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An Aerial Photographic Procedure for Estimating Recreational Boating Use on Inland Lakes

Compared to conventional ground-base surveys, the aerial method resulted in the acquisition of more accurate data, at lower cost, and with less administrative complexity.

Abstract: *A pilot project was conducted to evaluate the practicality of using 70-mm aerial photography as a means of obtaining a survey of recreational boat use on Lake Minnetonka–an intensively used 5721 hectare lake located approximately 13 km west of Minneapolis, Minnesota. Color transparencies at a scale of 1:15,000 were successfully interpreted monocularly to count and discriminate between the following boat types: (1) runabout, (2) cruiser, (3) sailboat, (4) rowboat, (5) pontoon boat, (6) houseboat, and (7) miscellaneous. In addition to being used for the boat count, the aerial images facilitated the identification and location of permit-regulated features such as boat moorings and swimming rafts. Specialized boating activity such as water skiing and sailboat racing could be readily interpreted, while attempts to positively identify fishing activity were not successful.*

The gound-based techniques currently used to perform the recreational boat surveys of Lake Minnetonka entail approximately 220 person-hours of effort and the employment of 100 observers for each "instantaneous" count. The aerial technique involved 60 person-hours of effort and $465 of aircraft time and photographic materials (1981 dollars). The aerial photographic approach not only proved to be more practical economically and administratively, it resulted in a virtually permanent record of lake surface conditions–a record which has a host of additional potential uses (e.g., shoreline zoning compliance, weedbed growth monitoring, study of shoreline erosion, etc.).

On the basis of the success of this pilot project, the photographic methodology will be adopted for future surveys over Lake Minnetonka. Improvements to be made in the operational phase include the use of slightly larger scale stereo photography (1:10,000) and underexposure of all images one-half to one f-stop.

Introduction

Data on the extent and type of recreational boat use on inland lakes are essential to effective management of these resources. Such data are particularly important to the management of large lakes located in or around metropolitan areas. These lakes tend to be used intensively by diverse groups which often have conflicting recreational demands. Policies and regulations restricting boat operation are often formulated in such situations in order to minimize user conflict, to preserve the quality of the lake as a recreational resource, and to provide adequate public safety. Periodic surveys of boat types and number are needed to develop and implement such policies and regulations. These data are also essential to the planning and administration of recreational support facilities such as launching sites, parking areas, restaurants, service stations, and emergency facilities.

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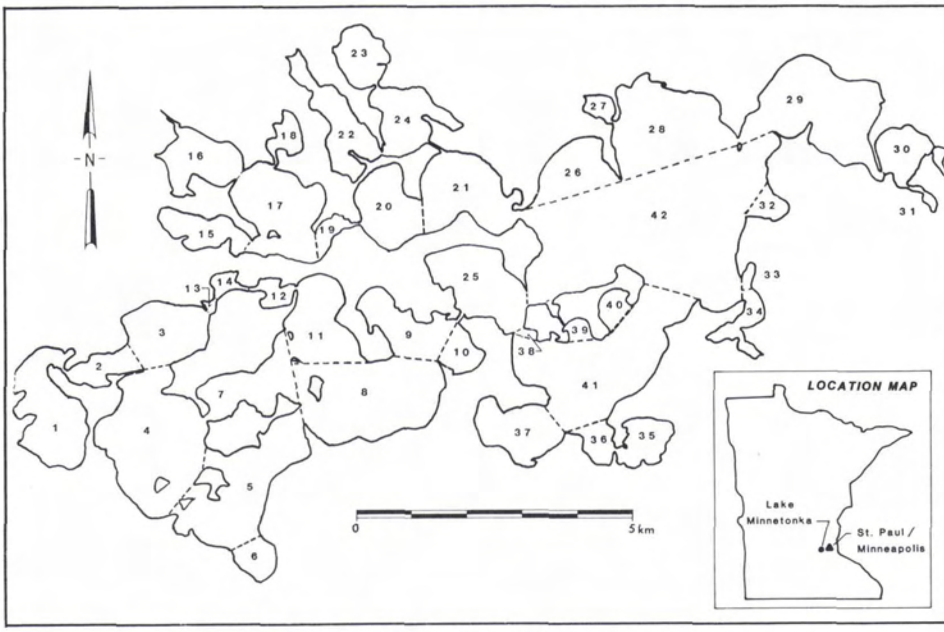


FIG. 1. Lake Minnetonka Management Areas.

Figure 1 is a map of Lake Minnetonka, which epitomizes an intensively used and highly valued recreational resource. Five municipalities ranging in population from 550 to 4000 persons are located on its shores, and most of the shoreline is developed with year-around residences.

This lake is located approximately 13 km west of Minneapolis, Minnesota, and is managed by the Lake Minnetonka Conservation District (LMCD). In support of its management activities, this agency typically acquires boat survey data over the entire lake three or four times a summer, during periods of peak lake use. Given the size and geographic complexity of the lake, this task is indeed a monumental one logistically. To conduct a survey, approximately 100 people equipped with binoculars are stationed at predetermined locations both on and around the lake. At a given time (normally 2:00 P.M. on a weekend) the observers classify and tally all boats in their assigned observation territory. These data are then aggregated to quantify boat use by type in each of 42 geographical lake-management areas (Figure 1). This procedure is administratively complex, costly, time consuming, inherently single-purpose, and (most importantly) inaccurate. Generally, the technique results in an undercount bias in the survey data.

In hopes of circumventing the above problems, the LMCD contracted with the University of Minnesota Remote Sensing Laboratory (RSL) to develop and evaluate an aerial photographic alternative to the ground-based procedure. This article describes how this very practical problem was approached.

DATA ACQUISITION

The present authors are certainly not the first to have designed a procedure for conducting aerial photographic boat counts. A number of different sampling schemes and camera system configurations had been tested prior to our work. The literature contains lists of systems ranging from oblique 35-mm cameras (James *et al.*, 1971), and dual oblique 35-mm cameras (Becker *et al.*, 1980), to large format oblique and panoramic photography (Heller and Murphy, 1977). Our effort was patterned most closely after that employed by the National Park Service to obtain counts along the Lower St. Croix National Scenic Riverway (Hudick, 1980). This involved the use of 70-mm vertical photography to obtain a full-lake boat count, by type, under conditions of intense use.

In order to typify peak watercraft use, the LMCD requested that the lake be photographed beginning at 2:00 P.M. on a Saturday or Sunday during July or August. Weather and aircraft scheduling problems delayed the photographic mission until 15 August, 1981. Fortunately, because of the poor weather conditions on previous weekends, this date proved to be one of very high lake usage. (Also, the time of day during which the survey was made tended to minimize specular reflection effects in the resulting photography.)

The camera system used was a 70-mm Hasselblad 500EL/M with a 50-mm focal-length lens mounted in a belly hole of a Cessna 180 aircraft. The film/filter combination consisted of Kodak Aerochrome MS Type 2448 color positive film and a Tiffen UV-2A (haze) filter. The survey area was photographed at a flying height above ground of 750 m, resulting in a contact scale of 1:15,000 with a nominal endlap and sidelap of 30 percent. A total of 285 exposures was required along north-south flight lines to cover the lake.

Because most boats were presumed to be lighter in color compared to the darker lake surface, we found that using the *f*-stop from a normal light meter reading would tend to over-expose the boats, thus reducing detail and subsequent image interpretability. To compensate for this, the film was underexposed by one-half *f*-stop, resulting in a setting of *f*/8 at a shutter speed of 1/250 sec for the lighting conditions of our survey. Plate 1 is a sample image resulting from the mission. Among other things, this image typifies the exposure conditions realized and the number and appearance of boats in a very intensely used portion of the lake.

Interpretation

Guidelines

All boats depicted in the imagery were classified, within each of the aforementioned 42 lake management units, into the following categories: (1) runabout, (2) cruiser, (3) sailboat, (4) rowboat, (5) pontoon boat, (6) houseboat, and (7) miscellaneous water craft. In addition to the boat tallies, the locations of all swimming rafts and moorings with boats attached were interpreted and transferred visually to a base map. This additional information was collected because it was important to the LMCD permit verification process for these items, and these features could be located with virtually no additional effort during the boat count interpretation procedure.

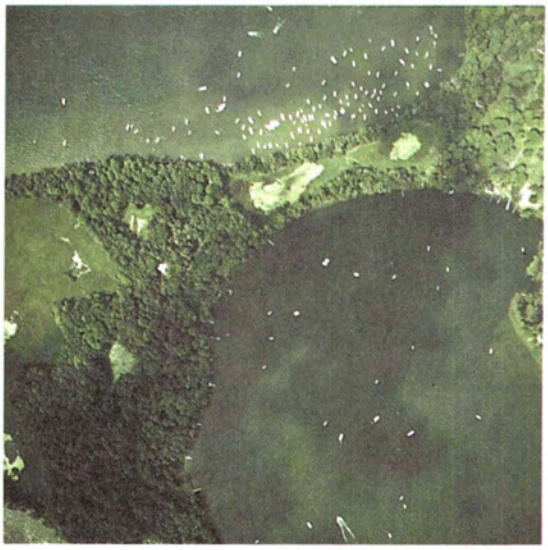


Plate 1. Typical mission image. Taken between Lake Management Areas 40 and 42 (Figure 1).

Among the criteria followed during the interpretation process were the following:

- In addition to those boats in obvious use, boats anchored in bays or around islands and not attached to permanent moorings were counted;
- Boats beached on public property in recreational areas were counted;
- Day cruisers (cruisers without superstructures) were classified as runabouts; and
- Moving boats were included in the count for the lake management unit in which they first appeared in the imagery.

Photo Preparation

Prior to the actual photointerpretation, all photos and flight lines were assigned reference numbers. Because adjacent flight lines had to be viewed simultaneously in order to track boat movement, they were separated and placed in protective plastic sleeves. Due to the large number of photos to be interpreted and the potential for missing areas, all photo centers were marked onto a post-flight index map to help orient the interpreter as the count progressed.

Interpretation/Tallying Procedure

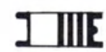
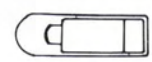
To facilitate the interpretation process, the interpreter developed an interpretation key by visiting a marina and locating boats that were present in their slip storage positions during the time of photography. This proved to be a valuable aid in the interpretation process. Table 1 lists some of the distinctive features included in the interpretation key developed from the ground check.

The photointerpretation was accomplished using a Bausch and Lomb Zoom 70 Model II Stereoscope mounted on a variable intensity light table. A magnification of 10× proved to optimize interpretation.

The interpreter began tallying boats at the western end of the lake (area first photographed) and proceeded eastward in an orderly sequence, interpreting each designated management area separately. After marking the management area boundaries on the plastic sleeve overlay for each flight strip, the interpreter then counted all boats, placing a black dot next to a boat as it was tallied. Before moving on to the next photo, all swimming rafts and boat moorings were identified, and marked with a blue dot and their location was subsequently transferred to a lake base map.

In order to reduce the chance of recounting boats as subsequent photos were examined, all previously counted boats were first relocated and marked with a red dot. This same basic procedure was followed when viewing a new flight line. The previously interpreted flight line was viewed in conjunction with the new flight line, again taking

TABLE 1. INTERPRETATION KEY FOR DISCRIMINATING BOAT TYPES

Boat Type	Descriptive Features	General Shape
Runabout	single hull—pointed bow, tri-hull—blunt bow, hull may be partially covered, windshield often visible.	
Cruiser	super-structure, flying bridge, two windshields usually visible, hull mostly covered.	
Sailboat	sails often visible, single hull—long slender shape, catamaran—twin hulls visible.	
Rowboat	three seats usually visible, with or without outboard motor	
Pontoon boat	rectangular shape, outboard motor, pontoons extend beyond the platform. Often with colorful canvas top.	
Houseboat	relatively large, rectangular shape with blunt rounded bow, superstructure sometimes present.	

care to relocate and mark all previously counted boats.

RESULTS

The total number of boats counted was 1913 (Table 2). In that this number is nearly twice the average obtained on the previous occasions when ground-based counts were used, it seems to indicate the undercounting bias of the ground surveys and the increased accuracy achievable by the aerial survey method. Again, the placement of permit-regulated swimming rafts and boat moorings was readily interpreted from the photos as "an extra added attraction." Also, specialized boating activity such as water skiing was readily apparent, and this information was provided for each lake management area. If desired, the imagery could also have been interpreted (at increased cost) for additional purposes, such as monitoring aquatic weed control measures.

TABLE 2. BREAKDOWN OF INTERPRETATION RESULTS BY BOAT TYPE

Type	No. Counted
Runabout	1012
Cruiser	214
Sailboat	385
Rowboat	88
Pontoon Boat	43
Houseboat	19
Miscellaneous	152
	1913

As would be expected, certain problems complicated the interpretation process. These were as follows:

- Occasionally there was some difficulty discriminating between small cabin cruisers and runabouts;
- It wasn't possible at the image scale used to identify fishing activity reliably;
- In some cases it was difficult to determine the exact type of fast moving boats because of slight motion blur and increased specular reflectance from the boat wake;
- The boat counting process was difficult in those images where there was a large number of boats moving perpendicular to the flight lines;
- It was also difficult to trace sailboat movement from adjacent flight lines when sailboats were grouped together in regatta fashion; and
- The large number of photos needed to cover a lake the size of Lake Minnetonka led to a relatively lengthy interpretation time in that all previously counted boats had to be meticulously relocated on adjacent photos and flight lines.

The aerial survey procedure involved a total of 60 hours of personnel time distributed in the following manner:

Task	*Hours Required*
Flight planning and mission preparation	5
Mission Execution	3
Interpretation key development	6
Photo preparation	11
Interpretation	30
Compilation of results	5
	60 hours

The costs of photographic supplies and services required for the mission (in 1981 dollars) were

Aircraft rental (@ $88/hour)	$264
Film	84
Film processing	97
Camera maintenance cost applied to mission	20
	$465

The above effort and cost figures underscore the practical utility of the aerial photographic approach in that the previously conducted ground surveys involved 220 hours of effort. Furthermore, if we were to repeat the aerial survey, the personnel time required would probably decrease due to the experience gained from the initial test.

Conclusions/Recommendations

Compared to conventional ground-based boat surveys, the aerial method reported herein resulted in the acquisition of more accurate data, at lower cost, and with less administrative complexity. It should also be noted that our effort/cost figures are probably biased upward, given the unusually large size, complexity, and intensity of recreational boat use of the lake studied. Furthermore, in our comparison we have employed a "single-purpose" purview of the photography. Information such as the swimming raft and boat mooring locations, the impact of weed control measures, and a host of other lake management information needs could be met by the imagery. Also of interest is the fact that purchase of copies of the imagery by lakeshore residents and other interested parties will likely recover the entire cost of the photographic survey.

The following variations to our approach are recommended for the benefit of others who might attempt a similar effort:

- *Use a larger scale.* An increase to a scale of approximately 1:10,000 would greatly aid in differentiating between boat types.
- *Obtain stereo coverage.* This would aid in detecting boat movement and in the overall interpretation of boat types. For example, differentiating cabin cruisers would be simplified by easily detecting the presence of a superstructure.
- *Underexpose by up to one full f-stop.* This is dependent upon the weather condition. On a clear day a full *f*-stop is recommended. Under partly cloudy conditions, as it was during our photo mission, one-half stop is recommended.

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