An Evaluation of the Inventory and Monitoring Program Isle Royale National Park, Michigan

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I. Introduction

A. Overview of Park Inventory and Monitoring Objectives and Program

Isle Royale National Park is, because of its isolation from modern human development and its relatively undisturbed character, ideally suited for long-term monitoring of biogeochemical and physical processes in the ecosystem and the effects of anthropogenic pollutants on those processes; similarly it is well suited for research into basic biological processes as well as studies of landscape level or mesoscale changes. As a large, isolated island ecosystem, it possesses a unique flora and fauna, including many species which are threatened, endangered, or distant outliers from other populations. It is one of the few national parks dominated by boreal forest, and of those has had the most research conducted to date.

The park has a long history of research, and park management has long recognized the need to systematically collect physical and biotic data in order to monitor changes in the Isle Royale ecosystem. Prior to the initiation of the NPS Inventory and Monitoring initiative in FY88, many data sets had been set established. Nevertheless, limited staff and resources had made it difficult to follow through on many of the identified needs -- including both initial collection of data (inventory) to determine the current status of a particular ecosystem element; and systematic cyclic monitoring to establish trends and document changes.

B. Summary of Funded Projects (model program)

Isle Royale National Park was one of eight parks approved for I&M funding in FY88, receiving $86,000 that year and then another $25,000 in FY89. An additional $5,000 was received in FY90 for report preparation. Funded projects emphasized those which synthesized and enhanced existing spatial and temporal data sets. At least one product (the permanent plots database system) which was developed at Isle Royale will be readily usable in other park units. The lessons learned at Isle Royale through the implementation of this I&M program will provide benefits to many other NPS areas as they develop their I&M efforts.

The three funded projects were:

(1) Permanent Plots
(2) GIS Database Construction
(3) Ecosystem Modeling

These projects will be discussed and evaluated in detail in chapter II of this report.

A summary of the I&M awards and projected distribution (when we began) appears in Table I.

Table I

Summary of I&M Awards and Projected Distribution

Year/Project	**Award**
FY88	
Permanent Plots Project	$30,000
GIS Project	20,000
Modeling Project	30,000
Unspecified	6,000
FY88 Summary	86,000
FY89	
GIS Project	25,000
FY90	
Report Preparation	5,000
Total/All Projects FY88-90	**$116,000**

C. The Park I&M Program - Other Than the Model Projects

All of the funded model I&M projects were highly technical, data-oriented projects whose aims were to capitalize on previously existing information about park resources which had never been synthesized. With the exception of the permanent plots project (which involved visiting and relocating existing research sites in the park), there was no fieldwork involved. Most of the work was accomplished indoors, far from the park resources themselves.

This type of work is critically important in order to keep each generation of park managers and researchers from "re-inventing the wheel"; it should allow us to build on resource information that has been learned (inventoried and/or monitored) over a long period of time. But it is of little value without a parallel program of labor-intensive physical and biological inventory and monitoring -- the traditional type of science in the parks.

Recognizing this, the park funding proposal in FY88 had included four less glamorous but no less important projects of the more traditional variety:

(1) Fisheries baseline survey
(2) Rare plants survey
(3) Post-fire monitoring
(4) Automated climatological monitoring

None of these were funded as part of the model program. Fortunately, the last two projects received enough funding from other sources to begin in FY90, and it looks as though at least some of the fisheries work may begin in FY91. One additional project (Data Automation) in the FY88 proposal was both "high-tech" <u>and</u> labor intensive. Most of the "unspecified" funds awarded in FY88 went toward this project, but the park has never been able to fund staff to accomplish its tasks systematically. Considering that, the park has made good progress establishing resource-related databases, automating data archival of existing information in the context of other workload.

Prior to 1988, the park never used the phrase "Inventory and Monitoring." Nevertheless, when added together it would appear that we have a fairly extensive program of regular resource monitoring already in place, primarily focused on key wildlife species. The nature of these activities has never been systematically planned, catalogued, nor critiqued. until now. The scope of these activities (including data automation aspects) will be summarized in Chapter III of this paper, but a more complete plan and analysis will await another effort, sometime in the future.

II. Funded Projects (Model Program)

A. <u>Permanent Plots</u>

1. <u>Objectives</u>

Isle Royale has benefitted from many studies which were based on study plots located throughout the park, beginning with the classic work of W.S. Cooper more than seventy years ago. The objectives of this project were to:

(1) Compile and catalog quantitative and replicable information on vegetation plots previously established by various researchers. This information would include location data as well as particulars for each project and the data collected using the plots.

(2) Develop a computerized database management system to store, analyze, and retrieve this information which can serve as a prototype for other NPS areas.

(3) Establish standards for marking both permanent and temporary plots, including "criteria for permanence," a field marking scheme, and a plot identification, numbering, and nomenclature system.

(4) Physically relocate and mark as many plots as possible in the field, and test a Loran-C navigation system for recording and relocating plot locations.

(5) Institutionalize this system so it will be in place and usable for future research projects, so that future work can capitalize on previous work.

(6) Establish a park research archive to permanently curate/store original (and possibly computerized) data and field notes from important research projects.

The project was conducted as a cooperative venture between Isle Royale National Park and NPS Cooperative park Study Unit (CPSU) at Michigan Technological University (MTU). The project administrator was park Natural Resource Management Specialist Robert J. Krumenaker, although the investigator of record was Dr. Robert Stottlemyer of the CPSU. Christian J. Martin was hired as a Research Associate to oversee the details of the project and conduct the initial research. When Mr. Martin resigned, he was replaced by Stephen M. Fettig, who finished in that role. Both Mr. Martin and Mr. Fettig also worked for the NPS as Park Rangers or Biological Technicians when they were not on the MTU payroll.

2. Methods

We began by searching the park's library and resource management files to establish a catalog of previously established study sites on Isle Royale National Park. Whenever possible, we contacted the researchers directly for more information. Libraries at the University of Minnesota and at Michigan Technological University were also used. We then prioritized the study areas on the basis of their likelihood of being re-located: Those areas most likely to be found were re-located first.

Using written directions from each researcher (as well as the researcher's help in the case of Robert A. Janke), a 2-3 person field crew located (in the prioritized order) as many individual plots as time allowed, making corrections to the directions as needed. We re-measured and confirmed distances and compass bearings to prominent geographical features at each site. The field crew recorded all updated information onto permanent plot data base field data sheets (see Figure A-2 of Appendix A). These data sheets were completed in accordance with the definitions in the Data Dictionary for the Permanent Plots Database (see Appendix B). Technicians added hand-drawn maps and narrative descriptions to the field data sheets whenever there were locations without obvious landmarks.

The field crew used a SI-TEX brand Loran-C receiver[1] to georeference ground locations and increase the likelihood of relocating each plot or plot group over the long term. We recorded plot locations in latitude and longitude, as well as in lines of positions (LOPs). The Loran-C receiver was powered by two 6-volt lantern batteries wired in series with the ground terminal wired to the negative pole of the batteries. Technicians carried the unit in a waterproof plastic case with a protective foam interior along with a detachable, eight foot marine-style antenna which was re-attached at every site.

At sites where the original plot marker was a plastic or wooden stake, field crews replaced the marker with a 65 cm (24 in) long, 6.35 mm (0.25 inch) diameter steel rod with the top portion painted orange. If the substrate prevented exact positional replacement, technicians measured the displacement and bearing from the original marker, recorded the resulting vector in the narrative on the field data sheet, and left the original marker in place. When a metal stake was already there, workers left it in place.

Field workers attached a National Park Service identification tag to each metal stake. The first tags used in the project had a paper layer between two thin aluminum layers.[2] Technicians hand-inscribed the NPS identification code into each three-layer tag.

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[1] Model EZ-97 from SI-TEX Marine Electronics, Inc. P.O. Box 6700. Clearwater, Florida. 33518. Telephone: 813/535-4681. We paid $683 for this model, with antenna, in 1988 from a discount marine equipment catalog. This specific model, normally mounted on the dashboard of a boat, is no longer available, but prices have decreased while quality has increased in the last few years. Hand-held models are available from several manufacturers in 1990. These have not been tested at Isle Royale but would seem to have much promise for this type of terrestrial application.

[2] Stock number #79271 from Forestry Suppliers, Inc., 205 West Ranklin Street. Jackson, Mississippi 39284-8397. Telephone: (601) 355-5126.

Later in the project, much sturdier 3.81 cm by 8.89 cm by 0.813 mm (1.50 in by 3.50 in by .032 in) solid aluminum tags were used.[3] These tags also bore the National Park Service arrowhead emblem and the words "NPS RESEARCH -- Please Do Not Remove" (see Figure A-1 of Appendix A). Technicians stamped the NPS identification code into these solid aluminum tags using a die set. The numbering system and nomenclature for the National Park Service plot identification codes is described in Appendix A.

Simultaneously with the compilation of field notes, we constructed a database using dBase III Plus software. When the first field season ended, the location information was input into the data base and edited. As the final phase of the project, we programmed user-friendly menus, data-entry screens, and reports (creating a database management **system** -- see chapter II.A.3.c) to make it easy to use. We started the planning to construct two additional databases that would be related to the plots database: one for research projects and one for keywords (the data from both will come from the research catalog and other sources). The completion of this phase will await additional funding and/or staff resources.

3. Results and Discussion

a. Research Catalog / Field Work

Our catalog of previously established Isle Royale studies lists 23 investigators with summary information concerning their research plots.[4] Plots established by Peter A. Jordan, Robert A. Janke, and Janice M. Glime were chosen as the highest priority sites for permanent marking.

We re-located one hundred ninety (190) plots established by Peter A. Jordan. He had established his plots with the intention of re-finding and re-sampling them over a long period of time, and, in many cases these plots are still clearly marked after nearly 30 years without a visit. He used 60- to 90-cm angle irons with the top several centimeters painted red or orange, which provide

[3] Available from Pan Nam Imaging. 18531 South Miles Road. Cleveland, OH 44128. Telephone: 800/229-0049 or 216/475-6204.

[4] This catalog, compiled by Chris Martin, is filed in the Natural Resource Management Office of the park. Disk copies can be distributed upon request.

a flat surface and some color for which to visually search. These markers were very visible except in thick brush (such as in alder [Alnus sp.] swamps) or young stands of balsam fir (Abies balsamea) where no stake would be visible until a technician was only one to two meters away. Because of the re-locatability of Jordan's markers, his system was deemed the best for Isle Royale in most boreal forest situations.

We found ninety-five (95) of Robert A. Janke's plots. All the remaining unlocated plots have a very low likelihood of being found. Janke's plots were established 10 to 20 years ago with the intention of using them for only a few years, with no attempt being made to mark them in a long lasting manner. Much of the originally marking scheme used tree flagging and 20 to 30 cm long, orange, plastic tent stakes or short wooden stakes. In addition, field notes written by students frequently contain poorly documented plot locations. In other cases, all signs of the plots were gone due to the passage of time, accumulation of litter, falling of trees, and activity of moose.

Plastic tent stakes, although seemingly convenient to transport and use, are actually quite ineffective for marking plots for decades of use. Being very low to the ground, they become nearly impossible to find after green foliage appears in the spring and are easily concealed by thick herbaceous ground cover or the accumulation of forest litter. They also become brittle with age and exposure to temperature extremes and eventually break. Once broken, the stakes easily become displaced or lost. Thus plastic tent stakes are an untenable option for permanently marking research plots.

Throughout the project, the field crew used steel rods to replace any plastic tent stakes or wooden plot markers. Although this marking system was an improvement, we found that it still does not make plots nearly as re-locatable as with Jordan's system of using angle irons. Because of their rounded nature, silver-colored metal rods are hard to find when searching in stands of young firs. The thin rods blend into the visual jumble of stem and twigs, making relocation nearly impossible at times.

Thirty (30) bryophyte plots used by Janice M. Glime were re-located. She marked her plots using a former NPS marking standard employing 10-cm (4-in) square aluminum plates which rest on the ground and are held in place by short metal rods. Each rod rises to a height of 10 to 20 cm (4 to 8 in) above the ground. These markers are visible only from a short distance away and required very specific directions (compass bearings and measured distances) to be found.

The inexpensive three-layer tags used early in the field season had the advantage of being easy to write on. However, because of the glue used to keep the layers together, the tags became a favorite chewing item for red foxes (Vulpes vulpes) and other wildlife. At most plot the tags were chewed within just a few weeks of their emplacement. In most cases this left the tags completely mutilated. In addition, once these three layered tags became water soaked the layers separated. These problems were solved by using a thicker, one layer metal tag. More durable than the three-layer tags, the current tags appear to be working well.[5]

b. Loran-C

Loran is an acronym for LOng RAnge Navigation. Loran-C navigation technology uses timed low frequency (100 KHz) radio pulses from shore-based transmitters to determine a receiver's position.[6] (On the Great Lakes Loran-C navigation uses transmitters in four locations: Dana, Indiana; Malone, Florida: Seneca, New York; and Baudette, Minnesota.) Because these low frequency pulses follow the earth's surface and travel at a constant speed over water, a time/distance relationship is established. Inland areas can also be used. However, topographic relief may modulate the propagation time and therefore effect the accuracy of the results.

The set of all points having a particular delay time (and therefor distance) from a transmitter is call a line of position (LOP). The propagation of the radio pulses over the surface of the planet causes all LOPs to be very large hyperbolas. The distance per time-separation (gradient) between LOPs changes over the broadcast area because the geometry of hyperbolas with a common focus. With the gradient at Isle Royale, and

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[5] The price difference is substantial, however. The original tags (Forestry Supply, Inc., see footnote 2) cost $0.23 each ($22.25 for 100 tags); the custom replacements (Pan Nam Imaging, see footnote 3) cost $1.58 each plus a one-time graphic arts set-up charge of $56.28. The total was $846.28 for 500 tags.

[6] SI-TEX. 1987. Loran-C receiver model EZ-97: installation and operation manual. Marine Electronics, Inc. Clearwater, FL. 2 pp.

with six digit Loran-C display with 0.1 microseconds (millionths of a second) being the smallest displayed unit, there is an accuracy limit of 18.3 m (in the northwest-southeast axis) from the Baudette, MN transmitter and 32.1 m (in the southwest-northeast axis) from the Seneca, NY transmitter. This can be visualized as a parallelogram of uncertainty centered on each Loran-C readout point and oriented according to the LOPs. For latitude and longitude positions the parallelogram of uncertainty is one-hundredth of a minute of latitude by one-hundredth of a minute of longitude, namely 18.6 m by 12.4 m of Isle Royale, respectively.

The ability to return to a specific position is known as repeatable accuracy. Under optimal conditions, repeatable accuracies of 12 to 18 m (40 to 60 ft) may be obtained in areas were the lines of position area are nearly perpendicular.[7] For land areas in Rhode Island less than 16 km from the coast, Patric et. al. determined repeatable accuracy was 35.5 m +/- 21.2 m (115.4 ft +/- 69.0 ft).[8]

The repeatable accuracy of Loran-C was not determined for Isle Royale, although based on the experience of the field crew, the repeatable accuracy is likely near that measured by Patric et. al.. This means that Loran-C will only return a researcher to the general area of a research plot. Once in the area some visible marker is needed to direct a researcher to the specific plot location. Without a visible marker, a local area map is needed.

The Loran-C produces valuable visual alarms.[9] These take the form of blinking colons, decimal points, and other display panel features. They indicate when the currently displayed position may not be correct due to a high signal to noise ratio or problems in receiving a signal from the master and/or a secondary transmitter station. In the field this is an extremely helpful and

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[7] SI-TEX, p. 12.

[8] Patric, E.F., T. P. Husband, C. G. Mckiel, and W. M. Sullivan. 1988. Potential of LORAN-C for wildlife research along coastal landscapes. Journal of Wildlife Management 52(1):162-164.

[9] SI-TEX, pp. 28-50.

time saving feature and helped to prevent technicians from recording error filled data.

Visual alarms alerted the permanent plots field crew to many Loran-C readouts which should be questioned (these are noted in the narrative fields of the pertinent data base records). The alarms also led to the discovery of broken wires in the antenna mount due to twisting of the mount in relation to the antenna cable. In the future field use of the portable Loran-C setup, it will be important to prevent this relative twisting from occurring. This can be done by forming an "s" loop in the antenna cable near the antenna mount, then taping the loop to the mount.

A small number of transects and plots were visited twice in the course of the field work in order to complete work in an area. Based on these return visits, the field crew found that in shoreline areas where there were clear points of reference (small rock islands, distinctive promontories, large shoreline boulders, etc.) using good notes, a tape measure, and a compass worked better than the Loran-C technology. However, in areas without good landmarks or with thick vegetation which prohibited taking compass bearings, the Loran-C was a helpful tool for reaching the general area. However, once to the general area some searching was needed and descriptive notes were helpful. Thus, detailed location description will always be useful whether in conjunction with the Loran-C is or not.

Many plot locations descriptions start from a designated park trail. Since trails are occasionally moved by park managers, all transects or plot groups should have at least one Loran-C location recorded in order to help in re-locate the area in the event that a key trail is moved.

To each plot we assigned an NPS plot identification code using the standards in Appendix A. Beyond these standards, we use a code similar to the researcher's own code whenever possible. For example Janke's Card Point plot CP-9-B was given a NPS plot code JRA-209-002 and his plot CP-11-C was given a NPS code JRA-211-003 where the 200 series in the transect number means the transect is at Card Point. Other noteworthy transect numbers are listed below:

Transects NPS-100 are Stanley Ridge burn plots.
Transects JRA-200 through JRA-214 are Robert A. Janke's Card Point burn plots.

Transects JRA-300 through JRA-304 are Robert A. Janke's McGinty Cove burn plots.
Transects KLW-001 are moose exclosures established by Laurits W. Krefting.
Transects SPC-001 through SPC-003 are photo points established by Philip C. Shelton.

c. <u>The Database Management System</u>

The Permanent Plots database system, as previously mentioned, was written in dBase III Plus. Field descriptions appear in Appendix B to this report. Unfortunately, it is difficult to describe in a report the way a program or system operates, and dBase does not permit screen graphics to be written to a file so they can not be reproduced here as the user would see them. Nevertheless, we will attempt to describe the way the system operates; dBase must be loaded on the user's computer but s/he need not be a particularly experienced user to add, edit, or report data in the system.

A schematic of the main menu of the system, which appears upon entering, appears in Figure 1.

Figure 1
Main Menu

```
Permanent Plots/Research Databases
  park name

   1.  Permanent Plots
   2.  Research Projects

   6.  Customize System
   7.  Backup Files to Diskette
   8.  Exit to dBase III+
   9.  Exit to DOS

           select __
```

Note that the *park name*, here designated in italics, appears on each menu. It is customized for each installation by choosing #6 on the main menu. Note also that the system is designed to expand; some menu choices are blank and some others (e.g. #2, Research Projects) will generate a **"Not Implemented Yet"** message.

When the user selects #1 (permanent Plots), s/he is greeted with the menu shown in Figure 2.

Figure 2
Second Level Menu

```
Permanent Plots Database
  park name

     1.  Add New Plot Records
     2.  Browse Items (In Groups)
     3.  Print Reports
     4.  Edit Plots (Complete Records)
     5.  Edit Plots (Narratives/Locations Only)

     8.  Reindex Database
     9.  Exit to Previous Menu

         select __
```

The reports menu is shown in Figure 3. Program files, sample reports, and a working disk version are all available upon request.

Figure 3
Third Level (Reports) Menu

```
Permanent Plots Database Reports
  park name

     1.  All Plot Data, For All Plots, One Per Page
     2.  All Plot Data For a Single Plot
     3.  Locations/Marker Summary Table
     4.  Plot ID and Narratives Only
     5   List of Plots Requiring Monitoring

     9.  Exit to Previous Menu

         select __
```

4. Funding

This project required a tremendous amount of searching old files, field work, data entry, and oversight. It shouldn't be surprising, then, that the vast majority of money spent was on people. This was one of those classic projects that could have been best done (or perhaps only done) by park staff, yet the nature of the funding required that we channel the money through a university. We were fortunate to be able to establish a good relationship with the Biology Department and Research Services Office at MTU -- particularly after the NPS decided to shut down the CPSU there. The price of this arrangement, of course, was the university's indirect costs (overhead), which were necessary but unproductive since none of the work was done at the university.

The total cost of the model project (not including NPS funds expended for salaries of Isle Royale's Natural Resource Management staff) exceeded the original estimates. The difference was made up by the lower cost of the Modeling project (Chapter II.C). A summary of the estimated project costs appears in Table II.

Table II

Budget Summary: Permanent Plots Project

Permanent Plots (ESTIMATED COSTS)	**MTU**	**NPS**	**TOTAL**
Research Associates	$11,352		
Consultant	2,419		
Field Technicians	5,797	260	
Plot tags/stakes	1,070		
Other supplies	842		
Travel	862		
Computer Software	85	599	
Laptop Computer Hardware	2,995	504	
Loran-C unit		683	
University Overhead	5,607		
Project Summary	**$31,029**	**2,046**	**33,075**

5. Evaluation of the Success of the Project

a. Degree of Completion/Future Plans

We accomplished all of the objectives we set for ourselves in this project, except for the establishment of a research archive. We still hope to accomplish that task, working with the archive library at Michigan Technological University.

Standards for marking and numbering plots are in place and the system for transferring information from the researcher in the field to the NPS is established, if not yet "institutionalized."

There are currently 447 records in our permanent plots database, representing all the plots and transects we located in one and a half field seasons. The information on these plots is complete, though some records may require some editing for spelling, capitalization, etc.[10] The database will continue to be updated as we relocate other plots and return to the same ones again.[11] To address the backlog of work and keep up with the expected increase in park research activity, maintaining the permanent plots system --in the field as well as on the computer-- will need to be a key task of a summer biotech on the park staff (a job which currently does not exist). We need to set up a re-visit rotation schedule for all plots, perhaps as often as every five to ten years.

The database management system works well, though it needs refinement; a skilled dBase programmer could improve the program flow and add several enhancements which we desired but didn't have either skill or time for.[12] The research projects database needs to be fully implemented; the information for this database will come largely from the research catalog already compiled. We foresee a keywords database as well, to

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[10] Especially Jordan's plots ≥ Transect 016.

[11] Field priorities for the near future include locating more plots established by Jordan and Glime. These can probably best be done with their assistance. Shelton's photo points need to be located and better documented. This will <u>require</u> his assistance. We also want to finish setting up NPS post-burn plots on the Stanley Ridge. We need to consider how to document David Smith's chorus frog study pools before the study ends.

[12] These include:
-Instituting a default UTM zone in data entry
-Improving the printer codes for non-Epson printers
-Consider changing "other" fields to same # of characters
-Adding a "pack" option with security password to PLMENU2
-Programming look-up or pull-down lists for data entry of fields with defined choices
-Adding an ESC clause to bail out of a long report and several other places
-Compiling the entire program in Clipper, to make it independent of dBase

facilitate searching when the investigator is not known by name. All three databases will be relationally linked together.

One important data management enhancement that needs to be added to our system is the capability of scanning field maps and diagrams and adding these graphically to the plots database.[13] We are currently keeping all field data sheets and many of these have hand-drawn maps whose salient features we have attempted to describe -- but the pictures themselves, in the database, would be far more useful.

b. Standard of Quality

The literature search we conducted is complete and thorough. Narrative descriptions of plot locations in the database are generally adequate for relocating and describing the plots. Data that's in the system is of high quality except for Loran-C locations, all of which should be verified.

We learned many lessons in our field work and our techniques improved as we went along. That means, of course, that plots visited in 1989 need to be revisited to replace tags with the new, improved version that we used in 1990.

The Loran-C system was not as successful as we had hoped; if we continue using it we need to quantify the error, similar to Patric's work in Rhode Island. Wiring problems with the antenna system plagued our field technicians throughout the 1989 season, and we did not detect and fix the problem until 1990. Unfortunately, all Loran-C numbers recorded in 1989 are suspect.

A better solution for recording field locations already exists, though it is significantly more expensive (several thousand dollars or more). Global Positioning Systems (GPS) can supposedly relocate sites within a few meters, therefore bridging the gap between the field work and the data management system. We will attempt to get a GPS for use at Isle Royale, perhaps to be shared with other parks in the region.

[13] We may need to upgrade the program from dBase III Plus in order to accomplish this.

6. Servicewide Applicability of Project Methods or Results

The plot marking standards, NPS plot tags, and the database system have applicability throughout the NPS system and we would look forward to sharing them with any interested parties. We plan to write an article for Park Science in 1991 describing the project successes.

B. Geographic Information System (GIS)

1. Objectives

Isle Royale National Park staff outlined a comprehensive strategy[14] for developing a Geographic Information System in 1988. Several themes existed at that time in digitized form, though there was considerable variety in format since there had been no direct park involvement in their development.

Having learned some hard lessons by participating in and observing GIS development schemes in other parks, Isle Royale Natural Resource Management Specialist Robert J. Krumenaker, the project administrator, planned on investing 100% of the funds available for GIS on data acquisition and development until such time as the park could support a dedicated GIS operator on staff. We saw no point in acquiring expensive computer equipment to run the system in-house if it had to be done as a collateral duty of existing staff -- it wouldn't work.

The objectives of this project, therefore, were to fulfill the initial <u>data</u> goals of the GIS strategy:

(1) Acquire, convert, and standardize the existing automated themes.

(2) Register and digitize a GIS base map of the park followed by additional key themes of existing non-digital data to make up a nominal GIS database. These "old" maps included at least two historic vegetation maps.

(3) Acquire remote sensing imagery to generate a new vegetation map for the park.

(4) Develop relational attribute databases linked to the GIS for all themes to name and describe the mapped data.

(5) Convert the GIS to the NPS standard GIS software (GRASS) running on a 386 DOS-based microcomputer.

(6) Hold a workshop for park users to become familiar with the contents of the database and how to use it.

All data layers were to meet NPS standards for GIS data.

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[14] This "plan" was actually written as the first project statement in a revised Resource Management Plan for the park.

Some imagery was acquired directly using NPS funds, but the bulk of the funding was transferred to Dr. Ann Maclean, director of the Remote Sensing/GIS Laboratory of the School of Forestry and Wood Products at Michigan Technological University. The "instruments" of transfer were two simple purchase orders, though the close cooperation between the principals suggests (in retrospect) that a cooperative agreement would have been more appropriate.

2. Methods

It was much easier to delineate the project boundary for the Isle Royale GIS than it would be at most other parks: We drew a rectangle around the extreme outlying land areas of the park and included everything inside that line. Hence some parts of Lake Superior are included, although we have no bathymetry or other lake themes at this time. There are no adjacent landowners or other jurisdictions close to the park, since it lies in the middle of the largest of the Great Lakes.

MTU used ERDAS, a powerful PC-based raster GIS and image processing package, to develop the spatial database for the Isle Royale GIS. ERDAS data formats can be converted to GRASS or other formats, so we had no significant concern about data compatibility with NPS standards. Non-spatial attribute data have been compiled on dBase III Plus and will probably be converted to dBase IV to facilitate linkage to the spatial database. ERDAS now has the capability to link this information (in dBase IV) with the spatial thematic data, allowing the thematic layers to be more robust.

Existing digital data was acquired and converted to ERDAS format. Other layers were scanned when feasible, but most layers were added to the database using manual digitizing techniques. Data registration and editing was a key step to assure that all information was georeferenced properly.

While most of the work was performed at MTU, we stationed one technician[15] on Isle Royale during the summer of 1990 to work on the attribute databases in an environment where park staff, library, and archives were constantly available. Since the library and archives stay in the park during the winter (while the staff moves to Houghton and the park is closed and inaccessible), this greatly facilitated information transfer. During this time, additional maps and other attribute information were

[15] Steve Perry.

located which will enhance the usefulness of the GIS but are not part of the current project.

Before completion of the contract at least one park representative will be trained in the use of ERDAS.

3. Results and Discussion

At the completion of the project the Park will have a GIS composed of a minimum of 21 thematic layers. Depending on the accessibility of other digital data, there could be a maximum of 25 thematic layers.

The first phase of the project, completed except for some minor editing in 1990, was devoted almost entirely to data entry of 16 of the thematic layers. These included:

(1) **Base map** - derived from 7 1/2 minute USGS quad sheets on a mylar base. Data was hand digitized from the quad sheets and georegistered to the Universal Transverse Mercator System, Zone 16.

(2) **Government Land Office (GLO) survey boundaries** - all section boundaries were hand digitized from the mylar quad sheets. While this is not the most accurate positioning, it will be sufficient until the section corners can be georeferenced by a global positioning system (GPS). This layer has been extremely useful in screen digitizing several of the data layers.

(3) **Digital elevation model** - purchased from USGS. Scale is 1:250,000. This scale is too large to accurately portray all the needed topographic detail. The park will need to incorporate 1:24,000 DEMs into the GIS when they become available.

(4) **Vegetation cover type map** - the maps were scanned by a high resolution digital scanner. Editing of the data is ongoing.

(5) **Historic vegetation** - hand digitized from a paper line copy. This map is based on the original (1847) GLO survey of Isle Royale in 1847.

(6) **Trails** - hand digitized from the USGS 7 1/2 minute quad sheets on mylar base. Updates from 1990 field notes were transferred to the mylar base and also hand digitized.

(7) **Hydrology** - currently part of the base map. Will become a separate thematic layer before the end of the project.

(8) **Wilderness boundaries** - hand digitized from paper line drawings.

(9) **Beaver sites (1986)** - screen digitized utilizing the base map overlaid with the GLO section lines and referencing to map sheets provided by the park. The park has beaver survey maps from several other surveys since 1960 which will need to be incorporated into the GIS at a later date.

(10) **Wildlife (backcountry management) zones** - hand digitized from paper line drawings.[16]

(11) **Fire history** - hand digitized from paper line drawings.[17]

(12) **Management Zones** - hand digitized from paper line drawings.[18]

(13) **Raptor nest/rookeries** - screen digitized utilizing the base map overlaid with the GLO section lines and referencing to map sheets provided by the park.

(14) **Research sites** - hand digitized from paper line drawings.[19] This information predates the Permanent Plots project.

(15) **Cultural sites and classified structures** - hand digitized from paper line drawings.[20]

The second phase of the project, underway in late 1990 and to be completed by June 1991, is adding the following thematic layers to the GIS:

(16) **Soils** - photo maps are being evaluated to determine if they can be scanned using the high resolution digital

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[16] Park staff had laboriously drawn this and other themes on mylar masters in the early 1980s but these "resource management maps" split the park into two segments and were, unfortunately, not adequately georegistered. This created large editing problems for the MTU technicians.

[17] See above note.

[18] See above note.

[19] See above note.

[20] See above note.

scanner rather than hand digitizing. Data is "brand new," from the just-completed (and not-yet-published) park soil survey.

(17). **Archaeological/cultural sites** - data to be provided by the NPS, from the ongoing five-year archaeological survey. We will take steps to ensure that this data be secured from unauthorized access.

(18) **Permanent research plots** - preliminary data will be taken from paper line maps, with additional information to be provided by the NPS. The Loran coordinates will probably not be precise enough to use in the GIS, despite our intentions. This will be a preliminary data layer, to be augmented in the future, especially if we can use a GPS to accurately locate the plots.

(19) **Moose carcass locations** - Existing computerized data set (to be provided by Dr. Rolf Peterson) consists of locations of over 2000 dead moose found in the park since 1959. Data must be evaluated to determine if it can be georeferenced, since it was developed using an arbitrary grid pattern that follows the axis of the Island.

(20) **An updated vegetation map** - We are evaluating the use of scanned aerial photographs versus Landsat Thematic Mapper (TM) Imagery to generate an updated land cover map of the island via digital image processing techniques. The NHAP (National High Altitude Photography) photos <u>may</u> provide better resolution than a TM scene (28.5m pixels), though the satellite scene will provide other benefits. We <u>will</u> generate an up-to-date vegetation map from one or the other.

(21) **Bedrock geology** - Already in digital format, we will acquire this from the University of Minnesota/Duluth (UMD) in trade for other data themes. Other themes will be acquired as available from UMD.

(22) **Other themes** - The Michigan statewide GIS system, currently under development, may provide us with additional themes.

Conversion packages will be available the summer of 1991 for transfer of the spatial data to PC/ArcInfo, GRASS, or a standard DXF format. This will enhance the usefulness of the data to Park Service personnel and researchers, who will very likely need to transfer and use data to/from other systems.

The relationship we have established with the Remote Sensing Laboratory at MTU is a productive, exciting one. The MTU system is open to NPS personnel for their use, and both organizations hope the exchange and updating of information will continue even after the current contract has formally expired.

4. Funding

The bulk of the costs of this project were spent on the purchase orders with MTU -- and most of that cost was for personal services, since no equipment was purchased. A summary of the estimated project costs appears in Table III.

Table III

Budget Summary: GIS Project

GIS (ESTIMATED COSTS)	MTU	NPS	TOTAL
Base Map Development	$6,000		
Data Layers/Attribute Files	2,893		
Imagery	2,200	1,456	
Principal Investigator	8,624		
Student Assistant (lead)	4,896		
Summer Field Technician	4,570		
University Overhead	13,800		
Project Summary	**$42,983**	**1,456**	**44,439**

5. Evaluation of the Success of the Project

a. Degree of Completion/Future Plans

All of the data layers originally planned for will be complete by June 1991, although one key theme - topography - will not be at a useful scale. The NPS will seek to add this layer to the database as soon as possible, with other funding sources. The park's quadrangles have been the region's top priority in the annual A-16 process[21] but it doesn't seem likely that DEMs will be available from USGS in the foreseeable future. We will attempt to have the mylar topographic sheets scanned by the NPS Geographic Information Systems Division or a private contractor.

Relational attribute databases will have been developed for most themes, though these will need considerable editing by park staff when the contract is complete. Linkages will be made between database and GIS software, but how "user-friendly" these will be remains to be seen. We had hoped to have this worked on as an MTU master's degree project (not technically part of the contract), but these plans fell through.

Plans to convert the ERDAS database to GRASS on a 386 PC were scrapped when it became clear that the 386 version of GRASS would not be the functional equivalent of the workstation version (the NPS standard). All ERDAS themes can be converted to GRASS format whenever we request it in the future.

With the success of the region's Global Climate Change Program proposal for the Western Lake Forest parks, it appears that Isle Royale will have funds to hire a full-time GIS/Data Management Specialist in FY91. This good news answers the question that has nagged us throughout the GIS database development contract, i.e. what will we do with the data when its done? The park <u>will</u> have a qualified operator soon, and therefore we will immediately seek funds to purchase the full GRASS workstation hardware configuration. We hope nevertheless to continue the excellent working relationship with MTU to share data, contract for specific products beyond our capabilities, and provide research and student opportunities which will be mutually beneficial.

b. <u>Standard of Quality</u>

We won't be able to completely judge the quality of the database until all editing is complete, but the early indications are very positive. There is no question that we could not have developed a spatial database this complete for the money at any other institution.

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[21] Whereby the US Geological Survey requests input from other federal agencies to determine where its assistance is needed.

6. Servicewide Applicability of Project Methods or Results
GIS technology is an accepted tool in the Service, and we did not pioneer any new techniques. Our strategy, however, of investing all the money in database development, using whatever technologies available at the nearest high-quality university (provided that they meet the NPS GIS data standards), gives all indications that it will bear great results. That "lesson" will be incorporated into the Midwest Region's GIS plan, to be written by the principal author of this report, in early 1991.

C. Ecosystem Modeling

1. Objectives

In order to better quantify gaps in present knowledge and improve future research hypotheses, there is a need to take the first steps toward integration of existing spatial and temporal data into a comprehensive park management ecosystem model. Component modeling will permit initial predictions as to future change in ecosystem components and processes as a result of selected natural and anthropic factors.

Isle Royale has sufficient historical data on selected components to begin testing models for predicting trends in wet precipitation chemistry, hydrology, surface water chemistry, change in living biomass and composition, the influence of beaver on long-term biomass and nutrient change, and the relationship of soil chemistry to precipitation and surface water chemistry. Few other quality datasets exist in the National Park Service to consider this type of modeling effort.

The objectives of this project were to begin testing modeling techniques for predicting trends and to develop a strategy for building the comprehensive ecosystem model for a specific park. This exercise was, if successful, to serve as a demonstration and training project for other NPS I&M modeling efforts.

2. Methods

The first step was to discuss the question with a number of modeling experts in a workshop setting. The workshop was organized by Drs. Margaret R. Gale, School of Forestry and Wood Products, and Robert Stottlemyer, National Park Service Cooperative Park Study Unit, Michigan Technological University. The workshop was held November 14-15, 1989, at the College of Natural Resources, University of Minnesota, St. Paul, MN. The following invited participants summarized their knowledge regarding the performance and status of an array of different models, and were involved in the general discussion during the workshop.

Dr. Paul Barton, School of Forestry and Environmental Studies, Yale University, New Haven, CT.

Dr. Paul Bloom, Department of Soil Science, University of Minnesota, St. Paul, MN.

Dr. David Grigal, Department of Soil Science, University of Minnesota, St. Paul, MN.

Dr. John Nicholson, Canadian Forestry Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario.

Dr. John Pastor, Natural Resources Research Institute, University of Minnesota, Duluth, MN.

Dr. Gerry Wright, NPS-CPSU, College of Forestry, University of Idaho, Moscow, ID.

3. Results and Discussion

Models have demonstrated their value in contributing to ecological theory, in examining ecological networks, in environmental management, and in the understanding of large and small lake ecosystems. In this workshop, we examined the use of models in looking forward to predict what variables might have greater potential for indicating change in long-term inventory and monitoring of natural ecosystems. A number of the relatively few long-term ecosystem-level studies conducted to date demonstrate the potential for this.

One example is the long-term aquatic and terrestrial ecosystem studies undertaken at Hubbard Brook. These studies adequately demonstrate the potential for use of models to determine important variables in lake eutrophication, lake water residence time, mineralization of particulate organic carbon, and sediment accumulation. On the terrestrial side, research results show the potential value of modelling for forest development, nutrient cycling, linkages between the terrestrial and aquatic ecosystem, and the study of watershed ecosystems.

The results of this workshop are presently being prepared by the organizers for publication in the Journal of Forestry.

4. Funding

This project was entirely funded through cooperative agreement with MTU. Park costs were minimal, limited primarily to time spent for coordination with the investigators. This project was a low priority and therefore took longer to get started than the other projects, and at this writing is not yet complete. Overruns in cost from the Permanent Plots project (Chapter II.A) were absorbed from the original estimate of the costs of the Modeling project. A summary of the estimated project costs appears in Table IV.

Table IV

Budget Summary: Modeling Project

Modeling (ESTIMATED COSTS)	MTU	NPS	TOTAL
Workshop 11/89	$10,000		
Future costs	11,572		
University Overhead	5,393		
Project Summary	**$26,965**	**0**	**26,965**

5. Evaluation of the Success of the Project

a. Degree of Completion/Future Plans

The original objectives were ambitious considering the available funding, and it is unlikely that they will be fully accomplished. We hope to leverage the remaining funds to begin testing the ecosystem modeling concept in concert with a larger project (funded from other sources) modeling and comparing several sites and linking hydrologic models to GIS databases.

The Wallace Lake watershed study site at Isle Royale will be used because it has an extensive biogeochemistry I&M database (see chapter III.D.1 of this report). The study co-investigators will be Drs. Paul Barton, Yale University School of Forestry and Environmental Studies, and Robert Stottlemyer, NPS-WRD, Fort Collins. The focus will be on the hydrology and energy (carbon) and nutrient cycling in a wetland contained within the watershed. A wetland was selected because there are some excellent wetland models, it is a pervasive ecosystem on Isle Royale, and it is a very sensitive indicator of change in climate.

b. Standard of Quality

Cannot be evaluated at this time.

6. Servicewide Applicability of Project Methods or Results

Models have clear applications in furthering our understanding of park ecosystems, particularly in wetland and other sensitive areas. Whether or not this project generates specific tools applicable in other areas depends on the work not yet accomplished.

III. Summary of the Isle Royale I&M Program

A. Wildlife

1. Wolves

Intensive winter behavioral observations since 1959, including precise annual census. Genetics monitoring of marked individuals (seven to date) since 1988.

2. Moose

Annual statistical census, estimate of winter calf recruitment, and behavioral observations since 1959. Nutritional analysis each winter (through urine studies) since 1988. Detailed locations have been recorded for over 2000 moose carcasses found since 1959; data is recorded when possible for each carcass data on sex, age, metatarsal length, bone marrow fat, cranial volume, etc. All observations of twin calves are noted each summer. Seventeen moose were collared in 1984-86 and used for intensive behavioral studies and to improve precision of aerial population survey estimates.

3. Beaver

Periodic aerial counts since 1960; every two years since 1978. We have trapped animals approximately every ten years to measure average family size, parasite loads, weight, etc.

4. Loons

Population surveys done in 1985 and 1990 and hopefully every five years in the future -- or more often. Seven adult males experimentally vocal tagged in 1990 do determine if technique has promise at Isle Royale to study the turnover rate and site fidelity. All dead individuals found are necropsied. We hope to construct a loon observation database to record all nests and other key information.

5. Bald Eagles

We have documented all nests and the number of successful young fledged each year since eagles have returned to nest at Isle Royale in the mid-1980s. Intensiveness of observations has markedly increased since 1988. Early season activity and the status of old nests are recorded using an overflight each spring. Two eaglets were banded and blood-sampled in 1989 for toxic analysis.

6. Osprey

Observations identical to those for eagles, without the banding and blood work.

7. Colonial Waterbirds

Great blue heron rookery survey done in 1984. Intensive survey of four species (herring gulls, ring-billed gulls, great blue herons, and double-crested cormorants) was done in 1988. A less intensive survey was repeated in 1989. We hope to repeat the intensive survey every five years.

8. Other Raptors

Peregrine falcons have been hacked in the park every year since 1987. This project is scheduled to end in 1991, but we expect to do early season breeding surveys for several years or more, depending upon activity. All adult peregrine sightings are recorded. Nest locations and sightings of all merlins and goshawks are recorded. Merlin breeding activity was surveyed in 1988 and 1989.

9. Breeding Bird Atlas

Data from Isle Royale from 1986-88 was forwarded to the organizers of the statewide program; the Michigan Breeding Bird Atlas is due to be published in 1991.

10. Other Wildlife

Park visitors and staff are encouraged to record all unusual or noteworthy observations, using the NPS Natural History Observation card system. These are compiled by species and year, but their quality and reliability vary widely. Peregrine hack attendants record all birds observed at the hack sites over the summer.

B. Vegetation

1. Fire History and Fire Effects

All known fires in the park have been mapped and entered into the GIS database. A scalar database is maintained which includes details on each fire. Post-fire succession studies were done 1976-82 and two 1976 fires were monitored intensively for five years and again in 1990. We hope to return to these fires every five to ten years. Plots were laid out in 1990 on the 1988 Stanley Fire (the largest prescribed natural fire in park history) but these have not yet been monitored.

2. Windthrow

The number of trees that have to be cleared from park trails each spring has been recorded since 1974.

3. Balsam Fir Mortality

Plots were established in 1988 to measure the change in canopy cover of balsam fir, expected to decrease due to heavy browsing pressure from moose.

4. Forest Insect Infestations

Spruce budworm and other major forest pest outbreaks have been monitored and mapped as necessary since 1985.

5. Other Vegetation Inventory and Monitoring

There have been a vast number of vegetation studies on Isle Royale, beginning with the work of W. Cooper in 1912. Recent inventory work includes a complete lichen inventory and extensive bryophyte monitoring studies. Four moose exclosures were established in 1948. These have been maintained but monitoring of vegetation has been sporadic. A fifth moose exclosure was built in 1980. Intensive vegetation monitoring in two park watersheds is described under "Small Watersheds" below.

C. Physical Systems

1. Meteorology/Fire Weather

The Mott Island weather station has been part of the US Weather Bureau / National Weather Service system since the 1940s. We currently maintain three manual weather stations (including Mott Island) according to AFFIRMS (fire weather) standards. Data from several park stations has been archived in the National Fire Weather Data Library since approximately 1965. NOAA maintains remote automated weather stations (RAWS) at two park lighthouses. We maintain another one at the Ojibway air quality station, and the NAPAP program has yet another in the Wallace Creek watershed. A major goal is to establish a comprehensive park weather database which contains all the outstanding weather observations we can find.

2. Air Quality

We maintain a criteria pollutant (ozone, SO_2, meteorology) monitoring and visibility camera monitoring station at the Ojibway Tower; this has been in operation since 1987. An

IMPROVE particulate monitor has been in operation at Windigo since 1988.

3. Geology/Soils

A bedrock geology map was published in 1974. A three year soil survey project will be completed in early 1991. Soil maps will be entered into the park GIS.

D. Aquatic Systems

1. Small watersheds (NAPAP/NADP)

The Wallace and Sumner Lake watersheds at Isle Royale have been both intensively and extensively monitored since 1981 as part of the NPS involvement in the National Acid Precipitation Assessment Program (NAPAP). Isle Royale is one of four NPS areas designated for long-term research and I&M at the watershed ecosystem level.[22] While the research focus is on terrestrial ecosystem processes and their relationship to change in surface water chemistry, considerable energy has gone into site I&M.

Both the quality and quantity of precipitation inputs is measured year-round. The park has seasonally operated a National Atmospheric Deposition Program (NADP) station since 1980. The on-site RAWS records soil temperature and solar radiation in addition to standard weather parameters.

Surface water quality and quantity have been measured at gaging stations located near the lake outlets, and on the major tributaries to the lakes. Complete streamwater inorganic chemistry along with total N, and DOC. Some, but by no means all, have been published.

Permanent 0.1 ha vegetation plots have been established in both watersheds. These were inventoried in 1983 and species, stem distribution, biomass by species, and nutrient content quantified. The quality and quantity of forest litter has also been determined but on an annual basis. These plot measurements will be repeated in 1991. Vegetation throughout the watersheds has also been mapped. Other inventory variables include mapping of soils, determination of soil properties and chemistry, and intensive study of soil water quality.

[22] This research is now funded by the NPS Water Resources Division.

Quality assurance has been a concern of this project from the start. Precision and bias are continuously measured for all laboratory instruments, and these are within accepted standards. It is more difficult to maintain consistent standards with field work, of course, though procedural steps have been taken to minimize error. These include regular calibration of field instruments; sampling at a consistent time; identical sample processing in the field; replicate samples; and using blanks to detect errors in equipment or technique.

The intensive I&M of these sites was a major factor in the design of the NPS Western Lake Forest global climate research proposal which included Isle Royale and, as was the case for most of the other successful global climate proposals, likely a significant factor in the proposal being funded.

2. Other Watershed Monitoring

The oldest United States Geological Survey Hydrological Bench Mark Station in Michigan, located at Washington Creek, has been gaged since 1968. Bulk annual precipitation as well as seasonal water quality parameters and trends have been monitored throughout that period.

3. Water Quality

A two-year monitoring program which measured physical, chemical, and biological characteristics of several near-shore sites was conducted as a resource management trainee project in 1985-86. Bacteriological monitoring studies were conducted in 1985 to 1987 at a number of sites near park campgrounds. Despite being a water park, we have no regular water quality monitoring program in place.

4. Lake Levels

The US Army Corps of Engineers measures the height of Lake Superior monthly, and this data has been logged in a park database since 1985. Earlier data is available upon request from the Corps. Record high water levels in 1985-87 stimulated us to measure shoreline erosion at one cultural site in the park; this project ended when the site (Edisen Fishery) was stabilized.

5. Fisheries Assessment

The US Fish and Wildlife Service (US FWS) has surveyed the Lake Superior fishery approximately every two years for almost 30 years. The states of Michigan and Minnesota have also compiled assessment records and studied various aspects of the park's fishery resources. The NPS has had little involvement (or interest, until recently) in these programs. We are currently working with the US FWS in an effort to compile the known information into a working document to determine the kind and level of fisheries monitoring needed in the future.

E. Human Use

1. Visitor Statistics /Backcountry Permits

Visitor statistics have been compiled since 1941, shortly after the park was dedicated. Monthly and annual statistical calculations have been completely computerized since 1985. Backcountry permits have been computerized in one form or another since 1980. These data have been converted to the present dBase/Clipper BACKTRAK database system, in use since 1987. In 1990, field ranger stations went on-line, issuing automated permits with direct entry into the database.

2. Research Permits

Research permits have been computerized, using the RITS (Resource Information Tracking System) software since 1987. A complete dBase database exists of all permittees and natural resource projects since that time.

3. Park Bibliography

A history of scientific studies and a park bibliography were prepared as U.S. Man and the Biosphere Program publications in 1985. The park has kept the bibliography up to date since that time and expanded it to include general interest publications. In 1990 we converted it to **ProCite** bibliographic software, which allows searching and sorting. It currently contains 883 citations. A Lake Superior research bibliography was completed in 1986, but it has not been kept up-to-date.

APPENDIX A

PLOT MARKING STANDARDS
Isle Royale National Park

I. INTRODUCTION

The lands and waters of Isle Royale National Park are part of the public domain of the United States, which puts a mutual responsibility upon the managing agency (the National Park Service (NPS)) and anyone seeking to study park resources. The NPS will provide opportunities for high quality research efforts, subject to a stated policy (see the park's research guidelines) aimed at protecting park values and resources; and the researcher **must** work with the NPS to ensure that (1) those resources are not degraded in any way and (2) that information learned is made available to the public. The latter can be accomplished through publication of research results and the completion of annual reports to the NPS each year the project is underway.

Most field natural resource research projects involve intensive study of one or more specific sites or plots that need to be visited and studied over a period of time. These sites generally need to be marked in order to be relocated precisely. The following discussion is designed to ensure that a consistent, minimally intrusive scheme for marking and locating plots is employed by all investigators at Isle Royale. **The following guidelines are flexible but it is vital that the investigator and an Isle Royale National Park resource manager discuss and agree upon research plans and plot marking schemes well before the commencement of field work.**

The NPS will work with legitimate investigators to facilitate their projects. We will provide permanent marking tags for those plots agreed to be of long-term research value. The permanent markers will aid in relocation, provide identification information, and <u>may</u> help protect research sites from unwanted interference by other park users, staff, or managers. We will maintain an extensive database of plots and projects which will be available to all those interested in historical and future research in the park. In return, we ask your cooperation and we look forward to working with you.

II. CRITERIA FOR DESIGNATING PLOTS AS PERMANENT

The long-term significance of a research plot, along with its associated data, is the fundamental reason for nominating it for permanent marking. A plot's significance can be based purely on scientific merit or on its usefulness to resource managers; any area which has little long-term value should not be permanently marked. Correspondingly, areas which are anticipated to be increasingly useful to park management or to the scientific community should be permanently marked. Forecasting the future value of a plot and its dataset clearly has a large element of subjectivity. However, there are three initial considerations helpful in evaluating the long-term value of a research plot, independent of the research subject. Fulfillment of any one of the following criteria indicates a research area may deserve permanent marking:

1. Consider research areas where many years of credible research have been conducted.

2. Consider research areas where a large volume of data has been collected and is available (in raw or summarized form) for further study or analysis.

3. Consider research areas where the research has been published.

Based on these criteria, plots for new, short-term projects should not be permanently marked at the outset unless the research results are certain to be published. Typically, plans frequently change as projects evolve and in most cases a few seasons' perspective shows that only a subset of plots will be worth marking permanently. Photo points or other projects having many years between sample-collecting episodes may be an exception. Often, if a photo point is not permanently marked initially, it may not be re-locatable after a decade or two. In such a case, permanent marking at the commencement of the project would be warranted. Therefore, a fourth criteria could be stated as follows:

4. Consider research areas where the site is a photo point or other long-interval, cyclically visited area.

Permanent marking of some long-term study areas may be undesirable or unmerited. This situation occurs when marking is not needed to relocate or protect the sites, or when marking will be extremely difficult or aesthetically intrusive. The study of chorus frogs (Pseudacris triseriata) on the small islands at the northeast end of the Isle Royale archipelago provides an example. The rocky, shoreline, splash pools used in the study do not require physical marking because individual pools are easily findable with good maps or photographs. (The section "Standards For Permanent Marking Of Research Plots" will emphasize that thorough, very usable maps are absolutely required for all permanent research plots.) Large, well-defined and obvious study areas such as moose exclosures, while needing identification tags and quality directions for re-location and use by other researchers, are an example of plots not requiring any additional marking (i.e. a separate stake is not needed). A fifth criteria could be stated as follows:

5. Consider only research areas where permanent marking is essential for long-term re-locatability, identification, or protection.

In many cases, the designation of a plot as permanent or temporary will rely on the judicious appraisal by park managers. For wilderness areas such as Isle Royale National Park, or when there is doubt as to a project's long-term merit, the study area should be marked as temporary in the first year or years. In subsequent years, after a project has had the time to fulfill one or more of the above criteria, its worthiness for permanent marking can be re-evaluated.

III. STANDARDS FOR TEMPORARY MARKING OF RESEARCH PLOTS

Sites used for short term research should be marked with short wooden stakes or other biodegradable markers which stand only a few inches above the ground. **No plastic tent stakes, metal materials, or paint (except on the biodegradable marker itself) should ever be used.** Conservative use of marking materials such as colored yarn or biodegradable flagging is acceptable although discouraged. However, the color scheme needs to be agreed upon with the NPS in advance. Such materials should be replaced when old, removed when no longer needed, and not left in place indefinitely to degrade. These materials should be minimal and used only as navigational aids for relocating sites during mid-summer field work (when thick vegetative growth hides many on-the-ground markers). All markings should be invisible from trails, shorelines, and other areas frequently used by park visitors.

At the end of the last data collection period, all marking materials must be removed from the park by the researcher. In all cases, a sunset clause, specifying a removal date for all materials, will need to be agreed upon prior to issuance of a research permit. This date can be changed as is warranted by further research or NPS interest.

IV. STANDARDS FOR PERMANENT MARKING OF RESEARCH PLOTS

Once a research site is designated for permanent marking, a rust-resistant, angle iron (with sharp edges rounded or dulled for safety) should be normally used as a plot marker. Every angle iron should stand 30 to 60 cm above the ground, or as low as possible and still findable. It should be inconspicuous from a great distance away, although paint can be used on markers to increase their local visibility. **Do not put paint marks on**

trees, rocks, etc. Each marker must be placed far enough into the ground (20 to 30 cm, deeper if possible) so that it is unlikely to be pushed over by moose or other animals, or dislodged by frost heaving. This anti-moose criteria is very important due to the high moose density on Isle Royale and their propensity to rub against or step on things left in the woods. Cylindrical stakes or metal rods should not be used because they are difficult to discern in thick brush: thin metal rods often blend into the mass of small stems when in thick brush. Angle irons provide a flat surface, more easily noticed while searching.

In open rocky areas, as in the case of some bryophyte or lichen studies (where it is very unlikely that heavy brush will grow and cover the area in the next ten to twenty years), smaller markers can be used. However, because of their biodegradability, wooden markers should never be used for permanent sites. Experience shows that plastic stakes (of the tent stake variety) are not durable enough to reliably last more than ten years. After a few winters they can become brittle. Once brittle, moose can easily break a plastic stake and displace the pieces making site relocation difficult or impossible.

In extremely rocky areas, where there is little or no soil in which to firmly plant a stake or angle iron, very thorough maps of the location area must be made. These maps should be based largely on compass bearings to large, lasting geological features. Use of transitory biological features (such as birch clumps) should be avoided. When only biological features can be used as references, special care must be taken to map many features so that at least a few will survive over a ten to twenty year period or more. Very large trees are good to use since they are unambiguous when standing and often recognizable after falling over.

The final choice of plot markers requires the mutual agreement between the investigator and the NPS resource manager before any plot markers are positioned.

V. PERMANENT PLOT IDENTIFICATION TAGS

The NPS will provide permanent metal identification tags to be attached to each permanent plot marker. Each tag must be stamped with a unique identification number (see Numbering and Nomenclature) and must be attached to its plot marker using durable wire of 12 gage or larger. Any metal will suffice, however coated copper wire is preferred because it can be worked by hand without tools. The NPS will provide these wires.

Figure A-1 shows an image of the metal identification tags used at Isle Royale National Park. The actual size is 3.81 cm x 8.89 cm x 0.81 mm (1.50 in x 3.50 in x 0.32 in).

FIGURE A-1

Aluminum tag used for identifying a permanent research plot at Isle Royale National Park, Michigan.

VI. NUMBERING AND NOMENCLATURE

Each permanent tag must have the a National Park Service plot code stamped into it. The plot code must always be of the format XXX-TTT-PPP where "XXX" is the three initials of the primary investigator, with last initial first. "TTT" is the three digit plot grouping number, commonly call the transect number. It is important to keep in mind that all plot groupings have a transect number assigned for identification purposes. "PPP" is the three digit plot number. Example: If a researcher named Scott A. Carrier had a cluster of plots given a transect numbered 25 with a plot in the cluster numbered 9, the NPS code would be CSA-025-009.

Plot and transect numbers will be assigned per mutual agreement between the researcher and the NPS. The responsibility for stamping and placing tags is on the researcher, though NPS staff will often assist as possible. The NPS will maintain a die set available for loan.

VII. INFORMATION TRANSFER

At the completion of the first field season, a thorough description of the locations for all plots must be provided to the NPS for entry into our research plot location data base. This applies to both temporary and permanent plots.

For those plots designated as permanent, the location information must include maps, compass bearings and measured distances, as well as narrative descriptions. Compass bearings and measured distances must be to permanent landmarks, rocks, shoreline promontories, and edges of islands. Species composition and habitat descriptions are useful supplementary information, but must not be substituted for references to non-transient features. For inland areas with no visible landmarks, rock boulders, or outcrops, very complete maps of tree sizes (using diameter at breast height [DBH]) and measured distances may be used. In all cases the emphasis is on the usability of this location information to future researchers or park staff who have never visited the plots. A field data sheet is shown in Figure A-2. We encourage you to use this form while you do your field work and will provide you with as many copies as you request.

All location information must be updated in subsequent seasons as is needed to keep the database current. Assistance in recording locations may be available from NPS staff once any permanent plots have been established in the field.

NPS PERMANENT PLOT DATA BASE

FIELD DATA SHEET

NPS ID CODE: _ _ _-_ _ _-_ _ _ DATE: _ _ / _ _ / _ _
PROJECT NUMBER: _ _ (month/day/year)
LOCATION: ________________
OTHER ID CODE: ____________ NPS TAG ATTACHED? Y or N

PLOT GROUP: (circle one)	PLOT TYPE: (circle one)	LORAN-C: (in deg, min, 1/100 min)
TRANS ect	QUAD rat	LAT: _ _° _ _._ _"
CLUST er	CIRC ular	LONG: _ _ _° _ _._ _"
GRID	PHOT o	
POINT	STEM	S1: _ _ _ _ _ _._
OTHER	OTHE r	S2: _ _ _ _ _ _._

BEARING: _ _ _°	UTM ZONE: _ _	MARK SITE: (circle one)
DISTANCE: _ _ m	UTM N: _ _ _ _ _ _ 0	CEN ter of plot COR ner of plot (which) ______
Previous mark: ____________	UTM EAST: _ _ _ _ _ 0	OTH er site ____________

MARK TYPE: (circle one)	MARK COLOR: (circle one)	MARK HEIGHT:
MR = metal rod	WHI = white	_ _ _ cm
AI = angle iron	SLV = silver	
OM = other metal	RED = red	
PS = plastic stake	ORG = orange	
FL = flagging	YEL = yellow	
NM = no marker	BLU = blue	
OT = other marker	UNP = unpainted (not metal)	
	OTH = other color	

NARRATIVE DESCRIPTION:
(use back side as needed)

FIGURE A-2
Isle Royale National Park permanent plot database field data sheet.

APPENDIX B

PERMANENT PLOTS DATA DICTIONARY
Isle Royale National Park

Field types are classified in accordance with dBASE III Plus nomenclature. See a dBASE III Plus manual for more information.

FIELD NAME	DEFINITION
BEARING	A three digit numeric field containing the magnetic bearing to the current plot from the previous plot or other reference point. All bearings are positive integers with north recorded as 360. When "999" appears in this field it indicates that the narrative field contains additional location information related to the bearing. Use "999" in this field whenever a bearing is measured from a point other than the next numerically lower plot on the transect according to the **TRANSECT** and **PLOTNUM** fields.
DATE	A eight digit date field containing the date on which the plot was last visited. The format is "mm/dd/yy".
DISTANCE	A two digit numeric field containing the distance to the current plot from the previous plot or other reference point, recorded to the nearest whole meter. An explanation is recorded in the narrative field when this field contains "99". Use "99" whenever the distance is measured from a point other than the next numerically lower plot on the transect according to the **TRANSECT** and **PLOTNUM** fields.
GROUPTYPE	A five digit character field containing the type of plot grouping or an abbreviation for the type of group to which the plot belongs. The only choices which can be used are TRANS (transect), CLUST (cluster), GRID, POINT, and OTHER. When OTHER is used it must be explained in the **NARRATIVE** field.
INITIALS	A three digit character field containing the initials of the primary investigator in the order: last-first-middle.
LATDEGREE	A two digit numeric field containing the degrees portion of a plot's latitude. This number is readable directly off of most Loran-C receivers.
LATMINUTE	A five digit numeric field containing the minutes portion of a plots latitude. The two rightmost digits are decimal places representing hundredths of minutes. All seconds of latitude must be converted to decimal minutes. Most Loran-C receivers do this automatically.

LOCATION An alphanumeric field of 25 characters containing the general location of the plot using well-known place names. Do not use a cadastral (township-range) description.

LONGDEGREE A three digit numeric field containing the degrees portion of a plot's longitude. This number is readable directly off of most Loran-C receivers.

LONGMINUTE A five digit numeric field containing the minutes portion of a plot's longitude. The two rightmost digits are decimal places representing hundredths of minutes. All seconds of longitude must be converted to decimal minutes. Most Loran-C receivers do this automatically.

LOPS1 Stands for "line of position from station one". This is a seven digit numeric field (with one decimal place) recorded directly from the S1 display panel of a Loran-C radio receiver.

LOPS2 Stands for "Line of position from station two". This is a seven digit numeric field (with one decimal place) recorded directly from the S2 display panel of a Loran-C radio receiver.

MARKCOLOR A three digit alphabetic field containing an abbreviation for the color of the paint used on the plot marker. The only choices are WHI (white), SLV (silver), RED (red), ORG (orange), YEL (yellow), BLU (blue), OTH (other color), and UNP (unpainted).

MARKHEIGHT A three digit numeric field containing the height of the plot marker rounded to whole centimeters.

MARKSITE A three digit alphabetic field containing an abbreviation for the location of the plot marker within the plot. The three options are CEN (center of plot), COR (corner of plot), and OTH (other site). If OTH is used it must be explained in the narrative field. If COR is used, the **NARRATIVE** field must describe which corner was used.

MARKTYPE A two digit alphabetic field containing an abbreviation for the type of plot marker used at the site. The options are MR (metal rod), AI (angle iron), OM (other metal), PS (plastic stake), FL (flagging), OT (other marker), and NM (no marker). OM, OT, and NM need to be explained fully in the **NARRATIVE** field.

NARRATIVE A memo field for recording plot history and relocation information, as well as other plot related explanations. There is no size limit to this field.

NPSTAG A logical (true or false, yes or no) field of one digit for recording whether a National Park Service identification tag has been attached to the plot or plot marker. Input "Y" for yes, and "N" for no.

OTHERID A 15 character alphanumeric field for recording any plot identification codes other than the one used by the National Park Service. Most often this field is use to record a researcher's original plot designation code.

PLOTNUM A three digit numeric field for the plot number. This field is normally used in association with the **TRANSECT** and **INITIALS** fields. All three field must follow the guidelines set forth in the document "Plot Marking Standards" (see Appendix A).

PLOTTYPE A four digit alphabetic field which contains an abbreviation for the type of plot. The options are QUAD (quadrat), CIRC (circular), PHOT (photo), STEM, and OTHE (other). If OTHE is used it must be fully explained in the narrative.

PROJECTNUM A two digit numeric field which contains the project number. Input is limited to integers. An entry of "0" means no project number has been assigned.

TRANSECT A three digit numeric field which contains a transect number or plot grouping number. This field is normally used in conjunction with the **INITIALS** and **PLOTNUM** fields. All three fields must follow the guidelines set forth in the document "Plot Marking Standards" (see Appendix A).

UTMEAST A six digit numeric field containing the Universal Transverse Mercator Easting (UTM longitudinal component) coordinate for the plot, rounded to the nearest 10 meters.

UTMNORTH A seven digit numeric field containing the Universal Transverse Mercator Northing (UTM latitudinal component) coordinate for the plot, rounded to the nearest 10 meters.

UTMZONE A two digit numeric field containing the Universal Transverse Mercator zone of the plot. All zones covering the continental United States are integers from 10 to 19, inclusive. All lands and waters of Isle Royale National Park are in zone 16.