Assessing Effects of Geocaching as a Recreational Activity on Natural Resources Within Minnesota State Parks

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Abstract

Geocaching is a high-tech treasure hunt combining hand held Global Positioning System (GPS) receivers and hiking. This recreational activity has grown in popularity since publicly launched in 2000. Affordable recreational-grade GPS units, as well as cellular phones equipped with GPS, have increased the number of people geocaching worldwide. Popularity has brought with it an increase in environmental impacts caused by geocaching. This study details steps taken to assess environmental impacts caused by geocaching in twenty-one Minnesota state parks. Further, the study defines methodologies used to determine areas and causes of high impact, including procedures to create a geocache placement suitability assessment map, and a model identifying vulnerable areas that could be utilized by the Minnesota Department of Natural Resources or other interested parties for future geocache policy planning.

Introduction

Geocaching is defined as a high-tech treasure hunt that combines hiking with the use of handheld GPS units (Patubo, 2010). According to geocaching.com (2011), the idea is to locate hidden containers (caches) outdoors, then share your experiences online with a free account at the geocaching.com website. Multiple forms of geocaches exist. The most common is a standard geocache: a hidden container that includes, at minimum, a logbook for geocachers to sign (Figure 1). Other types include virtual caches (also considered a waymark), where no physical container exists – this type of cache generally marks a point of interest; an earth cache, similar to a virtual cache, but pertaining to geologic features; and a multi-cache, which involves two or more locations where the final location is the physical container, and preceding locations (or waypoints) give hints to the following locations. Other less common types of caches are defined at geocaching.com.

Geocaching has rapidly grown in popularity since it began in 2000 (Patubo, 2010). The availability of handheld GPS units to the public, and more recently the accessibility of GPS enabled phones, have contributed to its growing number of participants.

As with all other recreational activities, geocaching has a measurable amount of impact on the environment in which it takes place. To assess recreational impacts on natural resources, researchers are making use of Geographic Information Systems (GIS) software (Tomczyk, 2010). In addition,

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GPS data collection is often utilized for statistical analyses to understand dependent and independent variable factors in research efforts (Marion and Wimpey, 2010).

Figure 1. Photo of a standard geocache, located at Bear Head Lake State Park.

Geocaching in Minnesota State Parks

The first geocaches appeared in Minnesota, primarily in the Twin Cities area, in 2001. By May of 2002 there were 273 caches in Minnesota and as of December, 2011 there were over 4,000 (geocaching.com, 2011). The Minnesota Geocaching Association (MnGCA) was also established in 2002 with the mission of providing "a resource for Minnesota geocachers to organize activities and events that will improve the credibility of the sport, protect our natural resources and strengthen the community of geocachers in the state of Minnesota (Minnesota Geocaching Association, 2011)." The Minnesota Department of Natural Resources division of Parks and Trials (MNDNR-PAT) received increasing numbers of inquiries regarding geocaching on state park lands as the popularity of geocaching grew.

Initially, MNDNR-PAT did not allow placement of geocaches on division-administered lands because state park rules (MR 6100.1650 subpart 2) prohibit the storage or abandonment of personal property on state park lands without prior approval of the park manager. The division was also concerned about visitor safety, potential impacts to natural/cultural resources, liability and the likely increase to staff workload. In 2005-06, at the request of the Minnesota Geocaching Association, a number of meetings were held between division staff and MnGCA board members to see if there was a way that geocaching could be allowed on state park lands. As a result of those discussions, the division determined that geocaching may be permitted in state parks so long as it was managed to conform to statutory direction for outdoor recreational activities allowed in state parks. Minnesota Statutes (86A.05 subd. 2c) defines those as activities "which will not cause material disturbance of the natural features of the park or the introduction of undue artificiality into the natural scene." It also states parks "shall not be designed to accommodate all forms or unlimited volumes of recreational use."

In 2006, MNDNR-PAT began allowing citizens to apply for permits to place geocaches and letterboxes on division administered lands. Letterboxing is similar to geocaching but relies on clues rather than geographic coordinates to find a hidden container. The approval process was intended to minimize the potential for geocaching to cause impacts to natural and cultural resources and included such things as review of the proposed location compared to rare natural features, cultural resource sites, high quality native plant communities, and areas of active management such as prescribed burning. Only a handful of applications from citizens were received over the next two years.

In 2008, MN DNR-PAT established a nearly system-wide geocaching program called The History Challenge to coincide with Minnesota's sesquicentennial. Caches were established at all 72 state park and recreation areas. The program ran for one year. Upon its completion in 2009, a new program was launched, called The Wildlife Safari. It was scheduled to run for three years (2009-2011). Due to the success of these programs in terms of divisional goals to connect people to the outdoors, it is anticipated MNDNR-PAT will continue to sponsor system-wide programs and allow private citizens to establish geocaches on division-administered-lands through a permit process. Currently, there are approximately 339 active caches on state park and recreation areas. Approximately 32 percent are owned by private citizens and 68 percent by PAT.

Beginning in 2008, anecdotal observations by division staff, such as park managers, resource specialists and even some visitors, indicated impacts to natural resources were occurring. Typical impacts noted were trampling of vegetation, exposure of bare soil, soil erosion and damage to woody vegetation. Recognition of impacts taking place led the division to plan and conduct a study in 2010-2011 to identify and quantify types of impacts occurring, and identify driving factors behind impacts in order to assist the division in better managing geocaching within State Parks. All policies were written with the understanding that Minnesota state parks would develop management guidelines on geocaching and its impact on park resources.

Impacts were defined by MN DNR resource specialists. Damage to woody vegetation is described as broken or trampled saplings or vegetation with hard stems (Figure 2). Herbaceous vegetation includes plants with no persistent woody stem above ground. Trampling of herbaceous vegetation is self explanatory (Figure 3). Bare dirt is caused from trampling of vegetation to the point of elimination so that only soil remains (Figure 4).Eroded soil occurs where impact is associated with slope (Figure 5).

A distinct progression can be made between the severity of impact and the attributed definition of impact defined above. As use increases, the scale of impact does as well. One can expect to see trampled herbaceous vegetation, followed by bare dirt, and sometimes then followed by eroded soil (depending on slope). Damage to woody vegetation is a stand-alone attribute and can occur singly or in conjunction with other impacts (i.e., bare dirt, as well as damage to woody vegetation at one site).

Impacts occur at the location of geocache waypoints, at cache locations and at travelways in between cache locations. In order to better determine and quantify effects of geocaching on MNDNR-PAT administered natural and cultural resources, it was determined an assessment should be conducted in 2011 with the possibility of future periodic monitoring. In particular, MN DNR staff are seeking information on the effects of this activity on natural and cultural resources.

The goals of the study were to:

1. Quantify the amount and types of observed impacts to natural resources attributable to geocaching activity on state park lands.

Figure 2. Damage to woody vegetation at Lake Bronson State Park geocache; note trampled sapling.

Figure 4. An example of bare dirt at a geocache waypoint at Bear Head Lake State Park.

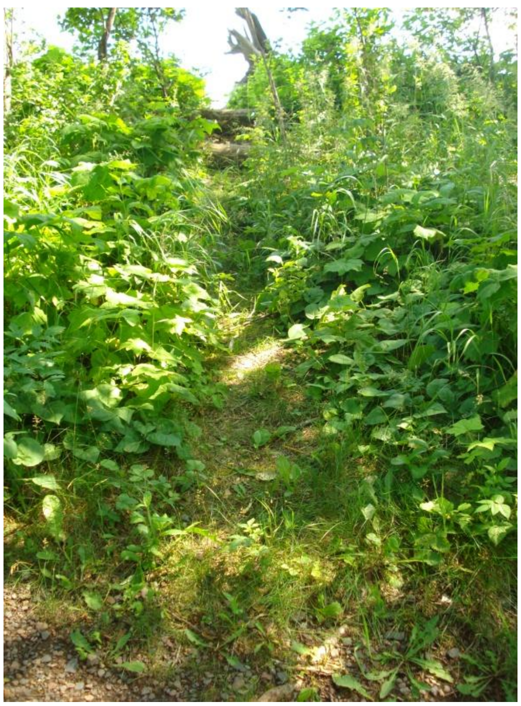

Figure 3. Trampled herbaceous vegetation at geocache waypoint at Gooseberry State Park.

Figure 5. An example of eroded soil, taken near geocache container at Afton State Park.

2. Identify factors correlating with the level of impact.
3. Create and analyze a suitability model highlighting areas with a high probability of impact caused by geocaching.
4. Define methodologies, including suitability modeling and collecting and analyzing data, which could be repeated in the future to assess further impact at these sites or at new locations.
5. Provide information to the MNDNR-PAT division or other interested parties to assist in developing and implementing policies to manage geocaching activities on protected lands.

In addition to categorizing and quantifying impacts, this study sought to identify factors associated with the development of impact at geocaching sites. These included:

- Is impact associated with park attendance?
- Is impact associated with online logbook entries?
- Is impact associated with vegetation type at cache location?
- Is impact associated with cache owner (private citizen, or MNDNR)?
- Is impact associated with "demonstration" State Parks, offering free GPS unit rental to visitors?
- Is impact associated with geocache distance from trail?
- Is impact associated with surface type at cache locations?

Assessing the Impact to Natural Resources from Recreation Activities

Defining Variables for Data Collection

In order to define measureable environmental impact, a literature review was performed which examined reputable scholarly articles assessing the impact to natural resources caused by low impact recreational activities.

In a GIS assessment of the environmental sensitivity of recreational trails, Tomczyk (2010) classifies impact to trails into commonly affected categories including vegetation, soil and topography. A further detailed definition of similar categories can be found in a review of impact of recreation and tourism on plant biodiversity and vegetation in protected areas in Australia (Hill and Pickering, 2007). Evident impact includes damage to herbaceous areas from human trampling and an assessment of severe impacts on native vegetation from the spread of invasive plants.

Specific to geocaching as a recreational activity, Patubo (2010) defines the environmental impacts of human activity associated with geocaching by reviewing past studies on recreational ecology related to environmental impact. Factors contributing to impact in his findings include trampling by hikers, soil compaction, change in trail width, spread of foreign plants and the spread of water mold.

Techniques to assess recreational impacts to native areas are abundant. Marion and Wimpey (2010) used GPS sampling to collect data for statistical analysis to understand factors that increase the width of formal hiking trails. Regression analysis was used to compare actual trail widths to proposed trail widths. Further, a study conducted by Nepal and Nepal (2004) analyzed visitor induced damage to park trails and factors that influence the severity of the damage assessed. The study determined the time of a visit and the activity of a visit affected the amount of damage to trails within parks.

Monitoring defined impacts is an important part of natural resource management. Recommendations for monitoring impacts to the environment related to recreational use is discussed by Cole, Leung, Marion, and Monz (2009). Ecosystem attributes and larger aspects of environmental conservation occurring at landscape scales are recommended for consideration (Cole et al., 2009). Further, Hawden, Hill and Pickering (2007) share findings on the need for collection of visitor load and environmental data in order to accurately assess impact.

The studies mentioned above were taken into account during the study design. The literature assisted in defining data to collect, plan database development, and analyze collected data.

Variables chosen for which to collect data were narrowed down to trampled herbaceous vegetation, bare dirt, eroded soil and damage to woody vegetation at defined locations including geocache, waypoint, or travelway.

Using GIS as an Analysis Tool

Suitability modeling is a common GIS procedure to identify optimal locations. It incorporates classifying and combining spatial datasets to identify sites most suitable for a specific use. Data are given numerical ranks that indicate if their existence in a GIS is detrimental or conducive to the desired use. Literature were summarized with the intent of defining impact data collection categories and techniques as well as identifying methods to create a suitability model to identify locations at high risk of impact caused by geocaching.

Tomczyk (2010) performed a GIS suitability analysis to assess the spatial distribution of areas with diversified degrees of environmental sensitivity to trail impact at a national park in Poland. The two variables analyzed through this study included soil erosion, based on slope and vegetation, characterized by resistance, resilience and tolerance to trampling. This data were input into a GIS with topographical layers, soil maps, aerial orthophotos and a map of plant communities within the study area. The result highlighted areas with a high likelihood of impact to trails.

This project identifies areas most at risk for geocache impact based on suitability modeling. Suitability modeling goals are to provide a resource to identify areas of impact in the event that site visits, impact data collection and analysis were not feasible. Products from this research are ultimately intended to assist MNDNR-PAT staff or other interested parties in developing and implementing policies to manage geocaching activities on protected lands.

Methods

Suitability Modeling

The goal of the suitability model was to visually display areas of high and low likelihood of potential impact caused by geocaching and could be used as a planning tool for park managers and resource staff to identify areas for geocache placement.

A literature review did not yield an exact GIS model to reference. Collaborative efforts from GIS and natural resource staff at the MNDNR, in conjunction with research in similar studies, defined the following variables for suitability modeling: geocache distance from trail, landcover vegetation type and soil erodibility (Figure 6 and Figure 7).

K Factor was chosen based on its definition as the soil erodibility factor within soil datasets. The K factor represents both susceptibility of soil to erosion and the rate of runoff. Low K values represent a low likelihood of erosion while high K values represent a high likelihood of erosion. Examples of soils with low K values include soils high in clay while high K value soils may include high levels of silt.

To spatially calculate this information, SSURGO Soils – K Factor – Whole Soils, State Parks Trails and Roads, and State Parks Landcover layers were obtained from the MNDNR's geodata resource site. All layers were clipped within the Itasca State Park boundary. Itasca State Park was chosen for use in this suitability model due to its size (it is one of Minnesota's largest state parks) as well as its diversity in vegetation and soil types throughout the park. The model built for this research could be used on a statewide level or input layers could be clipped to a specific park for faster processing and smaller scale outputs.

Reclassification of datasets to ordinal data were completed with input from natural resource managers within the MNDNR. A "Rank" short integer field was added to all three datasets, which holds calculated ordinal values. Vegetation data were ranked based on likelihood of impact defined by system group attribute (Figure 7) on the following scale in which low values represent less likelihood of impact caused by geocachers, while high values represent more likelihood of impact:

- Developed Areas: 1
- Non-Natural Community: 2
- Upland Forests and Woodlands: 3
- Upland Grasslands, Shrublands, and Sparse Vegetation: 4
- Other Natural Communities: 5
- MCBS Complex: 6
- Wetland Forests: 7
- Wetland Grasslands, Shrublands, and Marshes: 8

SSURGO Soil – K Factor – Whole Soil data were also ordinally reclassified to represent K factor ranks. Rank was based on the KfactWS (K Factor Whole Soil) attribute on the following scale in which low values represent less likelihood of impact caused by geocachers while high values represent more likelihood of impact:

- "KfactWS" = '.00' = 0
- "KfactWS" = '.02' = 1
- "KfactWS" = '.10' = 2
- "KfactWS" = '.15' = 3
- "KfactWS" = '.17' = 4
- "KfactWS" = '.20' = 5
- "KfactWS" = '.24' = 6
- "KfactWS" = '.28' = 7
- "KfactWS" = '.32' = 8
- "KfactWS" = '.37' = 9

See Figure 6 for a visual of the soil erodibility K factor in Itasca State Park, used for suitability modeling.

The State Park Roads & Trails GIS layer was converted from vector to raster format using an ordinal attribute field, thus there was no need to create an ordinal field. Figure 8 illustrates a distance raster in Itasca State Park.
A toolbox and model was created to hold project data for analysis purposes

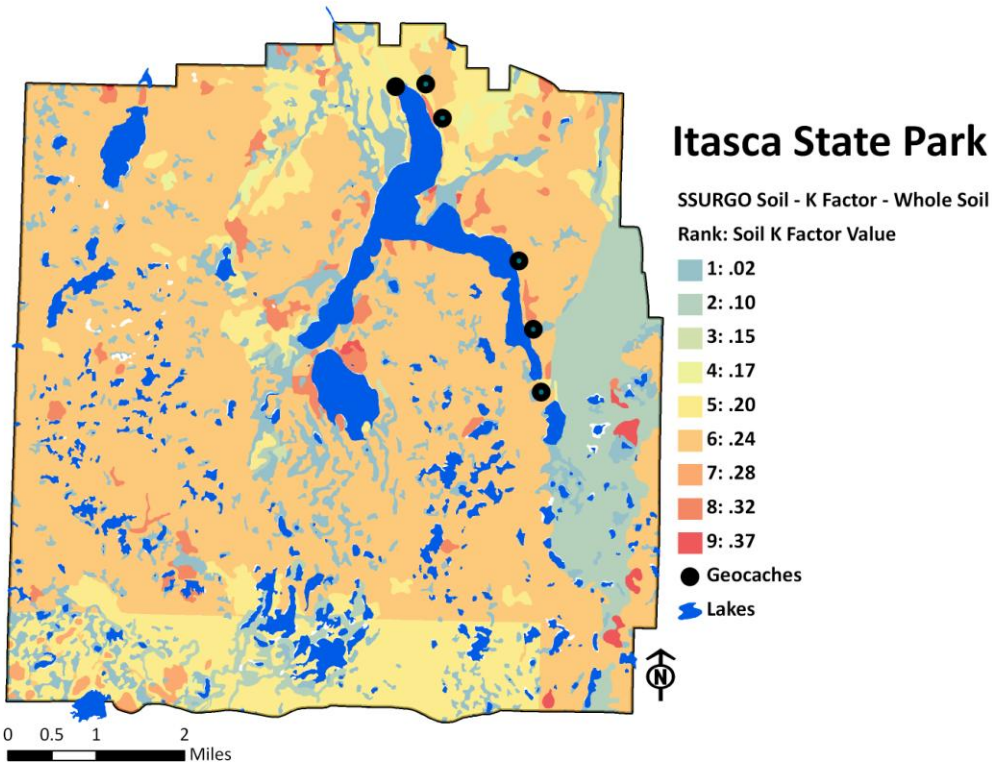

Figure 6. Map of SSURGO Soil – K Factor – Whole Soil values.

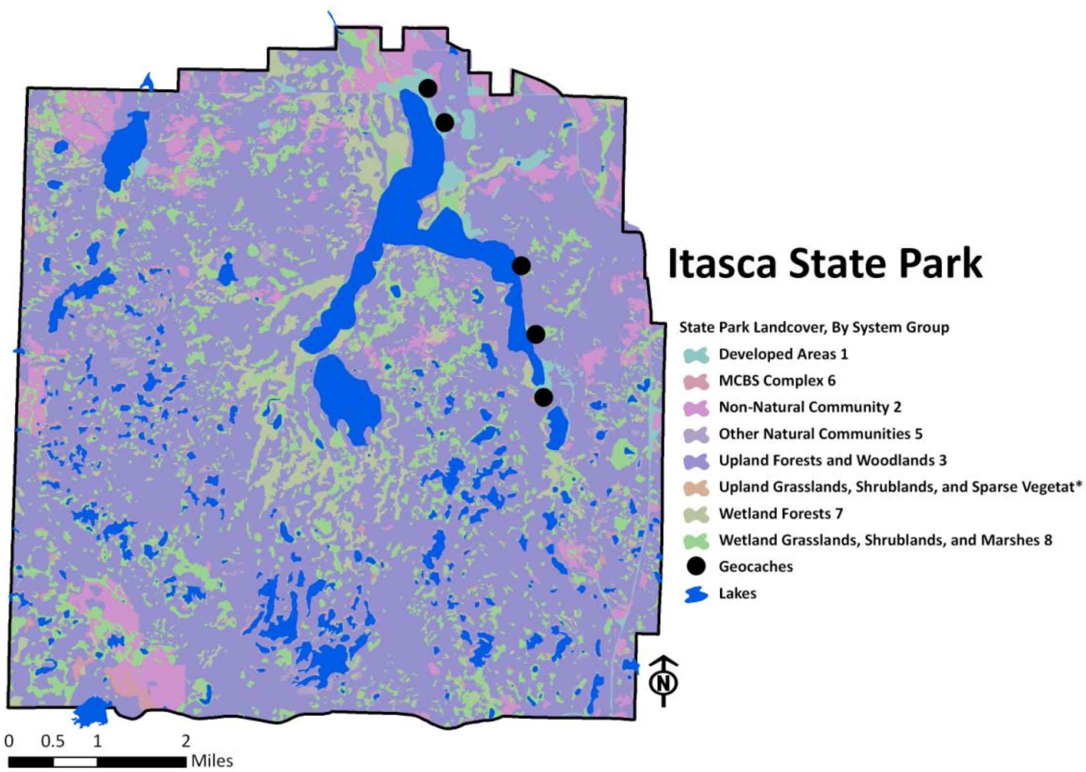

Figure 7. Map of State Park Landcover, symbolized by System Group.

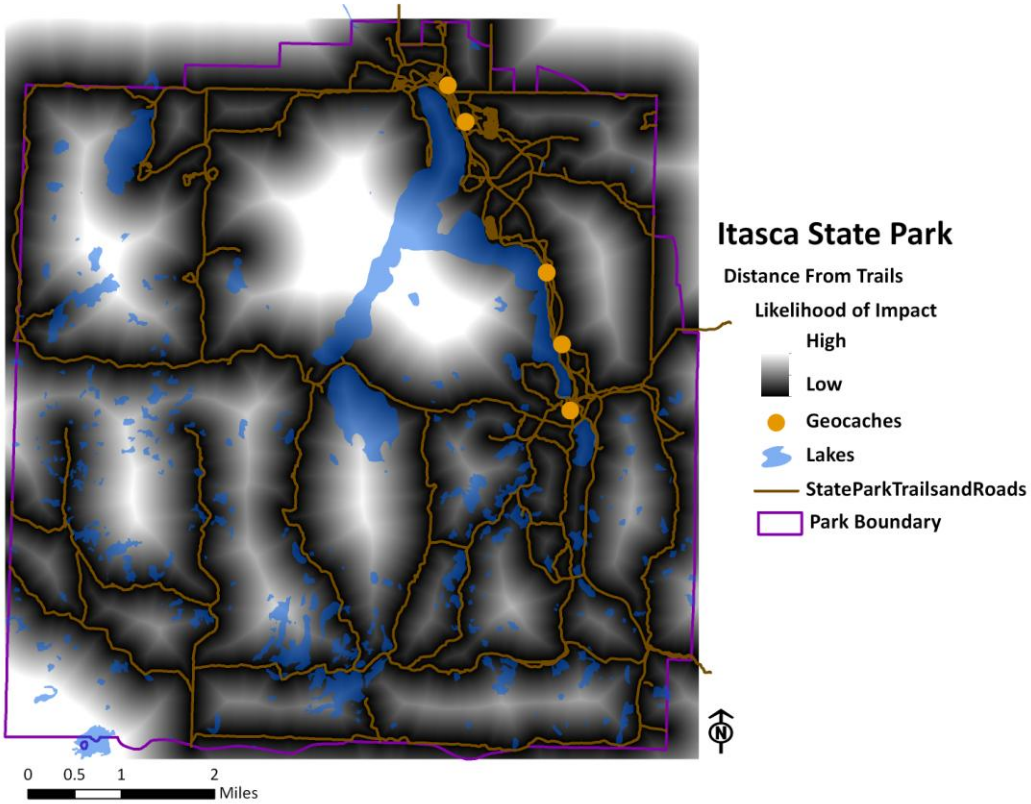

Figure 8. Map of raster analysis; distance from trails depicting high values further away from trails.

The vegetation, soil, and trail clipped datasets were then added to Model Builder.

Euclidean distance was used to create a raster of distances from State Park Trails and Roads. The output product displayed a continuous raster dataset showing distance from State Park Trails and Roads. In order to weight each of the three model input layers equally, each dataset was normalized to a zero to one scale. This was accomplished by dividing each dataset by its maximum value. Calculations used in the Raster Calculator are as follows:

- "%_(Distance Raster)%" / 2604.87 (the maximum distance in meters, from trail to park boundary).
- "%(Soil Raster)%" / 9 (the total number of previously defined soil classes)
- "%(Vegetation Raster)%"/ 8 (the total number of previously defined vegetation classes).

Finally, all three recalculated rasters were added together (distance, soil and vegetation) to create one final raster with values between one and three. The equation used in the Raster Calculator was: "%(Recaclulated Distance Raster)%" + "%(Recalculated Soil Raster)%" + "%(Recalculated Vegetation Raster)%". The lower the score of the output raster cell, the less likely the occurrence of impact from geocaching at that given area.

Database Development

All data collected in this project was stored in a personal geodatabase (GDB) created using ESRI's ArcCatalog software. The GDB consisted of one feature dataset created with the North American Datum (NAD) 1983 Universal Transverse Mercator (UTM) Zone 15N projection. This projection was chosen due to its designation as the standard projection at the MNDNR, since further analysis of the data was performed in conjunction with existing MNDNR data.

Within the feature dataset two feature classes were created. A polygon feature class was created to store areas of impact,while a polyline feature class was created to store linear impact features. (See Figure 9).

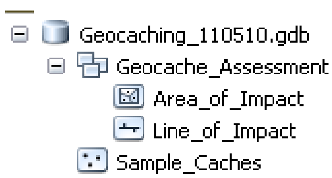

Figure 9. Geodatabase design.

A shapefile of current geocache locations within Minnesota state park boundaries was acquired from GIS staff working for Groundspeak, owners of geocaching.com. This shapefile was imported into the geodatabase in order to reference current geocache locations and names.

Geodatabase construction was planned with the intention of data collection. Data to be collected included data types and fields shown in Figure 10.

Field Name	Data Type
OBJECTID	Object ID
SHAPE	Geometry
Assessment_Location	Text
Type_of_Impact	Text
Geo_ID	Long Integer
Measured_Length	Double
Measured_Width	Double
Photo_1	Text
Photo_2	Text
Photo_3	Text
SHAPE_Length	Double
SHAPE_Area	Double

Figure 10. Polygon and polyline field names and data types.

The Geo_ID field represents a unique identifier existing within the MNDNR's geocaching Microsoft Access database. This allowed for collected polygon and polyline data to be joined to cache locations for further analysis. Measured Length and Measured Width fields allowed for the data collector to manually measure the area of impact and enter measurement information in these fields. These data were collected with the intention of evaluating statistical accuracy of the Trimble GeoXH GPS unit used for data collection. Since the Trimble GeoXH was not equipped with a camera, photo fields were included in the database to make referencing photos taken at sites of impact easier.

Three domains were defined at the feature dataset level for consistency in data collection. Domains included 'Assessment Location', 'Type of Impact', and 'Impact Line Width'. All were coded value domains, with the coded values as shown in Figures 11, 12, and 13.

Coded Values:

Code	Description
Waypoint	Waypoint
Geocache	Geocache
Travelway	Travelway
Virtual Cache	Virtual Cache

Figure 11. Assessment location coded values.

Coded Values:

Code	Description
Bare Dirt	Bare Dirt
Trampled Herb Veg	Trampled Herbacious Vegetation
Eroded Soil	Eroded Soil
Woody Veg Damage	Woody Vegetation Damage

Figure 12. Type of impact coded values.

Coded Values:

Code	Description
< 1 foot	Less than 1 foot
1 to 2 feet	1 to 2 feet
3 to 5 feet	3 to 5 feet
6 to 10 feet	6 to 10 feet
Unknown	Unknown

Figure 13. Impact line width coded values.

Mobile Data Application Development and Data Collection

A Trimble GeoXH GPS unit equipped

with a Zephyr Antenna was used for data collection in this report (Figure 14). The combination of the GPS unit with the antenna allowed for sub-millimeter phase center accuracy and provided low multipath, low elevation satellite tracking for enhanced data collection under dense tree cover.

Figure 14. Trimble GeoXH with Zephyr antenna attachment.

ArcGIS Mobile was used for all data collection throughout this project. In order to deploy an ArcGIS Mobile application on an equipped GPS unit, a map service created using ArcGIS Server was first created in ArcMap. A basemap was created with trail and park boundary layers and was saved as a map service document (MSD) in ArcMap. The MSD as well as the GDB created for data collection was placed on a MNDNR GIS server.

ArcGIS Mobile Project Center desktop software was then used to access the MSD and the GDB in order to alter cartographic representations, field name displays and labeling. ArcGIS Mobile streamlines data collection techniques and processes and allows application developers to limit user controls. The ArcGIS Mobile data collection process used throughout this project is illustrated in Appendix A.

For locational accuracy needed in this project, 'Stream GPS Position' was used for all line and polygon data. GPS Settings were defined in ArcGIS Mobile Project Center software. GPS Quality Filter Settings were set as follows:

- Required Fix Type: Fix
- Maximum PDOP: 6
- GPS Average Settings:
    - Minimum Positions: 5
    - Auto Stop When Reaching Minimum Positions
- Streaming Mode:
    - Time
    - Enter Time (seconds): 1

Data collection occurred during summer months, specifically between June 1 and August 31, to ensure consistency in vegetation analysis during park visits. Throughout the course of three summer months, data collection took place at a sample of twenty-one Minnesota state parks.

Hand written notes were taken during site visits for observations not pertaining to database values. Reliable and consistent site visit notes were ensured by one person conducting assessments and collecting data at all sites throughout this research. Photos were also taken at most sites and were referenced by state park name and the geocache unique ID value, derived from the MNDNR's geocache database.

Finally, collected data were synced to their geodatabase on the GIS Server by connecting the Trimble GeoXH to the desktop computer through the ArcGIS Mobile software.

Statistical Analysis

Statistical tests were performed on collected data to analyze if the independent variables had effect on the dependent variable (impact). Prior to this analysis a list of research questions was formulated. Questions included:

1. Is impact associated with park attendance?
2. Is impact associated with online logbook entries?
3. Is impact associated with vegetation at cache location?
4. Is impact associated with cache owner (private citizen, or MN DNR)?
6. Is impact associated with 'demo' state parks, offering free GPS unit rental to visitors?
7. Is impact associated with geocache distance from trail?
8. Is impact associated with surface type at cache locations?

Pertaining to these research questions, data were obtained from the sources specified below. Park attendance data was derived from the MNDNR attendance database which was based on 2009 total attendance values. Online logbook entries were calculated based on date of existence and individual online logs from geocaching.com as of October 20, 2011. Average number of online logbook entries per year was drawn from this data. Vegetation at cache locations was obtained from MNDNR's State Park Landcover GIS layer; System Group attributes were queried for this analysis. Cache owner data was obtained from the MNDNR geocache database. Demo parks include all state parks offering GPS unit rental to visitors free of charge. This information was obtained from internal MNDNR park reports. Distance from trails was calculated using ArcGIS utilizing the MNDNR State Parks Trails and Roads layer. Detailed steps to achieve distance results were described in suitability modeling section of this report. Surface type was manually collected at each cache site and was based on the following criteria: hardened surface defined as gravel or paved ground, use area defined as public use area including but not limited to picnic, beach, playground areas and natural area defined as any area not categorized as hardened surface or use area.

Pearson's Chi-Square test was the primary statistical test used in this report due to its common use for testing significance of the relationship between categorical values. Prior to analyses all data was attributed categorical numerical rank values in GIS using a natural break algorithm to classify variables. These natural break derived categories are defined in Table 1.

Results

Suitability Modeling

Completion of the suitability model highlighted areas at Itasca State Park with a high likelihood of impact from geocaching based on the calculated ordinal variable values defined in the suitability model.

Distance from trails, soil, and vegetation types were considered in this calculation. See Appendix B for suitability model architecture in ArcGIS's Model Builder.

Suitability modeling of geocache locations within Itasca State Park provided visual outputs highlighting likely locations of high impact based on defined variables in GIS (Figure 15). A shapefile of current geocache locations overlayed with the suitability map showed existing cache locations to be in areas of low to moderate likelihood of

Variable	Attribute	Categorical Value	Numeric Category Rank
Distance From Trail (feet)	0 - 13.3	Very Near	1
	13.4 - 45	Near	2
	45.1 - 93.7	Moderate	3
	93.8 - 100.9	Far	4
	101 - 923	Very Far	5
2009 Park Attendance	14,311 - 48,781	Low	1
	48,782 - 53,627	Medium	2
	53,628 - 174,725	High	3
	174,726 - 912,718	Very High	4
Vegetation at Cache Location	Developed Area		1
(based on System Group)	Non-Natural Community		2
	Other Natural Community		3
	Unclassified		3
	Upland Forests and Woodlands		3
	Upland Grassland, Shrublands, and Sparse Vegetation		4
	Wetland Forests		5
	Wetland Grasslands, Shrublands, and Marshes		5
Online Logbook Entries	0 - 34.8	Very Low	1
(average entries per year)	34.9 - 54.8	Low	2
	54.9 - 99.6	Medium	3
	99.7 - 177.1	High	4
	177.2 - 267	Very High	5

Table 1. Categorized datasets, based on natural breaks algorithm.

impact. Results from this analysis support conclusions that current cache locations in Itasca State Park are located in areas of low impact based on defined vegetation, distance from trails, and soil erosion variables.

Statistical Analysis of Collected Data

Alpha value outputs of Pearson's Chi-Square test were analyzed in this study. Any alpha value less than or equal to .05 constituted a statistical significance. A statistically significant alpha value supports an existence of a relationship between the two variables being tested. All Pearson's Chi-Square tests compared the dependent variable (impact) with an independent variable (online logbook entries, demonstration park, park attendance, etc.) to test for relationship. The expected count is calculated for each combination of variable categories (e.g., Impact = 4, Surface = Hardened) and is derived from a normal distribution assuming the two variables are independent. The observed count is then compared to the expected count during the Pearson Chi-Square analysis to determine if there is a significant difference. An expected count of less than 5 in 20 percent or more of cells can lead to inaccurate test results due to small sample size. Impact was initially calculated and classified based on total square feet of impact at each geocache location using a natural breaks algorithm to classify impact into 5 classes. See

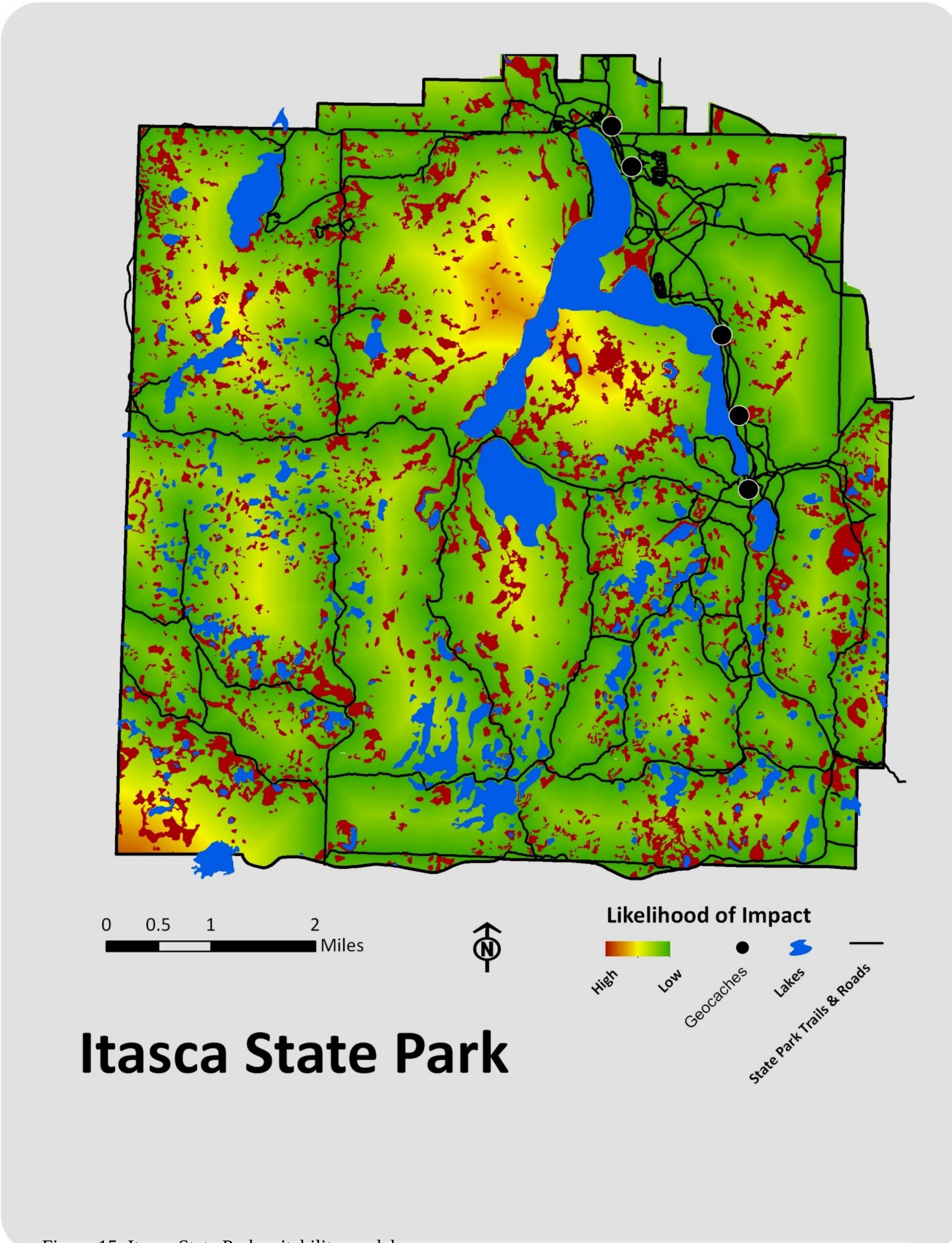

Figure 15. Itasca State Park suitability model

Table 2 for classifications.

Table 2. Ordinal impact rank scale based on total impact ft^2, determined by natural breaks.

Defined Impact Rank	**Total Impact (ft^2)**
0	0
1	1 – 29
2	30 – 71
3	72 – 133
4	134 – 324
5	325 – 532

For all tests performed in SPSS, impact variables were collapsed to meet requirements of the Chi-Square test parameters. Impact ranks were re-coded as follows: (0 = 0), (1, 2 = 1), (3, 4, 5 = 4). See Table 3 for collapsed classifications.

Table 3. Collapsed impact rank scale based and total impact ft^2.

Collapsed Impact Rank	**Total Impact (ft^2)**
0	0
1	1-71
4	72-532

Three major findings were concluded in this report:

1. Impact is associated with surface type
2. Impact is associated with cache owner
3. Impact is not associated with any other variables tested

Impact Is Associated With Surface Type

Results of Chi-Square testing between impact and surface type can be seen in Table 4.

Correlation is apparent between impact and surface type categories. SPSS outputs conclude less impact occurs at hardened surface and use areas, while the majority of impact collected results in natural areas. Note that in Table 5, 100 percent of zero impact (no impact) values occurred on hardened surfaces, and 78.4 percent in use areas. The highest percentage of collected impact, at a rank of 1, occurred in natural areas.

Table 4. Chi-Square test results of impact and surface type.

	Value	**Degrees of Freedom**	**Alpha Value**
Pearson Chi-Square	64.060[a]	4	.001
Likelihood Ratio	76.990	4	.001

[a].1 cells (11.1%) have expected count less than 5. The minimum expected count is 3.80.

Table 5. Cross tabulation of impact and surface type.

Impact Rank	**Hardened Surface**	**Natural Area**	**Use Area**	**Total**
0	100%	11.1%	78.4%	49.1%
1		51.9%	16.2%	30.9%
4		37%	5.4%	20%
Total	100%	100%	100%	100%

Impact Is Associated With Cache Owner

Analysis of impact and cache owner (MNDNR, or private citizen) show less impact occurring at private citizen sites with the majority of impact collected resulting at MNDNR geocache sites. Pearson's Chi-Square test resulted in an alpha value of .003 which is statistically significant.

Zero percent of cells had an expected count less than 5 which further supports the statistically significant relationship between the two variables.

Impact Is Not Associated With Remaining Independent Variables

Other variables statistically analyzed, including distance from trail, attendance, GPS availability (demo parks), online

Table 6. Chi-Square test results of impact and cache owner.

	Value	Degrees of Freedom	Alpha Value
Pearson Chi-Square	11.816[a]	2	.003
Likelihood Ratio	12.414	2	.002

[a] 0 cells (.0%) have expected count less than 5. The minimum expected count is 10.48.

Table 7. Cross-tabulation of impact and cache owner.

Impact Rank	MNDNR	Private Citizen	Total
0	37	41	78
1	27	7	34
4	12	10	22
Total	76	58	134

logbook entries and vegetation type show no statistically significant correlation to impact collected. Tables 8 through 12 show Pearson's Chi-Square test results and expected frequencies for these variables.

Table 8. Cross-tabulation of impact and attendance.

	Value	Degrees of Freedom	Alpha Value
Pearson Chi-Square	3.382[a]	6	.760
Likelihood Ratio	3.454	6	.760

[a] 3 cells (25%) have expected count less than 5. The maximum expected count is 3.61.

Table 9. Chi-Square test results of impact and distance to trail.

	Value	Degrees of Freedom	Alpha Value
Pearson Chi-Square	.743[a]	4	.946
Likelihood Ratio	.751	4	.945

[a] 0 cells (0%) have expected count less than 5.09. The minimum expected count is 5.09.

Table 10. Chi-Square test results of impact and demonstration parks.

	Value	Degrees of Freedom	Alpha Value
Pearson Chi-Square	1.726[a]	2	.422
Likelihood Ratio	1.732	2	.421

[a] 0 cells (0%) have expected count less than 5. The minimum expected count is 10.51.

Table 11. Chi-Square test results of impact and vegetation type.

	Value	Degrees of Freedom	Alpha Value
Pearson Chi-Square	6.750[a]	8	.564
Likelihood Ratio	6.865	8	.551

[a] 5 cells (33.3%) have expected count less than 5. The minimum expected count is 2.30.

Table 12. Chi-Square test results of impact and online logbook entries.

	Value	Degrees of Freedom	Alpha Value
Pearson Chi-Square	7.515[a]	4	.111
Likelihood Ratio	8.110	4	.088

[a] 1 cell (11.1%) has expected count less than 5. The minimum expected count is 3.42.

Discussion

SPSS analysis outputs support the conclusion that surface type (Hardened Surface, Use Area, or Natural Area) and geocache owner (Private Citizen, or MNDNR) show significant correlations with impact collected at geocache locations. Other variables statistically analyzed, including distance from trail, attendance, GPS availability, logbook entries, etc. show no correlation to impact collected. Insignificance could theoretically be due to time of data collection, environmental factors at time of data collection, and categorizing of collected data.

Factors Affecting Data Collection

Data collection took place at twenty-one

Minnesota State Park locations between the months of June and September, 2011. Between July 1 and July 20, 2011, the Minnesota State Government Agencies shut down due to a budget crisis. All state parks, waysides and recreation areas were mandated to be closed for the duration of the shutdown, at which time all geocache locations within Minnesota's state parks were temporarily disabled. Upon re-opening of the parks and reinstallation of the geocaches at their given locations, data collection for this project continued. In the two weeks preceding the government shutdown, 8 out of the 21 State Parks in this project were visited and geocaches were assessed. A factor that possibly hindered accurate data collection following the shutdown was overgrown vegetation due to the lack of maintenance at the parks during the shutdown. Another factor that may have affected collected impact is the lack of total impact due to cache removal during the shutdown. Visiting state parks was discouraged during July 1 through July 20. Park gates were locked and park staff personnel were off duty.

Further, flooding occurred at two of the highest attended parks visited during this study, Fort Snelling and Nerstrand Big Woods State Parks. Geocaches existed at both of these parks in the direct flood zone. In these areas, impact was indistinguishable, since silt and mud had been carried and deposited across most of the vegetation in assessment areas.

Finally, the system used to categorize and rank collected data may have affected analysis outputs. Using GIS to obtain natural breaks in the data was one of several categorical outputs that may have been used in this study. Unless a further analysis of categorizing data is performed, it will remain unknown how this system of data ranking has affected the collected data of this project.

Further Research

Based on the findings and results of this study, a few recommendations on further research have been made.

Statistical analysis would be stronger with a larger sample size. Trends in significance may be observed between a few of the variables in a Pearson's Chi-Square analysis and may have been strengthened with analysis of a larger number of geocache sites.

The suitability model used in this research did not incorporate the two statistically significant variables found in analysis of collected data. This was due to the fact that it was not feasible to model this data in GIS as a coverage. Surface type was collected at each cache location while cache owner is an attribute that exists only at geocache sites. Thus, the model used incorporated layers based on similar studies conducted in peer reviewed journal articles. Further research in suitability modeling, specifically in ordinally ranking vegetation and soil data in Minnesota and incorporating additional input datasets, may enhance the final suitability map output.

Conclusions

In conclusion, both GIS and statistical analysis of collected and existing data throughout this project has shown two variables statistically effect geocaching within visited samples of Minnesota's State Parks. These variables are geocache program type (DNR or private citizen owned) and ground surface type at geocache locations.

Taking these factors into consideration when managing geocaches may significantly lower detrimental impacts to the environment in which the geocache is placed. Ground surface and locational analyses must be taken into consideration from a management standpoint within Minnesota state parks.

Statistical calculations provided few significant results when determining independent variables correlation to the dependent variable in this study. A larger sample size could alter results of a statistical analysis. Considering the small sample size in this project (118 sites visited) many of the statistical analyses employed exhibited data errors due to small sample size. This may explain why so few variables had significant affect on the statistical analysis of data in SPSS.

A conclusion can also be drawn that the majority of geocaches within Itasca State Park exist in locations with a low likelihood of impact. Park staff and natural resource managers who placed caches were aware of policy to avoid impacts to natural resources and carefully selected cache locations based on this policy.

Through comparing results of the suitability analysis with statistically analyzed collected data, it can be concluded the suitability model used in this research is not an exact representation of location of impacts caused by geocaching within Minnesota state parks. The suitability model defined in this study could potentially be used in defining suitable areas for geocache placement within Minnesota's state parks if a lack of time or funding was preventing further study on this topic.

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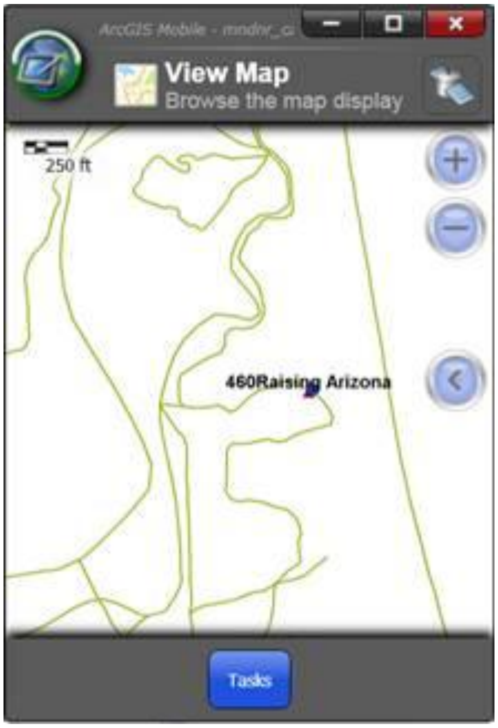
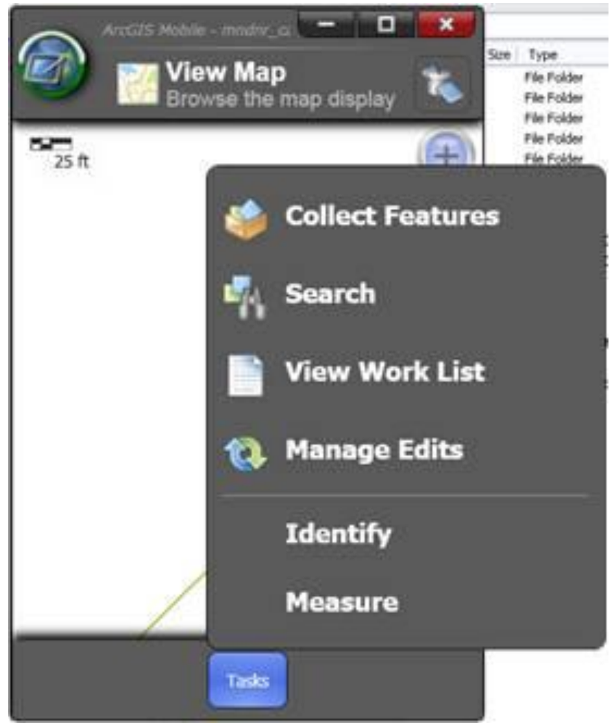
Appendix A. ArcGIS Mobile Workflow.

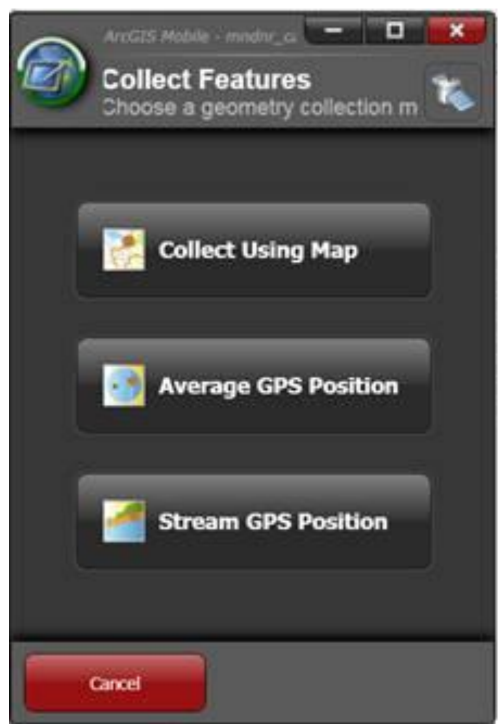


Step 1. ArcGIS Mobile, map view.



Step 2. ArcGIS Mobile, tasks.

Step 3. ArcGIS Mobile, collect features (domains).

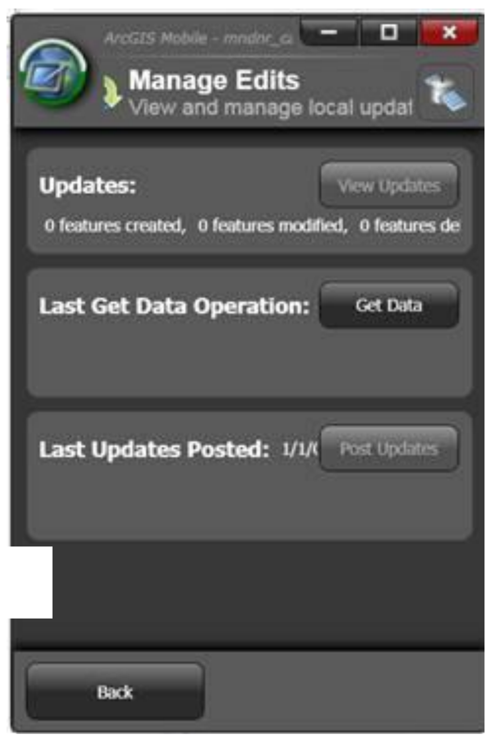


Step 4. ArcGIS Mobile, collect features, options.

Step 5. ArcGIS Mobile, collect features, options.

Step 6. ArcGIS Mobile, collecting attributes manually.

Step 7. ArcGIS Mobile, collect features, by defined domains.



Step 8. ArcGIS Mobile, managing edits; syncing to server.

Appendix B. Suitability Model Workflow