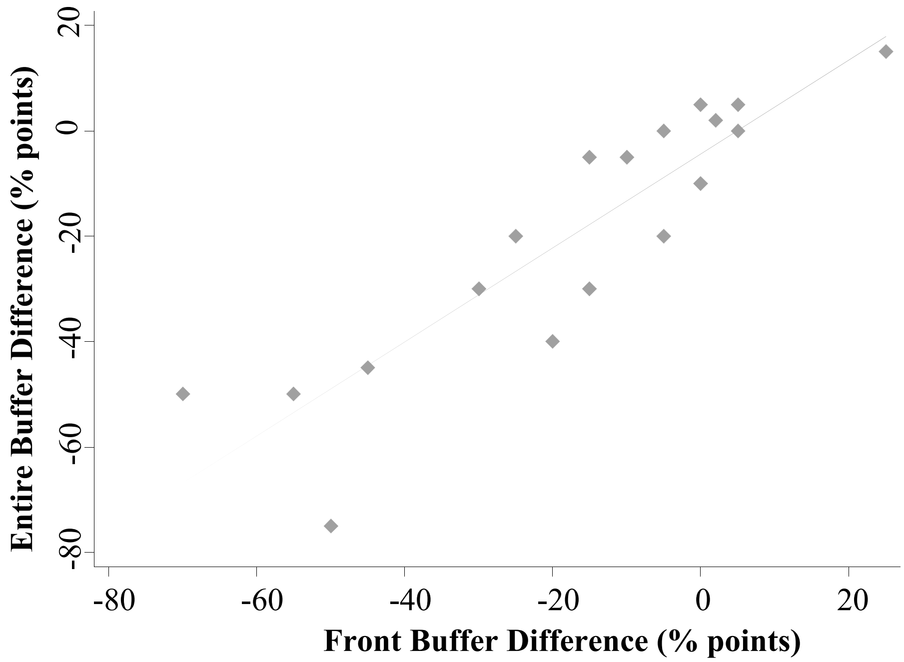


Figure 13. Difference between experts for entire buffer and buffer in front of house ratings, N = 18.

Regarding buffer rating observations, 61.1% of observations were at least 20% different in terms of percentage points. The number of tiers of vegetation present observed by experts was more similar, with only 16.6% of observations at least 20% different in terms of percentage points. Inconsistencies in difference values across all criteria; percent buffer vegetated, buffer quality, and tiers of vegetation, made a simple correction to align expert responses challenging. With this in mind I chose to compare only the surveys from one expert to the resident surveys.

Although the experts differed in terms of how large they rated buffers, and the quality of the buffers, in over 95.5% instances they both identified the presence or absence of a buffer.

Household-Expert Buffer Evaluation Comparison

The observed difference between an expert evaluation of percent of buffer vegetated, buffer quality, and the number of vegetation layers present in a buffer to those of residents reveals negatively skewed but normally distributed data. Across all four variables the mean difference was negative with -19.1 percentage points for percent buffer vegetated, -1.7 rank values for buffer ranking, and -1 rank value for vegetation

layers. Negative values meant the residents estimates were larger (more percent of shoreline vegetated, high buffer ranking, and more vegetation layers present) than the expert (Figure 10).

Percent of Entire Buffer Vegetated Difference Value

Great Pond and North Pond residents estimated the extent of their buffers significantly differently than the expert (Table 5).

Table 5. A t-test evaluating mean buffer difference, vegetation layers, and buffer quality rating values (created using survey respondent and expert buffer evaluations) from zero.

	Great Pond			North Pond		
Variable	**N**	**Mean**	**Pr (|T| > |t|)**	**N**	**Mean**	**Pr (|T| > |t|)**
Perc. Buffer Vegetated	28	-17.35	0.002**	34	-27.50	< 0.001***
Vegetation Layers	26	-1.08	0.009**	26	-1.08	0.024*
Buffer Quality Rating	24	-1.79	< 0.001***	25	-1.80	< 0.001***

	East Pond		
Variable	**N**	**Mean**	**Pr (|T| > |t|)**
Perc. Buffer Vegetated	14	-2.71	0.822
Vegetation Layers	10	-0.60	0.313
Buffer Quality Rating	10	-1.40	0.025*

(*), (**), and (***) indicate statistically significant at a 5%, 1% and .1% level (respectively).

East Pond residents were not found to be significantly different in their buffer extent estimations from experts. An analysis of variance (ANOVA) model suggests that for all three lakes means of buffer difference were not significantly different from one lake to another (Table 6).

Table 6. An ANOVA model evaluating the mean percent buffer vegetated difference values across Great Pond, North Pond, and East Pond.

Pond	**N**	**Mean**	**Standard Dev.**
Great Pond	28	-17.35	27.79
North Pond	34	-27.50	33.49
East Pond	14	-2.71	44.44
ANOVA Prob > F	0.072		
R-squared	0.069		
Adj R-squared	0.044		
Root MSE	33.835		

Although an ANOVA model found that the lakes were not significant predictors of the difference in the estimations of percent of buffer vegetated, a simple visual analysis of percent of buffer vegetated difference for all three lakes in terms of percentage points suggests that more North Pond respondents estimated a greater percentage of their buffer vegetated relative to the expert than in Great or East Ponds (Figure 11). Of North Pond respondents, 11 (32.3%) estimated a larger buffer by at least 50 percentage points, compared to Great Pond and East Pond with 6 (21.4%) and 2 (14.3%) respectively. Across all three lakes residents who overestimated the size of their buffer (entire and front) as vegetated by at least 50 percentage points fell between the reported income categories of $40,001-$50,000 and greater than $200,000 (Figure 14).

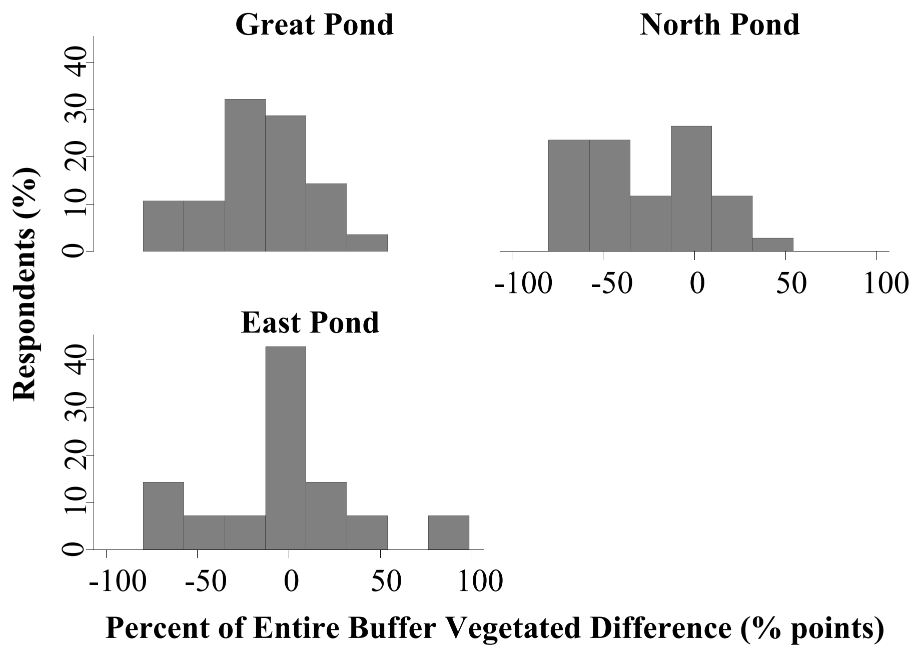


Figure 14. Distribution of percent of buffer vegetated difference in terms of percentage points for Great Pond, North Pond, and East Pond.

Using an Ordinary Least Squares Regression I evaluated log of lot size and found that it was not significant in predicting the percent of entire buffer vegetated difference value within or across lakes.

Buffer Quality Rating and Tiers of Vegetation Difference Values

Great Pond, North Pond, and East Pond residents estimated the quality of their buffers significantly differently than the expert. Great Pond and North Pond residents

estimated the number of vegetated layers present in their buffer significantly differently than the expert (Table 5). However, a Kruskal-Wallis equality-of-populations rank test suggested that difference in buffer rankings and identified vegetation layers were not significantly different from one lake to another (Table 7).

Table 7. A Kruskal-Wallis test evaluating the mean buffer quality and vegetation layers difference values across Great Pond, North Pond, and East Pond.

	Buffer Quality Rating		Vegetation Layers	
Pond	**N**	**Rank Sum**	**N**	**Rank Sum**
Great Pond	24	722.0	26	802.5
North Pond	25	726.5	26	806.5
East Pond	10	321.5	10	344.0
	Chi^2	0.232	Chi^2	0.309
	P-Value	0.890	P-Value	0.857

A visual inspection of the buffer quality rankings across lakes suggests that more Great Pond respondents rated their buffer closer to an expert than either North or East Pond respondents with 58.3% of respondents within one rank value of zero compared to 44.0% and 40.0% for North and East Ponds, respectively (Figure 15).

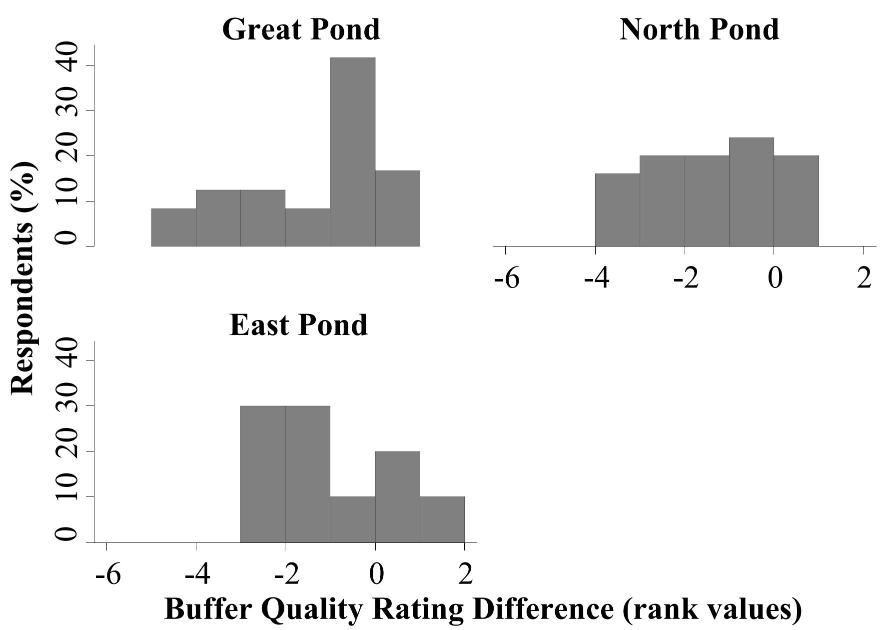


Figure 15. Buffer quality rating difference in terms of rank values for Great Pond, North Pond, and East Pond.

It appears that Great Pond respondents evaluated their vegetation layers more closely to the expert. A majority of Great Pond respondents, 61.5%, evaluated their vegetation layers within one rank value of zero compared to 42.3% and 40.0% for North and East Ponds, respectively (Figure 16).

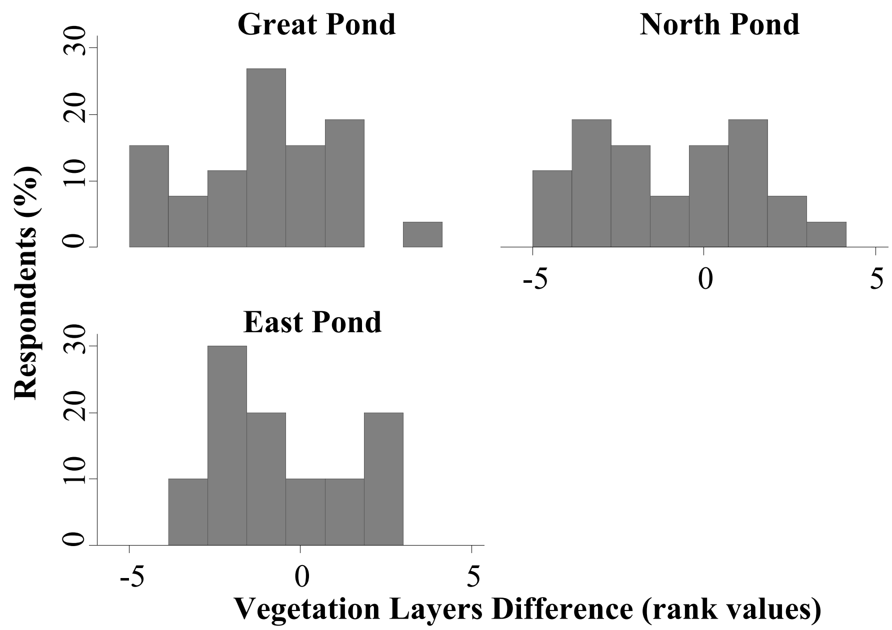


Figure 16. Vegetation layers observed present in buffer difference in terms of rank values for Great Pond, North Pond, and East Pond.

Remotely Sensed Land Cover Overview

Comparing the three land cover data sources it is clear that the *forest* land cover classification accounts for most of the land cover in shoreline lots across all three lakes (Table 8). ES494 and MELCD estimates of *cleared land/open*, *field/cropland*, and *wetlands/water/grass* percentages were comparable. The ES494 percentages were substantially greater than either Geoeye or MELCD estimates. The *wetlands/water/grass* land cover classification for the Geoeye data is a substantially greater percentage because it was the only data source to combine grass with the *wetland/water* land cover classification.

Table 8. Distribution of shoreline lots' land cover based on manually digitized land cover (ES494), classified Geoeye satellite imagery (Homeier Geoeye), and classified SPOT imagery (MELCD) (ES494 2010, MELCD 2004, Maine Office of GIS 2004).

Land cover	**ES494 (%)**	**Homeier Geoeye (%)**	**MELCD (%)**
Road/House	18.27	5.05	2.33
Cleared Land/Open Field/Cropland	1.63	-	1.79
Forest	74.04	70.74	91.22
Wetlands/Water/Grass**	1.96	23.33	3.68
Other*	4.10	0.88	0.97

(*) Other includes regenerating land, camp, reverting land, shore, water/shadow, and bare ground; (**) only the Geoeye data includes grass with wetlands/water.

Comparing land cover of the entire lots and just the shoreline portion of the lot (250 feet from shoreline) of lots suggests little difference between the levels of spatial analysis (Table 9).

Table 9. Distribution of entire lot and 250 ft of lot land cover based on classified Geoeye satellite imagery.

Land Use	**Entire Shoreline Lot (%)**	**250 Feet of Shoreline Lot (%)**
Road/House	5.05	6.64
Forest	70.74	70.59
Other*	0.88	1.85
Grass/Wetland	23.33	20.93

(*) Other includes regenerating land, Camp, reverting land, shore, water/shadow, and bare ground.

Because no one Geoeye image entirely encompassed a lake, the land cover data that results from the images is not necessarily representative of all the land cover surrounding the lakes. For this reasons I chose to perform a simple comparison using the MELCD data. Arranging the MELCD land cover data by lake and entire lot and shoreline portion of the lot allows for inter-lake comparisons (Table 10). North Pond stands out as having a higher percentage of *road/house* land cover (4.95% compared to 0.16 and 1.89%). Open land values are, however, higher for East Pond (5.09%). Comparison of entire lot to just shoreline portion of lot reveals little difference in overall distribution, except for *road/house* in North Pond. This land cover classification represents a substantially larger proportion of the shoreline of lots than it does the entire lot.

Table 10. Distribution of shoreline lots' land cover for entire lot and shoreline portion of lot (250 feet) for Great Pond, North Pond, and East Pond based on Maine Land Cover Map (MELCD), Maine Office of GIS, 2004.

	Entire Lot (%)			250 ft of Lot (%)		
Land cover	**Great Pond**	**North Pond**	**East Pond**	**Great Pond**	**North Pond**	**East Pond**
Road/House	0.16	4.95	1.89	0.21	12.33	2.71
Open Land*	0.27	0.00	5.09	0.34	0.00	4.94
Forest	95.11	91.26	87.27	90.55	77.35	69.02
Wetlands/Water	2.48	3.51	5.05	4.87	9.56	20.47
Other**	1.96	0.27	0.69	4.02	0.77	2.86

(*) Includes Pasture/Hay, Heavy Cut, Scrub/Shrub, and Cultivated Land; (**) includes Shore and Bare Ground.

Satellite-Expert Buffer Evaluation Comparison

Because of the relatively large disparity between the MELCD data and the Geoeye data in the *grass/wetland* and *water/shadow* land cover categories I used only the *mixed forest*, *house*, and *road/impervious* land cover categories in the following analysis.

Verification of Expert Buffer Evaluation

A Wilcoxon-Mann-Whitney test suggests that there is no significant relationship between an expert evaluation of buffer or tree canopy presence and the amount of *mixed forest*, *house*, or *road/impervious* land cover classification in the surveyed lots (Table 11).

Table 11. A Wilcoxon-Mann-Whitney test evaluating relationship between presence of buffer or tree canopy and percentage of land cover type for lots on Great Pond, North Pond, and East Pond.

	Mixed Forest				House			
Variable	**N**	**Rank Sum**	**Expected**	**P > |z|**	**N**	**Rank Sum**	**Expected**	**P > |z|**
Buffer								
No	22	694	627		22	637	627	
Yes	34	902	969	0.261	34	959	969	0.866
Tree Canopy								
No	21	677	598.5		21	603	598.5	
Yes	35	919	997.5	0.184	35	993	997.5	0.939

	Road/Impervious			
Variable	**N**	**Rank Sum**	**Expected**	**P > |z|**
Buffer				
No	22	689	627	
Yes	34	907	969	0.281
Tree Canopy				
No	21	677	598.5	
Yes	35	919	997.5	0.168

While there is no significant relationship between an expert evaluation of buffer or tree canopy presence and percentage of land cover, a simple comparison of mean land cover values and the expert evaluation of whether or not a buffer was present or had an active tree canopy as part of its vegetation layers revealed a few interesting results. There was some difference between lots identified to have a buffer and those not in terms of mean *mixed forest* values. Lots without a tree canopy or a buffer had higher mean values of *mixed forest* (~0.32 compared to ~0.27). Little difference was found relating presence of a tree canopy and mean *mixed forest* values. The same was true comparing buffer or tree canopy presence to mean *house* values. There was, however, a difference between presence of buffer or tree canopy and mean *road/impervious* values. When a tree canopy or a buffer was present the mean *road/impervious* mean value was lower (0.19 compared to 0.25).

A simple linear regression did not find a significant relationship between percent of entire shoreline vegetated and percent of lot composed of *mixed forest*, *house*, or *road/impervious* land cover classifications (Table 12).

Table 12. A linear regression evaluating the relationship between amount of land use classification types for lots on Great Pond, North Pond, and East Pond and expert evaluation of percent of buffer vegetated.

Variable	Coefficient	Standard Error	t	P > |t|
Mixed Forest	-23.97	15.74	-1.53	0.133
House	-134.62	75.55	-1.78	0.081
Road/impervious	-21.59	15.73	-1.37	0.176
Constant	71.13	8.83	8.05	<0.001
Number of observations	56			
Prob > F	0.109			
R-squared	0.108			
Adj R-squared	0.057			
Root MSE	32.3			

Similarly, a Kruskal-Wallis analysis of variance found no significant relationship between buffer ranking and percent of lot composed of *mixed forest*, *house*, or *road/impervious* land cover classifications.

Table 13. A Kruskal-Wallis test evaluating amount of land use classification types for lots on Great Pond, North Pond, and East Pond and expert evaluation of buffer quality ranking.

	Mixed Forest		House		Road/Impervious	
Buffer Quality Ranking	**N**	**Rank Sum**	**N**	**Rank Sum**	**N**	**Rank Sum**
0	21	677.0	21	603.0	21	677.0
1	12	325.0	12	395.0	12	336.0
2	8	241.0	8	194.0	8	274.0
3	6	94.0	6	137.0	6	133.0
4	2	16.0	2	84.0	2	42.0
5	7	243.0	7	183.0	7	134.0
	Chi^2	9.164	Chi^2	3.668	Chi^2	5.741
	P-Value	0.102	P-Value	0.598	P-Value	0.332

DISCUSSION

Household Survey

North Pond stood out based on the residential surveys regarding presence of buffer, percent of buffer vegetated, and tiers of vegetation in buffer. While a majority of residents from all three lakes reported having a buffer, North Pond had the lowest percentage of respondents reporting the presence of a buffer on their lot (71.4%). Similarly, North Pond had the highest percentage of respondents reporting less than 66% of their shoreline vegetated and had the lowest percentage of respondents reporting at least three tiers of vegetation in their buffer. Having greater than 66% of your shoreline vegetated is recognized by the LakeSmart certification program as important and is one factor that can help a property become LakeSmart certified (MDEP 2010B). Having at least three tiers of active vegetation in your buffer is another criteria import to the LakeSmart certification; this factor, however, is required for certification. Any property with less than three active tiers of vegetation does not qualify for LakeSmart certification (MDEP 2010B).

A few of the demographic characteristics collected by the household survey revealed interesting, and in some cases surprising, results. First, high lake association membership across all three lakes may suggest the household survey sample is biased and not representative of all shoreline residents (i.e., non-lake association members). Although lake association membership did not vary substantially from lake to lake, North Pond respondent membership in environmental organizations was the lowest of the three lakes by approximately 20%. North Pond again stood out in terms of income distribution with the smallest percentage of respondents reporting over $100,000 in income and the highest percentage of respondents reporting within $10,000 of the median Kennebec County household income (U.S. Census Bureau 2012). On the other end of the spectrum Great Pond stood out with one third of respondents making at least $200,000 annually.

Expert - Expert and Household – Expert Buffer Evaluation Comparison

Extenuating factors may help explain the disparity in how experts evaluated buffer quality. Given the opportunity to visit a property in-person, how a LakeSmart certification typically occurs, the experts may have come closer in agreement. A shoreline photo is limited in the information it can convey. While many of the shoreline photos were adequately representative of the buffer, some were hard to use for evaluation because they were not perpendicular to the shoreline, out of focus, or hazy due to a foggy lens. It is important to note that I had only two experts for comparison and would need more to draw any substantial conclusions as to the accuracy of an expert shoreline photo evaluation. Regardless of these caveats, experts disagreed substantially, calling into question the buffer quality criteria (Appendix B and C). For geotagged photos to work well as a buffer evaluation method it is important to create criteria (and understanding of these criteria) that provide consistent evaluation from expert to expert. Although the LakeSmart quality criteria may work well for in-person evaluations, they may not apply to other evaluation methods. Establishing clear and integrated quality criteria that translate well from one method to another will help clarify understanding of buffers and facilitate a variety of buffer evaluation methods, similar to integration of conservation criteria and assessment in other fields (e.g., river conservation) (Boon 2000). Training photo evaluators using clarified quality criteria, perhaps using a set of pre-evaluated photos, would help improve evaluator consistency.

A comparison of shoreline resident evaluation to an expert further suggests that there is a disparity in how people assess shoreline buffers. All three lakes varied significantly from an expert evaluation in at least one of the three buffer quality criteria. The importance of clarifying and integrating buffer quality criteria is highlighted by this difference in expert and resident evaluation. If experts differ in their evaluation of shoreline buffers it is likely homeowners will view their buffers and shoreline conservation practices differently. Regardless of whether or not residents may under or overestimate the need for a more robust buffer, they are less likely to address buffers as a conservation issue if they do not properly assess their quality and value their importance (Stern 2000).

Statistical analysis of percent of buffer difference across lakes, while not significant, is close (ANOVA, $p = 0.072$). Because the other two quality criteria did not suggest significant difference across lakes, it is difficult to suggest one lake is an outlier in terms of its buffer quality evaluation. However, there is sufficient disparity to suggest that residents on different lakes may evaluate buffers differently. For example, Great Pond respondents evaluated their buffer quality and the number of active tiers in their buffer closer to an expert evaluation with approximately 60% of respondents within one rank value of zero for both measures. This observation suggests that perhaps Great Pond's proximity to the Belgrade Regional Conservation Alliance, the presence of strong lake associations, or its relatively high average income, may influence how its residents evaluate buffer quality.

Satellite Imagery

The comparison of remotely sensed land cover data sets reveals how variable results can be based on the intended purpose, data source, and processing method. Both the ES494 data and the MELCD data were classified into over 25 land cover types, lending their use to analysis of vegetation types. I classified the Geoeye data for analysis of permeable and impermeable land cover. As a result I grouped many of the land cover types that the ES494 and MELCD data teased apart.

How the datasets were created further influences comparison. Because the ES494 land cover data were manually digitized using aerial imagery, it is reasonable to expect those data to be different from both the Geoeye and MELCD land cover data sets (both classified using an automated classification method). Separating the Geoeye and MELCD data (and explaining some of the difference), the MELCD data used 30 meter Landsat data for classification, compared to the 4 meter resolution of the Geoeye data. The substantially greater ES494 land cover percentages for the *road/house* classification were likely due to the loss of resolution that occurred when the digitizers delineated residential areas using DEP estimates of residential acreage (including the forest, grass, and wetland within them). Because an automated classification method analyses the data for each individual pixel using the near-infrared portion of the spectral band, it has the ability to tease out vegetative features to create a higher resolution land cover map (Bolstad 2008).

Using the MELCD or Geoeye datasets to analyze land cover on a lot scale has the potential to be more accurate than using the more generalized ES494 data. However, classifying satellite imagery is not without error. Classification schemes produce varying degrees of accuracy based on the training areas used, the clarity of the imagery, and the method employed (Gallego 2004, Lu and Weng 2007). As a result, it is important to assess the accuracy of a classification scheme using an error assessment model, such as an error matrix (Powell et al. 2004, Bhaskaran 2010).

I used the ground truth data I had collected in 2010 to inform my classification scheme and therefore could not use it for error assessment. Without error assessment it is hard to quantify the accuracy of the classified Geoeye imagery. That said, my inability to tease apart the grass and wetland land cover types suggests that there is inherent error in the classifications that include those land cover types. Similarly, the *water/shadow* classification is problematic because it does not distinguish between the two similar spectral responses. The *road/house* and *mixed forest* classifications, however, are similar to those found in the MELCD data, as are the impermeable and permeable classification of each dataset when combined. The differences between land cover datasets are inevitable and for this reason comparing different land cover datasets is challenging but fruitful considering they offer a variety of results worth considering (McCallum 2006).

Satellite – Expert Buffer Evaluation Comparison

The results comparing the satellite imagery to the expert survey suggest that the survey did not predict the land use classifications of *mixed forest*, *house*, and *road/impervious* at an individual lot scale. This is likely due to three factors. First, error in the classification resulted in inaccurate identification of particular features resulting in a land cover map not fully representative of the true land cover. Second, given more processing, such as more advanced cloud removal and an image merging method, the data could have been used to provide a more complete (and perhaps more accurate) land cover dataset for each lake. That said, even with more complete processing, different classification schemes will produce different results, highlighting the importance of choosing an appropriate scheme. Third, although the Geoeye imagery has a multispectral resolution of 4 meters, it may not be sufficient to provide useful data for analyzing a buffer of only a few meters in width, especially for a lot of less than 5,000 square meters (a substantial majority, approximately 71.0% of lots with land cover data, were 5,000 square meters (~1.23 acres) or less in size). A satellite, because of it bird's-eye perspective, is less effective in providing information concerning vertical stratification of vegetation, an essential aspect of a shoreline buffer (MDEP 2010B). While classified satellite data may suggest that an area has substantial tree canopy, it says nothing regarding the tiers of vegetation below that tree canopy and is therefore a limited tool for buffer analysis (Figure 17).

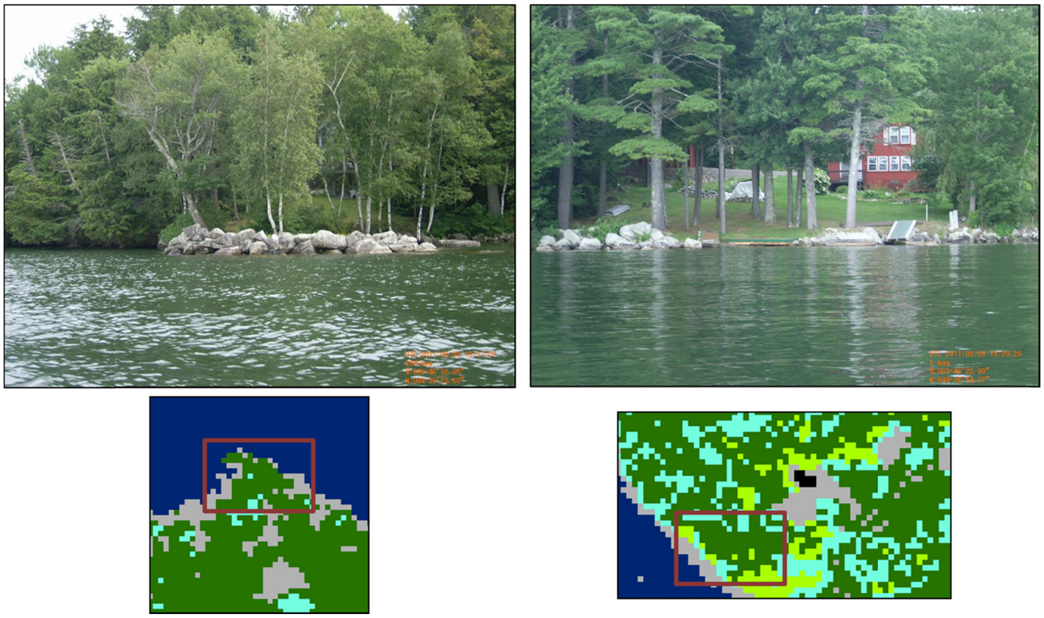


Figure 17. Comparison of two lots on East Pond, one (left) with a robust buffer, the other (right) with a weak buffer and their respective classified satellite images which suggests similar amounts of mixed tree cover (the dark green pixels within the red rectangle) regardless of the apparent difference in buffer quality.

The challenge of using satellite imagery such as Geoeye-1 to evaluate shoreline buffers is further demonstrated by comparing Geoeye satellite imagery to Bing aerial imagery (Figure 18). While the Geoeye imagery is limited by its 4 meter resolution, the Bing imagery has sub-meter resolution with which it may be easier to evaluate shoreline buffers (Microsoft 2011).

Figure 18. Comparison of Geoeye-1 (left) and Bing (right) imagery of the same lot on East Pond (highlighted by red rectangle).

CONCLUSION

This study suggests a few primary conclusions regarding household surveys, geotagged photos, and satellite imagery when used to evaluate shoreline buffer presence and scale.

Household surveys provide information at a lot scale but are limited to evaluating resident perceptions of buffer quality. Residents, compared to the expert, evaluate their buffers to be larger, of greater quality, and to have more tiers of vegetation.

Geotagged shoreline photos, when square to the shoreline, in focus, and clear, provide the resolution and perspective (side vs. bird's-eye view) needed to evaluate a shoreline buffer properly. Because they are verifiable they are valuable for assessing resident perceptions and general land cover trends identified at larger scales. Despite their advantages, shoreline photos proved to be time intensive for processing because of the difficulty in matching them to lots.

Satellite imagery, while informative and useful, is more appropriate for large scale research questions and analysis (e.g., lake or watershed analysis) and can provide different results depending on the classification scheme used. Shoreline buffers are too small to properly analyze using satellite imagery. This is especially the case considering satellite imagery is dependent on advanced processing and classification, making the results for a small scale analysis error prone. However, improvements in the lot layer may make more accurate analysis possible. In addition to the need for extensive professional processing, satellite imagery (pre-processed) can be costly. With this in mind, lake associations with limited budgets can utilize spatial data available publically through the Maine Office of GIS.

For a visual assessment of the applicable scale, and relative cost, of household surveys, geotagged photos, and satellite images see Figure 19. Part A depicts the approximate resolution for each method and its cost in terms of acquisition and processing time. This figure suggests that satellite images would work better at a larger sub-lake scale while geotagged photos and household surveys would function better at a smaller lot scale. Part B depicts the applicable scale of the evaluation methods, suggesting that surveys and geotagged photos may be most informative at the lot scale while satellite imagery may reveal lake or watershed trends suggested by the smaller

scale methods. Furthermore, part B highlights the importance of effective lot layer data in connecting evaluation methods at various scales. One challenge in this study was not having a spatially accurate lot layer. In both part A and B geotagged photos have the greatest acquisition and processing cost because it takes a considerable amount of time to photograph a large lake's shoreline, especially in comparison to preparing, sending, and processing a household survey or purchasing and processing satellite images.

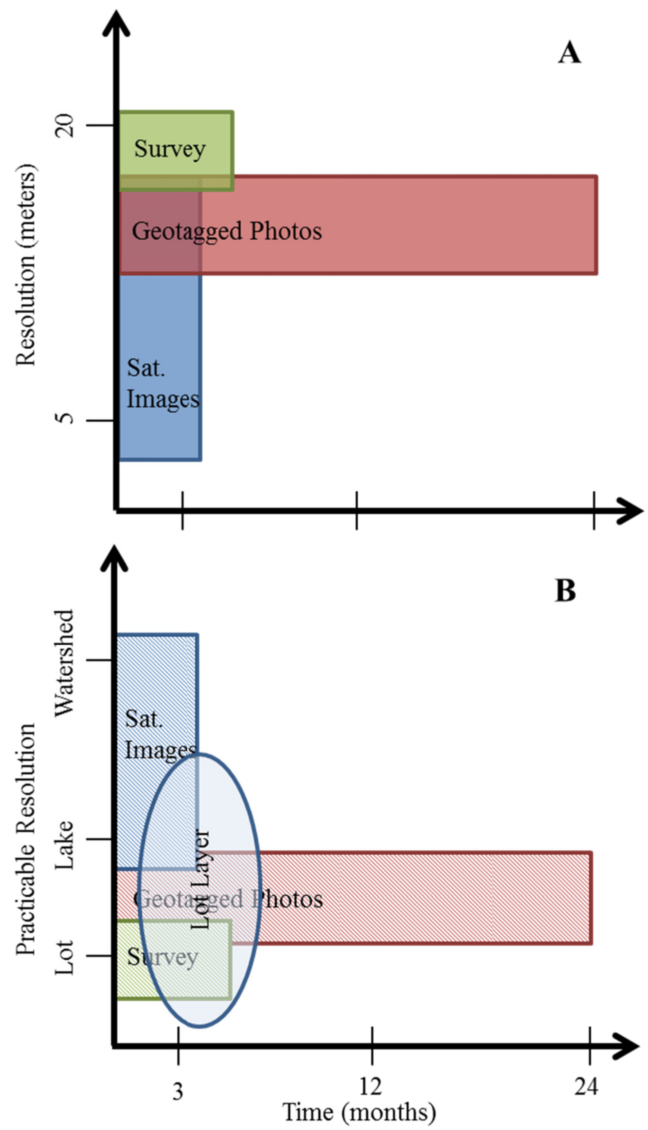


Figure 19. (A) Approximate scale (Y axis) and cost in terms of acquisition and processing time (X axis) of household surveys, geotagged photos, and satellite imagery as buffer evaluation methods; (B) applicable scale (Y axis) and processing time (X axis) of buffer evaluation methods used in this study.

Although additional expert surveys would ideally be needed to draw robust conclusions concerning expert and resident survey accuracy, there is a possibility that respondents and experts do not evaluate buffers the same way. To improve lake water quality it is important that residents understand shoreline conservation practices accurately (Story 2008). For this reason improving buffer quality criteria between stakeholder populations while integrating these criteria across evaluation methods is vital to improving shoreline buffers. Educational programs and resources, such as LakeSmart and the Maine Lakes Resource Center, may assist in this effort. Using today's technology and processing methods it is clear remote evaluation of buffers is valuable but should only be used to inform, not replace, current in-person evaluation programs.

Future Research Recommendations

Considering the results of this study, I have five future research recommendations:

First, buffer quality criteria ought to be improved with use of various buffer evaluation methods in mind. For example, training expert shoreline photo evaluators using pre-evaluated, demonstration images, may improve understanding of quality criteria and evaluation consistency. While different methods may require different criteria, creating a system to translate these criteria from one method to another will help improve the integration of evaluation methods.

Second, completing analysis of the household survey data to further explore behavior may help explain the difference between how residents and experts evaluate a buffer. Reviewing buffer quality criteria will complement future analysis of household behavior by enabling a more accurate analysis of resident buffer evaluation accuracy. Long term use of the residential survey could provide valuable temporal data.

Third, land cover analysis may be improved in the future by revisiting the classification scheme. Teasing apart the *grass/water* classification, for example, would provide for a more informative land cover analysis. However, keeping the classification limited to permeable and impermeable surfaces makes for faster classification and analysis, a fact that should be considered during future classification.

Fourth, the current lot GIS layer and shoreline photo database is functional but challenging. If the state of Maine, Kennebec County, or another local governmental body were to improve the lot GIS layer it would improve the accuracy of locating geotagged images and household surveys, thereby improving integration of evaluation methods. In lieu of a government agency improving lot data, Colby should consider re-digitizing the shoreline lot layer.

Fifth, using all three sources of data for inter-lake comparison proved challenging. Substantiating a few of the Sarkar (2011) conclusions, this study found that Great, North, and East Ponds are not significantly different from one another in terms of buffer evaluation. However, there are trends suggesting further analysis with more refined data may be valuable. Addition of Long Pond, Messalonskee Lake, and Salmon-McGrath Pond would improve inter-lake comparison and make for a more complete watershed dataset.

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APPENDIX A: HOUSEHOLD SURVEY

Belgrade Lakes Survey
Colby College Summer 2011

Colby College is conducting a collaborative research project funded by the National Science Foundation in the Belgrade Lakes region. Colby has partnered with the Maine Congress of Lake Associations and the Belgrade Regional Conservation Alliance. We are contacting residents who own or rent property along the shoreline of one of the Belgrade Lakes to learn about their recreation, perceptions of water quality, and general lake experiences. Your survey responses will be confidential. Responses will be analyzed and reported as summaries in which no individual's answers can be identified. Thank you for taking a few minutes to share with us your opinions about the lakes. **If you have internet access, please fill this survey out online. To access the online version, use the following URL:**

www.colby.edu/environ/lakesurvey

1. **Where is your lake residence? (If you own more than one, please answer the following questions about your primary lake residence)**

   ☐ East Pond ☐ Great Pond ☐ North Pond

2. **Do you own or rent your primary lake residence?**

   ☐ Own ☐ Rent ☐ Other (please specify):__________________

3. **In which town is your primary lake residence?**

   ☐ Belgrade ☐ Belgrade Lakes ☐ Mercer ☐ Oakland ☐ Rome ☐ Smithfield
   ☐ Other (please specify):_____________

4. **For how many years have you owned or rented your primary lake residence? _______________Years**

5. **For how many years have you spent time on the Belgrade Lakes (if different than Q.4)? _______________Years**

6. **Do you live in your primary lake residence seasonally or year round?**

   ☐ Seasonally ☐ Year round (Skip to 7)

   → **6a. If you are a seasonal resident, what is the zip code of your permanent residence? ________________________Zip code**

   → **6b. On average, how many days do you spend in your lake residence annually? _________________ Days**

   → **6c. During which months do you typically visit your lake residence? (Please check all that apply)**

   ☐ January ☐ February ☐ March ☐ April ☐ May ☐ June
   ☐ July ☐ August ☐ September ☐ October ☐ November ☐ December

7. **Are you a member of any of the following groups? (Please check all that apply)**

   ☐ Lake Association ☐ Hunting and Fishing Group ☐ Environmental Organization ☐ None
   ☐ Country Club ☐ Volunteer Lake Monitoring Group ☐ Road Association
   ☐ Other (please specify):_____________________

8. **Does your lake have a lake association?**

   ☐ Yes ☐ No (Skip to 9) ☐ Not sure (Skip to 9)

   → **8a. Do you have friends, family, or neighbors who are members of the lake association?**

   ☐ Yes ☐ No ☐ Not sure

   → **8b. In your opinion, how active is your lake association?**

Very Inactive	Inactive	Neither Active nor Inactive	Active	Very Active
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

9. Do you have a lawn at your lake residence?

☐ Yes ☐ No (Skip to 10) ☐ Other (please specify):_____________________________

→ **9a. Approximately what <u>percent</u> of your lake property is covered by lawn? _____________Percent**

→ **9b. Which of the following fertilizers do you use on your lawn? (Please select all that apply)**

☐ Standard ☐ Phosphorus Free ☐ Organic ☐ I don't use fertilizer

☐ Other (please specify):______________

→ **9c. While at your lake residence, approximately how many <u>hours/week</u> do you spend on your lawn (mowing, fertilizing, weeding)?**

____________**Hours/week**

Questions 10-12 refer to Photo A and Photo B below. When answering these questions, please disregard the house structures and focus only on the landscaping.

PHOTO A

PHOTO B

10. Which landscaping would you prefer? **Please tell us why you chose photo A or photo B**:________________________________

☐ Photo A ☐ Photo B

____

____

____

____

11. Is the landscaping at <u>your lake residence</u> more similar to Photo A or B? (Please answer as if you were viewing your house from the lake)

Very Similar to A			Between A and B			Very Similar to B
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7

12. **Is your <u>neighbor's</u> landscaping more similar to Photo A or B? (Please answer as if you were viewing your house from the lake)**

	Very Similar to A				Between A and B		Very Similar to B
Neighbor to the left	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Neighbor to the right	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7

Questions 13-15 ask about the shoreline on your property. The questions refer to your <u>entire shoreline</u> as well as the <u>shoreline directly in front of your house</u>. For example, in Photo C the red box outlines the shoreline directly in front of this lake house, while the yellow box outlines the property's entire shoreline.

PHOTO C

13. **Approximately what percent of <u>your entire shoreline</u> is vegetated? ______________Percent**

14. **Approximately what percent of the <u>shoreline directly in front of your house</u> is vegetated? _________Percent**

15. **A vegetated shoreline buffer is an undisturbed band adjacent to the water that consists of trees, shrubs, and ground cover. Would you consider the shoreline <u>directly in front of your house</u> to have a vegetated buffer?**

☐Yes ☐No (Skip to 16) ☐Not sure (Skip to 16)

→ **15a. How would you rate the buffer <u>directly in front of your house</u> in terms of potential for reducing stormwater run-off?**

Poor	Fair	Good	Very Good	Excellent
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

→ **15b. On average, how wide (from the shore to your yard) is the buffer <u>directly in front of your house</u>?**

☐ less than 10 feet ☐ 10-20 feet ☐ 21-30 feet ☐ 31-40 feet ☐ 41-50 feet
☐Over 50 feet

→ **15c. Which types of vegetation make up the buffer <u>directly in front of your house</u>? (Please check all that apply)**

☐ Natural debris/leaf litter ☐ Ground cover ☐ Grass ☐ Shrubs ☐ Tree canopy
☐ Other:_______________

16. **Approximately how many acres is your lake property? ________________Acres**

17. **Approximately how many feet of shorefront do you own? ________________Feet**

18. **Approximately how many square feet is your lake house? ________________Square feet**

19. **Have you been awarded a LakeSmart sign?**

☐ Yes ☐ No ☐ Not sure

20. **While spending time at your lake residence, in which of the following activities do you typically participate?(Please check all that apply)**

☐ Ice Fishing ☐ Open Water Fishing ☐ Swimming ☐ Motor Boating ☐ Jet Skiing
☐ Canoeing or Kayaking
☐ Sailing ☐ Hiking ☐ Snowmobiling ☐ Hunting ☐ ATV Riding

☐ Wildlife/Nature Viewing or Photography

21. **From which groups do you get information about your lake? (Please check all that apply)**

☐ Lake Association ☐ Maine Department of Environmental Protection ☐ Fishing and Hunting Organization ☐ Friends ☐ Neighbors ☐ Other:______________________

22. **From which media source do you get information about your lake? (Please check all that apply)**

☐ Newsletter ☐ Television ☐ Email ☐ Facebook ☐Website
☐ Other:_________________________

23. **In your opinion, how strong is the sense of community among shoreline residents on your lake?**

Very Weak	Weak	Moderate	Strong	Very Strong
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

24. **How familiar are you with the following?**

	Never Heard of It				Could Teach the Term to Someone Else
Best Management Practice	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Phosphorus and Nitrogen Run-off	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Erosion and Sedimentation	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Algal Blooms	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Lake Smart Program	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Shoreland Zoning	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

25. **To what extent do you believe your lake is currently at risk of declining water clarity?**

Very Low Risk	Low Risk	Moderate Risk	High Risk	Very High Risk
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

26. On average, how would you rate the water clarity of your lake during the 2010 summer months? (Please check one box for each month)

	Poor	Fair	Good	Very Good	Excellent	Not Sure
May	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
June	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
July	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
August	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
September	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
October	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6

27. How would you describe the trend in water clarity on your lake over the last five, ten, and twenty years?

	Large Decline	Decline	No Change	Improvement	Large Improvement	Not Sure
Last five years	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
Last ten years	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
Last twenty years	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6

28. How do you think the average water clarity of your lake compares to the average water clarity of the following lakes?

	Much Worse	Worse	Average	Better	Much Better	Not Sure
Belgrade lakes	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
Maine's lakes	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
US lakes	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
Permanent residence state's lakes (If different than Maine)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6

29. To what extent do you think the following could potentially harm or help lake water clarity?

	Very Harmful			No Impact			Very Helpful
Camp roads	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Lawns	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Decks near the shoreline	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Old septic systems	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Organic fertilizers	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Shoreline vegetation	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7

30. On average, how would you best describe the water clarity of your lake during the first half of the 2010 summer season (May-July)?

☐ Crystal clear water
☐ Not quite crystal clear, slight algae visible
☐ Definite algal greenness, yellowness or brownness apparent
☐ High algae levels with limited clarity and/or mild odor apparent
☐ Severely high algae levels with one or more of the following: massive floating scum on lake or shore, strong foul odor, or fish kill

31. On average, how would you best describe the water clarity of your lake during the <u>second</u> half of the <u>2010 summer season</u> (Aug-Oct)?

☐ Crystal clear water
☐ Not quite crystal clear, slight algae visible
☐ Definite algal greenness, yellowness or brownness apparent
☐ High algae levels with limited clarity and/or mild odor apparent
☐ Severely high algae levels with one or more of the following: massive floating scum on lake or shore, strong foul odor, or fish kill

32. To what extent do you think the lake's <u>water clarity</u> has <u>increased or decreased</u> your <u>lake property's value</u>?

Large Decrease	Decrease	Small Decrease	No Effect	Small Increase	Increase	Large Increase
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7

The following is a table describing different levels of water quality.

Quality Index	Level	Characteristics
Best Possible	A	Beautiful, could not be any nicer
	B	Very minor aesthetic problems. Excellent for swimming, boating and enjoyment.
	C	Swimming and aesthetic enjoyment slightly impaired because of algae levels.
	D	Desire to swim and level of enjoyment of the lake substantially reduced because of algae levels.
Worst Possible	E	Swimming and aesthetic enjoyment of the lake nearly impossible because of algae levels.

<u>Great Pond is currently at level C</u> and was added to the Maine Department of Environmental Protection's impaired lakes list in 2010 because of a trend of declining water quality. This trend is partially a result of phosphorus pollution that "runs-off" the surrounding land when it rains. One way to reduce phosphorus run-off is through the implementation of Best Management Practices, such as an effective vegetated buffer between a property and the lake, to reduce erosion and help prevent run-off from entering the lake.

<u>For this survey</u> please assume that improvements to water quality could be made through a watershed wide program that would redirect phosphorus run-off away from the lake. The program would increase the number of vegetated buffers between the lake and surrounding residential properties, commercial properties, and farms. The cost to build these buffers would be paid for by a conservation fund supported by monthly payments from watershed residents. These monthly payments would be made for as long as the residents lived on the lake.

33. How much would you be willing to pay in a <u>monthly</u> conservation fee to <u>improve</u> Great Pond's water quality from <u>level C to level B</u>?

☐ $0 ☐ $2 ☐ $5 ☐ $10 ☐ $20 ☐ $40 ☐$60 ☐ Other (please specify):______________

34. How much would you be willing to pay in a <u>monthly</u> conservation fee to <u>prevent</u> Great Pond's water quality from <u>falling</u> from <u>level C to level D</u>?

☐ $0 ☐ $2 ☐ $5 ☐ $10 ☐ $20 ☐ $40 ☐$60 ☐ Other (please specify):______________

35. If you selected $0 for either Q. 33 or Q.34, why would you <u>not be willing</u> to pay any amount? (Please check all that apply)

☐ Water quality is not important to me ☐ Water quality is not my responsibility

☐ I can't afford to pay anything at this time ☐ I don't think these pollution reduction efforts would work

☐ I don't want to participate in a group program ☐ I have already invested enough in conservation practices

☐ Other (please specify):

____
____
____

36. In which of the following activities have you participated over the last <u>2 years</u> at your lake house? (Please check all that apply)

Removed vegetation from your shoreline	☐
Controlled driveway runoff using rubber razors, turn-outs, water bars, or another method to slow/divert water	☐
Installed a rain garden	☐
Left natural leaf litter/debris on the ground	☐
Controlled roof runoff with gutters, a drip-line trench, a rain barrel, or a french drain	☐
Planted a new buffer of shoreline vegetation or enhanced a pre-existing buffer	☐
Minimized or avoided fertilizer, pesticide, or herbicide use	☐
Read information on lake conservation practices	☐
Attended a lake association meeting	☐

37. What is your gender?

☐ Male ☐ Female ☐ Other

38. What is your age? ______________Years old

39. What is your political affiliation?

Very Liberal	Liberal	Moderate	Conservative	Very Conservative	Other
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6

40. What is the highest level of schooling that you have completed?

☐ Some high school or less ☐ Some college/vocational school ☐ Some post graduate schooling
☐ High school graduate ☐ College graduate ☐ Advanced graduate or professional degree

41. Which of the following broad categories best describes your total income from all sources in 2010?

☐ $10,000 or less ☐ $30,001-$40,000 ☐ $60,001-$70,000 ☐ $90,001- $100,000
☐ $10,001-$20,000 ☐ $40,001-$50,000 ☐ $70,001-$80,000 ☐ $100,001-$150,000
☐ $20,001-$30,000 ☐ $50,001-$60,000 ☐ $80,001-$90,000 ☐ $150,001-$200,000

☐ More than $200,000

42. What is your current work status?

☐ Work Full Time ☐ Work Part-Time ☐ Work Seasonal Jobs ☐ Not Currently Working
☐ Student ☐ Self Employed ☐ Retired ☐ Stay at Home Parent

43. What is your primary occupation? ____

44. Do you have children under the age of 18 years living in your lake residence?

☐ Yes ☐ No ☐ Other (please specify):____________________

Thank you for taking the time to fill out this survey! If you have any questions, please email us at **lakesurvey@colby.edu**. When you are finished, please use the prepaid and preaddressed envelope to mail the survey back to Colby College. If you lose the envelope you can mail the survey to the following address:

c/o Lake Survey
Environmental Studies Program
Colby College
5300 Mayflower Hill Rd.
Waterville, ME 04901

Remember, if you prefer you can also fill out an online version of this survey instead by using the following URL:

www.colby.edu/environ/lakesurvey

APPENDIX B: SHORELINE PHOTO SURVEY

Belgrade Lakes Shoreline Photo Evaluation
Colby College
Spring 2012

Faculty and students at Colby College are collaborating with a variety of community partners on a research project evaluating lake water quality and conservation in the Belgrade Lakes region funded by the National Science Foundation. In the summer of 2011 a research team conducted a survey of residents who own or rent shoreline property. Part of this survey asked residents to self-assess their property's shoreline buffer.

We are now hoping to compare residents' evaluation of shoreline buffers to those of a panel of experts. The responses by experts will be used for analysis purposes only.

Thank you for your willingness to be an expert and provide your evaluation of the shoreline properties depicted in the following slides. The first slide is a subset of the survey sent to homeowners, please use it for reference when assessing the shoreline photos. The remaining slides show photos of shoreline properties taken from the lake. For each house please fill out the form directly below the photo.

Please return your completed survey to Dan Homeier, dhomeier@colby.edu, by Friday March 2nd.

Surveyor name: ____________________
Date completed:____________________

If you collaborated with another expert please put an X here (it does not matter if you did, I just need to know):_____

This is a copy of a subset of the survey that was sent to homeowners. This page is for your reference only, please use the same directions when answering the questions on the following slides.

Entire shoreline refers to all of the shoreline pictured (i.e., yellow and red rectangles) while *shoreline directly in front of house* refers to only the shoreline in front of the house (i.e., red rectangle).

1. Approximately what percent of the entire shoreline is vegetated?

2. Approximately what percent of the shoreline directly in front of the house is vegetated?

3. Would you consider the shoreline directly in front of the house to have a vegetated buffer?

☐Yes ☐No (Skip A and B) ☐Not sure (Skip A and B)

   a. How would you rate the buffer directly in front of the house in terms of potential for reducing stormwater run-off?

Poor	Fair	Good	Very Good	Excellent
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

   b. Which types of vegetation make up the buffer directly in front of the house? (check all that apply)

   c.

☐ Natural debris/leaf litter ☐ Ground cover ☐ Grass ☐ Shrubs ☐ Tree canopy ☐ Other:______________

Please fill out the questions below based on the shoreline photo pictured above using the same criteria used in the survey sent to residents. Note that some houses require more than one photo because the lot's shoreline extends beyond one photograph.

When this occurs there will be a white arrow to the bottom right of the first photograph in the series. Please fill out one evaluation form for the set of photos.

Question	**Answer**
1. Approximately what percent of the entire shoreline is vegetated? (**0-100**)	
2. Approximately what percent of the shoreline directly in front of the house is vegetated? (**0-100**)	
3. Would you consider the shoreline directly in front of the house to have a vegetated buffer? (**Yes/No/Not sure**)	
3a. How would you rate the buffer directly in front of the house in terms of potential for reducing stormwater run-off? (**1- Poor, 5-Excellent**)	
3b. Which types of vegetation make up the buffer directly in front of the house? (place an X next to all those that apply)	
Natural debris/leaf litter	
Ground cover	
Grass	
Shrubs	
Tree canopy	
Other	

APPENDIX C: LAKESMART SURVEY CRITERIA

Property Evaluation Form For LakeSmart Awards Program

The following evaluation and recommendations are based on commonly accepted Best Management Practices. The intent of this program is to improve or maintain the property for water quality. In most cases, award properties should exceed the minimum shoreland zoning regulations. This evaluation covers only areas that were visually inspected and is based on site conditions apparent at the time of inspection.

Please look out for violations of Environmental Law. We cannot give a LakeSmart award unless the violation is fully remediated. It is the evaluator's prerogative to withhold a LakeSmart award for properties that have been recently altered in a way that negatively affects water quality. If in doubt, hold off making an award. Consult the lake association for more information. This program should not be linked to enforcement action. If you have any question about the award qualifying score, do not give out the sign; wait for DEP confirmation.

Body of Water/Watershed:
Evaluator **Date**
Property Owner(s)
Mailing Address
Telephone number(s)
Email address
Own for # Yrs **Year round or seasonal?**
Town: Road Name or Fire Lane#
Permission to post name on web and newspaper? Yes No
Award winners will receive a framed certificate.

Send signs (circle one)**:**	yes, send 1,	yes send 2
	no, gave them 1	no, gave them 2

Lakesmart Award Status:	**Score**	**Recognition?**
Section 1 Driveway… **(**11/15 to qualify)		
Section 2 Structure… (13/18 to qualify)		
Section 3 Yard... (22/33 to qualify)		
Section 4 Shore… (25/37 to qualify) (For shorefront properties only)		
Sections 1- 4 = LAKESMART AWARD		
Section 5 Undeveloped land (11/15 to qualify)		

Comments (successes or other news worth story):

PLEASE make a copy and return original with a copy of recommendations with invoice within 2 weeks to Barb Welch either electronically to barb.welch@maine.gov or snail mail to Maine DEP, 17 State House Station, Augusta, ME 04333-0017.

Section 1: Driveway and Parking Areas

Criteria	Ranking System	Points
The driveway and parking area are defined and minimized	**0** = undefined and/or excessive **1** = somewhat defined and/or excessive **2** = mostly defined, slightly excessive **3** = well defined and minimal in size	
Driveway and parking surfaces are stable with no signs or erosion	**0** = > 10% eroding **1** = between 5% and 10% eroding **2** = between 1% and 4% eroding **3** = no erosion	
Shoulders and ditches are stable with no signs of erosion	**0** = > 10% eroding **1** = between 5% and 10% eroding **2** = between 1% and 4% eroding **3** = no erosion	
Stormwater moves as sheet flow over driving surfaces (***Except when channelized due to water bars or other BMPs designed to move water off road surface)***	**0** = mostly channelized **1** = more channelized than sheet flow **2** = more sheet flow than channelized **3** = entirely sheet flow	
Stormwater flow from road surface is directed to an effective vegetated buffer or other BMP	**0** **1** **2** **3** None Some Most All	
Total Available Points =15	(11 to qualify) Total =	

Recommended Action(s):

Section 2: Structures and Septic System

Criteria	Ranking System	Points
Roof runoff is infiltrated or directed to rain garden, barrel or stable outlet	**0** **1** **2** **3** None Some Most All	
*Pet wastes are not a threat to water quality ***(Do you have a pet?)***	**0** = much waste evident **1** = some waste evident **2** = no waste evident **3** = no pets	
*No evidence of septic system malfunction ***(What is the age of your septic system?)*** ***Out houses, grey water systems and holding tanks are considered legal septic systems. If an outhouse is utilized, a grey water system must be in place for household sink drains.***	**! 0 = significant evidence of malfunction** **1** = no knowledge of system design and/or location or system installed pre-1974 and potential evidence of malfunction **2** = Post-1974 system and potential evidence of malfunction **3** = no evidence of malfunction	
Septic system free of woody vegetation so system is not threatened by roots	**0** = much vegetation **1** = some vegetation **2** = threatened by encroaching vegetation **3** = free of woody vegetation	
*Septic system regularly pumped and maintained ***(How often do you pump your septic system?)***	**0** = more than 5 years **1** = every 4 to 5 years **2** = every 3 to 4 years **3** = every 2 to 3 years or less	
Home heating oil tank or exterior toxic chemical storage (like gas, pesticides..) does not pose a threat	**0**=exterior tank or toxic chemical container is leaking or rusty or not covered and where snow/ice cascading off roof would hit it **1**=exterior tank not covered, but not located where it could be hit by cascading ice **2**=exterior tank has valve cover **3**= exterior tank is completely covered or there is no exterior tank or toxic chemicals	
* ! Decks, stairs, … meet the setback requirement of 100 feet unless grandfathered *(What is age of structure?)*	Refer to Shoreland Zone Decision Tree for help. Eligible – OK for award Ineligible – no award allowed	ok no
Total Available Points = 18	(13 to qualify) Total =	

! A LakeSmart award cannot be issued if there is a malfunctioning septic system

*** Means this is a question to ask owners**

Recommended Action(s):

Section 3: Yard, Recreation Area and Footpaths
(Immediate area around home 1 acre or less)

Criteria	**Ranking System**	**Points**
Soil erosion is not occurring on site	**0** = > 10% eroding **1** = between 5% -10% **2** = between 1% - 4% **3** = no erosion	
Stormwater flow goes to an effective vegetated buffer or other BMP	**0** **1** **2** **3** None Some Most All	
* Use of pesticides and herbicides are omitted or minimized. **Pests are only spot treated as needed. (*Please tell me how you control pests?)***	**0** **1** **2** **3** Never Sometimes Mostly Always	
*Use of fertilizer is minimized and only used based on soil test. ***(How often do you fertilize your lawn or plants?)***	**0** = Areas fertilized yearly **1** = Areas fertilized less than 1/year **2** = areas fertilized based on soil test **3 =** fertilizer is never used	
Lawn area is minimized	**0** = Excessive **1** = Moderate **2** = Minimized **3** = **N**o lawn	
*Turf is maintained at 2.5 to 3.5 inches and Clippings are left on lawn (***What do you set your mower height at?)***	**0** **1** **2** **3** Never Sometimes Mostly Always	
Duff layer is maintained wherever possible (duff layer is thick & deep; mulch is a secondary solution)	**0** None **1** Some duff and/or mulch **2** Most areas with duff and/or mulch **3** All areas with duff	
Natural uneven topography is maintained, restored or enhanced	**0** **1** **2** **3** None Some Most All	
Cultivated areas are properly mulched	**0** **1** **2** **3** None Some Most All mulched or no cultivated areas	
Recreation areas are defined and limited	**0** **1** **2** **3** None Somewhat Mostly All	
Paths are limited, defined, curved and do not convey runoff directly into lake. (Receives full points if there are no paths but there is no obvious need or observed foot traffic.)	**0** **1** **2** **3** None Somewhat Mostly All	
Total Available Points = 33	(22 to qualify) Total =	

* Means this is a question to ask owners
Recommended Action(s):

Section 4: Shorefront and Beach Area

Criteria	Ranking System	Points
Buffer is properly sited along shoreline including drainage ditches	**0** **1** **2** **3** None Some Most All	
! Buffer contains 5 tiers of vegetation: canopy, shrub, understory, ground cover, duff that are effective in filtering stormwater	**0** = no tiers effective **1 =** 1 tier effective **2** = 2 tiers effective **3** = 3 tiers effective **4** = 4 tiers effective **5 =** 5 tiers effective	
Buffer vegetation is composed of native or native friendly species	**0** = mostly invasive plants **1 =** mostly native friendly **2** = both native friendly and native **3 =** all native plants	
Buffer is receiving sheet flow, not channelized, concentrated flows	**0** = all flow concentrated **1 =** most flow concentrated **2** = most flow is sheet **3 =** all flow is sheet flow	
! Buffer is sufficiently wide to filter stormwater effectively. (The steeper the slope, the wider buffer needs to be. The widths given assume a relatively flat area. The larger the area draining to the buffer, the wider the buffer needs to be.)	**0** = less than 10 feet in width **1 =** 10 to 20 feet **2** = 21 to 30 feet **3**= 31 to 40 feet **4=** 41 to 50 feet **5** = over 50 feet in width, negative slope or natural ice berm intact	
Duff layer is maintained wherever possible (duff layer is thick & deep; mulch is a secondary solution)	**0** None **1** Some duff and/or mulch **2** Most areas with duff and/or mulch **3** All areas with duff	
Natural uneven topography is maintained, restored or enhanced	**0** **1** **2** **3** None Some Most All	
Shoreline is stable	**0** = mostly unstable **1** = moderately unstable **2** = mostly stable **3 =** totally stable	
Shoreline is natural. Where riprap or concrete is used, it is vegetated and limited in size or appropriate to location as a BMP	**0** = 100% unvegetated **1** = 33% to 99% unvegetated **2** = 1% to 33% unvegetated **3 =** Totally naturalized shoreline or appropriate with location.	
Pathway and dock area	**0** = Effectiveness of buffer is compromised	

designed to compliment buffer (least impairment to buffer)	**1 =** some buffer still functioning **2** = most buffer still functioning **3 =** Design of pathway and dock totally compliments buffer	
Beach or swimming access is stable and designed to prevent runoff	**0** No **1** Somewhat **2** Mostly **3** Yes	
Total Available Points = 37	(25 to qualify) Total =	

! A buffer of 3 tiers, at least 10 feet wide (even if berm or neg. slope), and an effective width required for LakeSmart award regardless of score.

! All decks, stairs, etc. whether temporary or permanent, must meet the setback requirement of 100 feet unless grandfathered (built before 1986) **in order to receive a LakeSmart award. Refer to Shoreland Zone Decision Tree for help.**

Recommended Action(s):

Section 5: Undeveloped Land (Bonus Recognition)
All areas in excess of the one acre immediately around the home

Criteria	**Ranking system**	**Points**
Low % of impervious surfaces	**0** = > 10% **1** = between 5% and 10% **2** = between 1% and 4% **3** = < 1%	
Low % of lawn and cleared areas	**0** = > 30% **1** = between 15 and 30% **2** = between 15 and 7% **3** = < 7%	
Paths or road through undeveloped land is stable	**0=** numerous eroding roads **1** = a few eroding roads **2** = 1-2 well stabilized paths **3** = no paths	
Condition of undeveloped land is undisturbed	**0 =** recently cleared or graded with little vegetation **1** = several recently cleared or graded plots **2** = a few disturbed areas **3** = mature native forest.	
Conservation Easement on land	**0 =** no **1** = considering **2** = In process **3** = Yes	
Total Available Points = 15	**(11 to qualify) Total =**	

Recommended Action(s):

Thank you for participating in the LakeSmart Program!

The following recommendations are based on commonly accepted Best Management Practices. The intent of this program is to encourage people to maintain properties that protect lake quality. This evaluation covers only areas that were visually inspected and is based on site conditions apparent at the time of inspection.

Lake:
Owner:

Recommendations:

Lakesmart Award Status: Yes/No
SECTION 1 Driveway and Parking
SECTION 2 Structures and Septic
SECTION 3 Yard, Recreation and Paths
SECTION 4 Shorefront and Beach Area
(For shorefront properties only)
LAKESMART AWARD
SECTION 5 Undeveloped Land

Reviewer Date
Reviewer contact info

For more information on LakeSmart, check out our web site at www.MaineDEP.com, click on DEP Home page and put LakeSmart in *Search DEP*.