**Recreational Boating and Beach Capacity Analysis within Pool 6 of the Upper Mississippi River**

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**Abstract**

Analyses of physical boating capacity and beach use within pool 6 of the Upper Mississippi River were conducted to determine if the pool is being used beyond its capacity. Data from the Minnesota – Wisconsin Boundary Area Commission aerial surveys were obtained for several years between 1989 and 1997. Based on the counts of moving and beached craft it was possible to determine the number and types of craft utilizing the pool. The available recreation area in this study was limited to the main channel and main channel border of pool 6, and those areas were divided into three zones of use defined by the Boundary Area Commission which correspond to the natural composition of the pool. A range of acreage needed for each craft type studied was determined and the acreage being utilized was discovered. In addition to the boating capacity, a study of the number of groups that could comfortably recreate on beaches within the pool was also calculated based on a low-density and high-density standard. The number of boats per group was also found using a range of 1- 3 boats per group. These numbers could then be compared with the actual number of beached craft recorded in the aerial surveys previously mentioned. It was expected that results of both analyses would determine pool 6 use to be beyond its capacity. However, according to the models developed for this study, it was determined that pool 6 is not being overused in regards to recreational boating and beach use. When looking at the findings from both beach and boating analysis, it should be noted that there are several other factors that should be explored in further study, but were not considered due to study limitations. Still, the model developed was the most appropriate and flexible given the available data and purpose of this study.

**Introduction**

The Mississippi River Corridor is known for its picturesque setting and recreational opportunities. One form of recreation that has a strong presence both in the U.S. and in the Winona, Minnesota area is boating. Approximately 78 million people participate in recreational boating in the U.S. annually (National Marine Manufacturers Association, 1997). With this number of active participants, it is understandable that water accidents rank second only to highway accidents when considering transportation in this country (U.S. Department of Commerce, 1990). However, there is no need for mishaps to occur with such regularity and abundance. Proper management can help ensure that the number of injuries and fatalities is kept to a minimum.

Aside from being faced with safety concerns, as use of public recreation resources grows, "managers are increasingly faced with the prospect of limiting use to protect the resource, the recreation experience, or both. Managers usually recognize that such limits should be based on the resources physical and social carrying capacities (Tarrant, 1996)." Physical and social capacity are two of the four existing type classifications, which also include ecological and facility capacities. Defining these further, physical carrying capacity is concerned with space requirements and takes into account the greatest number of people that can be recreationally accommodated. When use levels exceed limits at which safe and efficient recreational activities can occur, the area is said to exceed its physical carrying capacity. Social capacity, which is subjective, deals with the impacts of physical density on the quality of the experience. Often, the number, type and location of encounters with others help determine a visitor's perception and reaction. The impact of recreational use on the environment is considered to be the third type of capacity. Ecological capacity, is considered to be exceeding the maximum when an "unacceptable or irreversible decline in ecosystem values occurs" (Pigram, 1983 in Falk et al, 1992). The final type of capacity is facility capacity. This focuses mainly on man-made structures such as parking lot or boat ramp availability. Facilities are generally stable, easy to measure and rarely a limiting factor in recreational settings. Each of these capacities can impose restrictions on the recreational opportunities in a given area, and at best a thorough management plan for a recreational region will take all of the applicable limiting factors into consideration.

Unfortunately, a comprehensive carrying capacity model that is applicable to a variety of circumstances has yet to be developed. Several attempts including various factors have been made to create a model for specific instances. Something that many of these models have in common is the incorporation of both scientific and evaluative (social) elements. However, most attempts to determine social carrying capacity, have proven to be particularly time consuming, costly and inconclusive. For example, overall boater satisfaction, appears to have little to do with actual use or encounter levels and is thus a poor criterion (Heberlein, 1986). The fact that people are sometimes apprehensive about expressing negative thoughts, and variability in perceptions also produce further difficulty in making social determinations.

Many of the existing models also take into consideration the management objectives of the recreation area. Overall, recreation planners require carrying capacity formulations that are flexible and reflect multiple influences on management decisions regarding use levels (Manning, 1985 in Tarrant, 1996). Depending on the area and type of experience the users are destined to have, managers may set primitive low-density standards or perhaps higher density standards if user perceptions allow it to be generally accepted.

An understanding of both the spatial and social limitations of a recreation area, is an important factor when determining the use and recreational future of an area. But finding or creating a thorough working model for making decisions regarding capacity can be difficult. Many variances exist within water habitats that can affect the quality and amount of use in an area. Some of these factors include type and number of boats, daily use levels, water level, weather, time of day, day of the week, and even the attitudes of boaters toward the experience and each other.

The focus and reason for this project on recreational boating and beaches in pool 6 of the Mississippi River is a direct result of boater observations. Some local boaters in the Winona, Minnesota area have voiced the perception that during times of peak use, an un-safe and crowded boating situation can result. Since this opinion is a social one, limited to the evaluative standards of a few people, the decision was made to perform a physical carrying capacity analysis. A model was developed to determine if indeed pool 6 was exceeding its boating capacity on busy days, known as peak days for this study defined as Friday through Monday of a given week and holidays. Similarly, the beaches were also analyzed in terms of space availability, for these peak times. In this study, only physical carrying capacity is addressed due to the absence of a solid comprehensive model, numerous variables, lack of management objectives for this particular area, and also time and money constraints. Still, keeping with what is emphasized by current research, capacity is defined in this project by making use of a range of density standards determined through consideration of combined objectives.

Since flexibility is imperative for a project involving recreational Guidelines established for the study were developed and an ArcView project carrying capacity, the decision was made to utilize Geographic Information Systems (GIS). A GIS provides the capabilities to accommodate a dynamic model which would be necessary for recreational managers. was created to provide a means for spatial display of the results.

## Methods

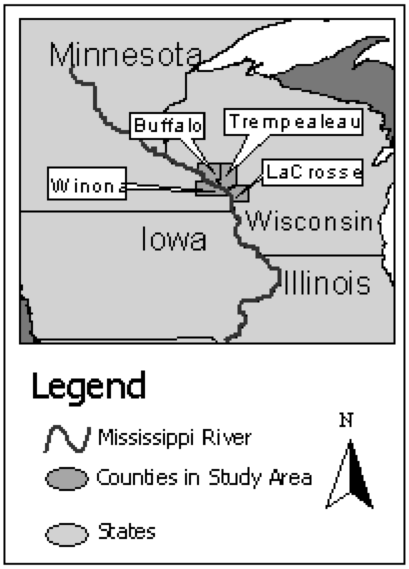
### *Data Collection*

#### Coverages

In addition to the boating and beach physical capacity analyses, this project includes a user-friendly interface through which visitors to the area could access information regarding recreational opportunities within a 10-mile buffer of pool 6. This includes parks (both local and state), biking trails, and canoe routes. A database of amenities including but not limited to restrooms, pavilions, grilling areas, picnic tables and campgrounds was associated with the coverages. Information was gathered for all of the recreation options that fell within the buffered four county (Winona, Buffalo, Trempealeau and LaCrosse) area (Figure 1).

The coverages necessary for depicting the available recreation options were obtained from a variety of sources. Street information (containing names and locations of roads, and highways) was acquired from the First Street data produced by Wessex, Incorporated of Winnetka, Illinois. These data were found to be comparable to USGS TIGER files, and slightly more complete. The data were extracted, attributed and edited as necessary. The second group of data displaying streams, cities, counties, railroads and lakes were downloaded

Figure 1. Location map of the study area.

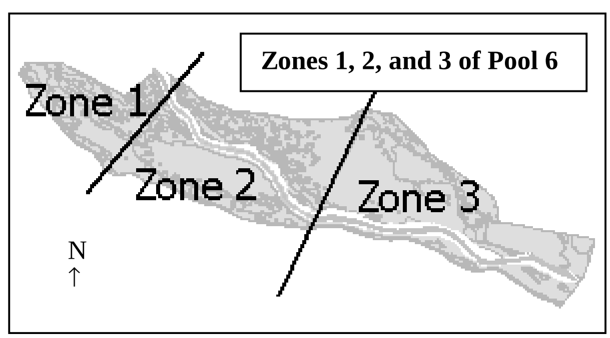



from a United States Geological Survey (USGS) website. The remaining coverages such as the canoe routes, bike routes, and park polygons were added via "heads up" digitizing from paper maps, TIGER files, and publications from various area tourism agencies.

Elements containing spatial information regarding pool 6 were also necessary for the project. An aquatic coverage of pool 6 containing area measurements from backwater, main channel and the main channel border was also utilized. In addition a coverage of existing beaches was also acquired. Both of these information sets were exported from UNIX, and imported into an ArcView project. The above mentioned coverages were created by the Upper Midwest Environmental Sciences Center (UMESC) based on data obtained from the Minnesota - Wisconsin Boundary Area Commission. In addition, the Upper Midwest Environmental Sciences Center also provided a point coverage containing the landings and marinas within pools 5A, 6, and 7. From these data, it was possible to select those facilities contained within pool 6. In addition to the facilities physically located within pool 6, the database included a few additional marinas and landings that are accessible via boat without having to lock through a dam. The marinas and landings were then separated into a marina coverage and a landing coverage for analysis and visual purposes. Some additional marinas, landings and beaches not in the UMESC database were added into the database, but due to lack of information, were not included in any analysis.

After collection of the pool 6 information was completed, individual aquatic coverages were then divided into three zones. These zones correspond with delineations made by the Minnesota - Wisconsin Boundary Area Commission for data collection in their aerial photography surveys. Zone 1 is located at Lock and Dam 5A and continues to the 5A daymark. The second zone begins at this daymark and continues to Mosquito Island, while the third zone is composed of this island and the rest of the pool to Lock and Dam 6 (Figure 2).

Figure 2. A pictorial representation of the three zones contained within pool 6 of the Upper Mississippi River




Said delineations mentioned earlier correspond to the natural composition of the pools. The upper end of each pool is typically a mixture of main channel, narrow side channels and islands with predominately flood plain forest. The middle section is more evenly mixed with backwaters and main channel. This area is also lined with long, narrow islands formed by sedimentation and placement of dredge spoils. A large expanse of shallow open water with small intermittent islands is characteristic of the lower end of a pool. These zones are not equal in area but do contain similar characteristics, therefore also potentially exhibiting similar boating tendencies.

Data

Three separate data sets were utilized for the analysis portion of this project. The first set included aerial survey information collected by the Boundary Area Commission from 1989, 1993, 1995, and 1997. This information was in regard to the types and numbers of boats in each zone that were beached on islands in or adjacent to the main channel. The particular data that were used included the boat types observed over the flight area, which encompassed pools 4 - 10. The surveyed boats included canoes, cruisers, houseboats, fishing, pontoons, sailboats and personal watercraft. An "other" category was also used for those boats that did not fit the above descriptions. These data sets were subset to include only the information for pool 6. In addition sailboats were eliminated from this study due to the fact that none were observed in the study area during the data collection periods. Towboats, canoes and “other” boats were also discounted from analysis due to low survey numbers and significance.

Since the times of most activity on bodies of water (Kelly, 1993, Tarrant, 1996, National Park Service, 1982, Heberlein, 1983 and Falk et al, 1992) are weekends and in particular extended holiday weekends (Friday, Saturday, Sunday, Monday), this "peak day" information (vs. Weekdays Tuesday - Thursday) was utilized for capacity comparisons and calculations. Weekend and holiday activity is substantially greater than weekdays at almost twice the number of craft as seen in the literature sources listed above. This includes the 1993 study on Mississippi River pools 4 – 10 by Kelly (Kelly, 1993).

Throughout the 8-year span of data collection, the number of flights flown per day type (peak or week) and per year were variable. This inconsistency was adjusted for in analysis by dividing overall numbers by the number of flights. For example, for zone 2 in 1989 there were 41 runabouts observed as beached craft for the sum of the flights. The total number of 41 was then divided by the number of peak day flights for 1989 which was 4. The resulting number is 10.3; the average number of beached runabouts observed at a given time on a peak day for zone 2.

The second data set put to use for analysis was very similar to the first in form and content but contained information on moving craft rather than beached craft. This data was collected the over the same period as the beached data and also includes the year 1993. “Peak day” data was utilized and variable numbers of flights was similarly compensated for. This data set also differs because it contains information about towboats in the moving craft counts. This category however, was eliminated from analysis along with the canoes and “other” boats due to small numbers.

The final set of information that was utilized came from the pool 6 coverage created by UMESC. This coverage contained polygons labeled as backwater, main channel, and main channel border. The polygons comprising the main channel and main channel border areas were divided into zones corresponding with those used by the Boundary Area Commission. The open water acreage amounted to 104.4, 749.86, and 1,236.65 acres for zones 1, 2, and 3 respectively (Table 1).

Table 1. Main channel, main channel border, and total surface area (acres) per zone.

| **Main Channel Border** | **Surface Area (acres)** |
|---|---|
| Zone 1 | 7.27 |
| Zone 2 | 41.29 |
| Zone 3 | 739.33 |
| **Main Channel** | |
| Zone 1 | 26.22 |
| Zone 2 | 293.49 |
| Zone 3 | 439.71 |
| **Totals** | |
| Zone 1 | 104.40 |
| Zone 2 | 749.86 |
| Zone 3 | 1236.65 |

For the purposes of this study the available backwater coverage was not utilized. As mentioned earlier, the main focus was on the main channel and its borders. There are several reasons for this exclusion: (1) the beach coverage information was based on beaches on or adjacent to the main channel, (2) backwater areas are subject to fluctuation in water depth and may be in-accessible and/or un-navigable, (3) even if navigable, determining specifically which boats could go where adds an extra element of variability to calculations. It is simpler and more scientific in this case to leave out data which implement so many uncertainties.

Photography

To familiarize the user with the area, including both river and parks, hotlinks with photos were added to the parks, landings, marinas, and beaches coverages in the GIS. All the pictures were either taken in digital form or later converted to digital form and when necessary edited using Adobe PhotoShop 4.0. Within ArcView a script was developed which combined the hotlink and identify functions. This script allows for display of both the database file information as well as the visual representation the photo provides, and was associated with a button in the user interface.

*Calculations*

Beach Use Capacity

The goal of the beach use capacity calculations was to determine from the amount of useable space, the possible number of camping groups which could use that area. The formula used requires a measurement of the length of a given beach, which is then divided by a high-density standard and a low density standard. These measures represent a range of space that a beaching or camping party would use while occupying an area. The determination to use 100-foot and 150-foot standards for the high and low-density requirements and were based on previous research from two separate studies. The first of these was a 1982 study in Glen Canyon on Lake Powell, (National Park Service, 1989) which placed one campsite per every 100 feet of shoreline. A Lake Mead Carrying Capacity Study (National Park Service, 1980) on the other hand used both the 100-foot density, and 150-

foot density for a more natural experience. Applying the given densities to an area of beach results in a range of potential camping parties that can comfortably occupy a given beach. The resultant number of campers can then be used to calculate the number of boats that would be beached on an island. This was found by multiplying by a range of 1, 2, and 3 boats per party. There are definitive reasons for the use of this particular range of boats. Firstly, a previous study on an enclosed body of water specified 1.25 as the number of boats per party (National Park Service, 1980). Given personal observations and the varying characteristics of pool 6 from the Lake Mead study, this number appeared to be rather low. Instead of designating an arbitrary number, a range was developed to account for variation and error that would result from picking one specific value. The results of those calculations allowed for an estimate of the number of boats that could be beached on a peak day.

Boating Capacity

As of yet, no governing agency of the Mississippi River has established a water surface average standard as a threshold for defining congestion. This lack of specific guidelines made the job of calculating physical boating capacity more challenging. The goal of the project was to develop a model that would accommodate the different types of boats and pool compositions. In order to develop a model that is flexible, regards the safety of boaters, and is applicable to many circumstances density ranges were applied. These density ranges were based on principles from several agencies for different types of watercraft.

Four classifications based on data and use tendencies were developed for this study. The types of watercraft that were taken into consideration were personal watercraft, runabouts, fishing boats/pontoons, and cruisers/houseboats. In the original data, the watercraft were not categorized together, but for ease of analysis were grouped based on size, speed, and approximate spatial needs for operation. As mentioned earlier, “other” boats, canoes and towboats were eliminated from the moving craft portion of the study due to low numbers of observation and infrequent encounters compared to the other more dominant boat types.

Based on the fact that different craft use different areas of available surface water, the main channel and the main channel border were analyzed with regard to the boat types specific to these areas. Three of the four craft type categories were associated with the main channel and main channel border. The exception to this was the Cruiser/Houseboat group (which tends to stick more strictly to the main channel area) due to their purpose of recreational mobility and need for deeper water. The acres of available surface area per zone then differed slightly for this category. Rather than having a total of 104.40 acres for zone 1, 749.86 for zone 2 and 1,236.65 for zone 3, availability calculations were made from 26.22, 293.49, and 439.71 acres respectively (Table 1). After determination of the area of use and corresponding acreage available for maneuvering each craft type category, the acres were then divided by a high and low density spatial estimation. This provided a range of area needed for the number of boats that were occupying the area and allowed us to consider the conflict between different types of boats. Using this methodology the number of potential crafts can be determined for a variety of boat types and can then be checked against the number of actual moving craft with the chi square goodness of fit (Zar, 1996). In this case a standard percentage of expected moving craft types per zone was used. This was based on an average of moving craft observed for all years in each individual zone.

With confidence in the numbers obtained for analysis from the raw data, the next step necessary was to calculate the open water surface area needed for moving watercraft types. Determination of the density ranges used for these calculations was a slightly arbitrary process, however an attempt was made to base the standards of this study to those that would be most suitable for pool 6 given the existing regulations elsewhere.

The most helpful document for making density determinations was a table listing boat space standards throughout the United States (Falk et al., 1992). This information showed the general standards from the Minnesota DNR to be 10 acres/boat, while the similar standard from the Wisconsin DNR was 20 acres per boat. Additional regulations for water-ski boats were provided by the Wisconsin Outdoor Recreation (Wisconsin OR) plan, and were 20 - 40 acres per boat. Several other sources had similar numbers including the Allegheny National Forest which had a water-ski standard of 20 acres per boat. Documentation by Sowman (1987) and Tiacheck (1975) place water-skiing in the 20 - 40 and 40 acres per boat category as well. The devised classification for runabouts, (which generally for this area, are water-ski boats) were based on the above observations. Because the Minnesota and Wisconsin information was particularly suited to this study, the decision was made to take the mean of the general standards (15 acres/boat) to be used as high density standard. This number was less restrictive considering other sources started their ranges at 20 acres per boat. The low-density number then, was placed at 40 acres per boat. The literature, including the Wisconsin OR Plan, agreed that this was a suitable number.

Ranges for the fishing/pontoon category were similarly determined. The Wisconsin OR Plan detailed a value of 8 acres/boat for fishing craft. Tichacek (1975) and the Louisiana Park Recreation Commission also back this level of usage. Sowman (1987) on the other hand proposed a range of 1.2 - 10 boats per acre while the general Army Corps of Engineer standard is 1 acre per boat. A range of 1 – 10 boats per acre was therefore appropriated as the fishing/pontoon group standards. This appears to be relevant given the fact that generally speaking, both of these craft are slow moving, and overall require less space than a water-skier does.

Unfortunately, no specific craft standards were available for houseboats, cruisers, or personal watercraft. It was therefore necessary to devise standards from those which were available based on knowledge of the recreation area and boat types. Personal watercraft, due to their great mobility, and capabilities to reach high speeds very quickly were given the same 15 – 40 acre per boat acreage range as runabouts. According to the U.S. Coast Guard personal watercraft such as jet skis account for 36 percent of all boating accidents and are involved in 40 percent of all boating related injuries (Morgan, 1997).

Although these are much smaller craft than any of the others, their ability to turn fast, tendency to jump waves and do tricks (which can throw the users off of the craft), requires that they have similar space as water-skiers for safety reasons.

The final category of watercraft was composed of the combination of cruisers and houseboats. Both of these boat types have a tendency to serve the primary purpose of movement, or getting to a particular destination. They seldom require a lot of turning, and therefore the range determined for these craft was 10 – 20 acres per boat. This is a derivation of the general standards from both the Minnesota and Wisconsin DNR respectively, and therefore gives these craft a little movement flexibility while suitably representing them. A summary of the values used for high and low density determinations for each craft type is presented in Table 2.

Table 2. A summary of watercraft types and the corresponding high and low density per acre standards.

| Watercraft Type | High Density | Low Density |
|---|---|---|
| Runabout | 15 | 40 |
| Personal Watercraft | 15 | 40 |
| Fishing/Pontoon | 1 | 10 |
| Cruiser/Houseboat | 10 | 20 |

## Results

### *Boating Capacity*

As mentioned previously, pool 6 was delineated into 3 distinct zones due to the unique characteristics inherent in each section. It was therefore necessary to group observations and calculations using the same delineations. Distribution of observed moving craft per type per zone over the course of the study is one such useful calculation. For example, assuming there were 231 total moving craft observed for all years within zone 1, and 77 of those were runabouts, it was calculated runabouts comprised 33% of the total moving craft for zone 1 all years. The percentages of moving craft can be viewed by craft type for each zone in figures 3, 4, and 5.

Figure 3. Distribution of moving craft by type for zone 1.

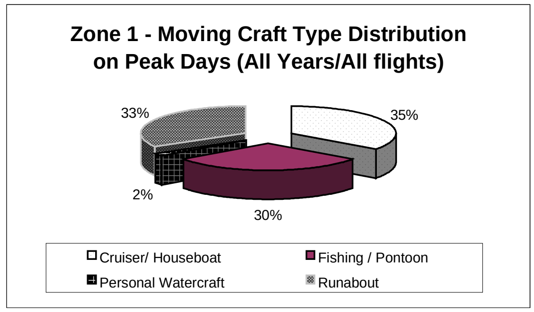



Figure 4. Distribution of moving craft by type for zone 2.

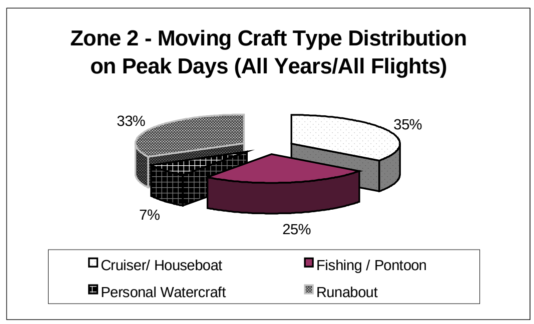
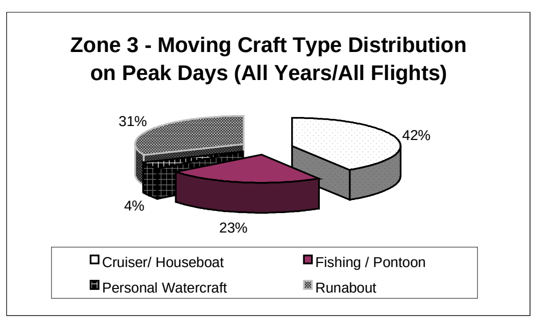



Figure 5. Distribution of moving craft by type for zone 3.




The expected number of moving craft was calculated for the purpose of statistical analysis. In order to derive an expected number of moving craft, it was necessary to determine the sum total of moving craft for each year for each zone. For example in zone 1 in 1989 there were 2.5 runabouts, 0 personal watercraft, 4 fishing/pontoon, and 2.8 cruiser/houseboats observed per flight for a grand total of 9.3 moving watercraft. Table 3 represents moving craft totals per year and zone without regard to craft type.

Table 3. Sum of moving craft without regard to watercraft per zone per year.

| | | 1989 | 1993 | 1995 | 1997 |
|---|---|---|---|---|---|
| **Zone 1** | Total Moving Craft | 9.3 | 4.9 | 5.5 | 6.0 |
| **Zone 2** | Total Moving Craft | 22.3 | 6.3 | 19.1 | 30.7 |
| **Zone 3** | Total Moving Craft | 21.5 | 9.4 | 21.0 | 20.8 |

Once the sum total of moving craft observed for each flight was calculated, it was possible to continue the expected value calculations. Based on the total moving watercraft for a given zone in a given year, it was possible to determine how many watercraft of a particular type should be seen. Because of great variability in craft numbers due to seasonal characteristics and water conditions, our proposed or expected number of watercraft was based on the overall percentage each watercraft type occupied per zone (Table 4). The hypothesized number of observed craft was then found simply by multiplying the total moving craft for a zone and year by the percentage occupation of the craft type for that zone. So continuing with the previous example, 9.3 moving craft were observed in zone 1 in 1989. When determining the number of expected runabouts, the observed 9.3 would be multiplied by the percent occupation, which is 33%. This would yield an expected number 3.0 boats that would be observed at a given time or flight for that year and zone (Figures 3,4,5). The results of these calculations for all zones, craft types and years are presented in Table 4. Table 5 shows the actual numbers for comparison.

Table 4. The expected number of each type of watercraft that could be seen in a flight for each year (observation).

| | Expected # boats/flight | | | |
|---|---|---|---|---|
| **ZONE 1** | **1989** | **1993** | **1995** | **1997** |
| Runabout | 3.0 | 1.6 | 1.8 | 1.9 |
| Personal Watercraft | 0.2 | 0.1 | 0.1 | 0.1 |
| Fishing/Pontoon | 2.6 | 1.4 | 1.5 | 1.7 |
| Cruiser/Houseboat | 3.1 | 1.6 | 1.8 | 2.0 |
| **ZONE 2** | **1989** | **1993** | **1995** | **1997** |
| Runabout | 6.9 | 1.9 | 5.9 | 9.5 |
| Personal Watercraft | 1.6 | 0.4 | 1.3 | 2.1 |
| Fishing/Pontoon | 5.3 | 1.5 | 4.6 | 7.4 |
| Cruiser/Houseboat | 7.6 | 2.1 | 6.5 | 10.4 |
| **ZONE 3** | **1989** | **1993** | **1995** | **1997** |
| Runabout | 6.5 | 2.8 | 6.3 | 6.3 |
| Personal Watercraft | 0.9 | 0.4 | 0.8 | 0.8 |
| Fishing/Pontoon | 4.7 | 2.1 | 4.6 | 4.6 |
| Cruiser/Houseboat | 8.6 | 3.8 | 8.4 | 8.3 |

Table 5. Actual moving craft observed per flight per year.

| | Actual # boats/flight | | | |
|---|---|---|---|---|
| **ZONE 1** | **1989** | **1993** | **1995** | **1997** |
| Runabout | 2.5 | 1.1 | 1.9 | 2.0 |
| Personal Watercraft | 0.0 | 0.1 | 0.0 | 0.5 |
| Fishing/Pontoon | 4.0 | 1.1 | 1.4 | 1.7 |
| Cruiser/Houseboat | 2.8 | 2.5 | 2.3 | 1.8 |
| **ZONE2** | **1989** | **1993** | **1995** | **1997** |
| Runabout | 10.5 | 1.6 | 4.9 | 9.0 |
| Personal Watercraft | 0.0 | 0.0 | 1.6 | 3.7 |
| Fishing/Pontoon | 7.5 | 1.5 | 5.0 | 5.3 |
| Cruiser/Houseboat | 4.3 | 3.1 | 7.6 | 12.7 |
| **ZONE 3** | **1989** | **1993** | **1995** | **1997** |
| Runabout | 7.8 | 2.8 | 5.5 | 5.8 |
| Personal Watercraft | 0.0 | 0.0 | 1.9 | 2.0 |
| Fishing/Pontoon | 5.5 | 1.8 | 5.0 | 4.2 |
| Cruiser/Houseboat | 8.3 | 4.9 | 8.6 | 8.8 |

With an expected number for all watercraft types in all zones for all years, (as derived and presented in Table 4) and the actual numbers (presented in Table 5) it was possible to use a chi square goodness of fit statistical analysis to determine if the observed values and theoretical values were relatively equal. The null hypothesis was that the observed moving craft numbers for the 4 vessel classifications were equal to the expected numbers. The calculations were based on $\alpha = 0.05$ and 3 degrees of freedom. The chi square table value was determined to be 7.815. In all cases there was no statistical significance observed (Table 6).

Table 6. A representation of the probabilities for each zone and each year obtained from the chi square goodness of fit calculation performed on the actual combined moving craft per flight results.

| **Chi Square Goodness of Fit Probability Statistics** | | | | |
|---|---|---|---|---|
| | **1989** | **1993** | **1995** | **1997** |
| **Zone 1** | .990<P<.995 | .50<P<.75 | .95<P<.975 | .50<P<.75 |
| **Zone 2** | .05<P<.10 | .50<P<.75 | .90<P<.95 | .50<P<.75 |
| **Zone 3** | .50<P<.75 | .50<P<.75 | .50<P<.76 | .50<P<.75 |

In addition to the chi square goodness of fit calculations, a three-factor analysis of variance without replication was performed on the data. The results determined that there was no effect of any of the three fixed factors (year, zone, and watercraft type) on the observed numbers of moving craft ($P > 0.25$).

In a separate calculation, a homogeneity chi-square test (Zar, 1996) was preformed on the yearly moving and beached craft data for peak days. This test compared each year to a hypothesized 68% for moving craft and 32% for beached craft which was noted by the Minnesota-Wisconsin Boundary Area Commission for pools 4 – 10 (1989). Test results revealed the observed craft for 1989, 1995, and 1997 did not fit these ratios. The only year that did fit the hypothesized numbers was 1993. Percentage representations of the beached and moving craft data also show similar findings and may be viewed in Table 7.

Table 7. Percentage of moving and beached craft per year.

| **Year** | **% Moving** | **% Beached** |
|---|---|---|
| 1989 | 49 | 51 |
| 1993 | 68 | 32 |
| 1995 | 59 | 41 |
| 1997 | 53 | 47 |
| Average | 57.4 | 42.6 |

Once satisfaction with the data set was achieved, it was then possible to analyze the physical boating capacity for the pool. As mentioned previously, ranges of numbers were used to give flexibility in estimation of capacity, accounting for both high and low density situations. The governing agencies consulted to determine density ranges included the Wisconsin Department of Natural Resources (WiDNR), the Minnesota Department of Natural Resources (MnDNR), and the Army Corps of Engineers. The ranges developed were based on these numbers and adjusted given the reasons discussed in the methods section (Table 2).

After analysis was completed on the four craft type categories for all years it was determined that the number of acres needed, using the high-density scale, did not exceed the number of acres available in the main channel and main channel border calculations. This held true for all zones within pool 6. The number of acres required for the cruisers and houseboats however, exceeded the available acreage in zone 1 for the main channel in 1989, but not in any other year or any other zone.

The low density standard required a larger estimate of acreage per type of craft. Still, according to the acreage estimations, and taking into account the culmination of all boat types for the area, only zone 1 exceeded it's capacity for boating in 1989 and also again in 1997. All calculations of required acreage show 1993 as having the lowest density of watercraft and 1989 generally had the highest density calculations with 1997 following closely behind.

*Beach Use*

As detailed earlier, a high-density standard of 100 feet of space per camping group and a low-density standard of 150 feet per camping group were used to analyze beach capacity in pool 6. It was determined that the smallest island, 182 feet in length, at a density standard of 100 feet per group can support 1.82 groups and 1.21 groups at a 150 foot density standard. A range of 1-3 boats per group was used to estimate a capacity number of beached craft. With those estimations, 2 groups would beach 2 - 6 boats. For the larger spatial allotment (1.21 groups) and slightly less crowded, the number of beached craft would range from 1 to almost 4 boats. At the other end of the scale, the largest island according to our beach coverage was able to hold 29.6 groups at 100 feet shoreline for a group, and 19.7 groups at 150 feet per party. The number of beached craft for 29.6 groups would range from 28 - 88 boats, while the estimate of 19.7 groups should potentially accommodate a smaller range of 20 - 59 boats.

When compared with results of the aerial surveys the sum total beached craft number was adjusted by dividing the raw data beached craft totals by the number of aerial surveys as done in the boating capacity analysis. This takes into consideration a variation in the number of surveys from year to year. The two previously mentioned islands were found to be greatly under utilized when comparing calculated beached craft to observed beached craft. The smallest island was the closest of the two to its projected theoretical usage levels of 4 beached craft in 1989, 1 in 1993, 1 in 1995, and 0 recorded for 1997. This places the group estimation at more than one, but less than 4. The calculated range as mentioned previously was 1-2 groups dependent on density standard.

The calculations for the largest and smallest islands are the extremes for all the islands within pool 6. A summation of the number of groups for all the islands at the low density standard was calculated and then divided by the number of flights and total number of islands which resulted in an average number of 5.05 groups per beach with 150 feet of space allotted. The process was repeated for the high-density standard which resulted in an average of 7.59 groups per 100 feet of beach space. This allows for a range of 5 - 15 craft per beach based on 1 - 3 boats per group with 150 feet of camping space, and 8 - 23 boats based on 1 - 3 boats per group at a higher density measurement of 100 feet.

According to the Boundary Area Commission data for all survey flights and years of study there was a total of 896 beached craft during peak days for all of pool 6. Given that 26 flights were flown to gather the data, and there are 28 beaches in the pool, an average of 1.23 boats per flight per beach resulted irregardless of beach size.

A one sample t test was performed on the beached craft data for each peak flight during all years to measure how far the sample distribution of 896 craft over 26 flight and 28 islands deviates from the theoretical distribution which is based on island length. The lowest theoretical boat value of 5 boats per 150-foot long recreational area was first tested. When considering 5 boats as the test value, the null hypotheses stated that the mean number of boats per island was greater than or equal to the expected test value of 5 ($H_o$: Population Mean >= 5). With 25 degrees of freedom and $\alpha$= 1, P < .0005 and the null hypothesis was rejected. Therefore less than 5 boats per island were observed for peak day flights when it was expected that this minimum number of craft could occupy a 150-foot space.

## Discussion

### *Beach Use*

Analysis of beaches within pool 6 found that generally speaking, the beaches are being under utilized. This included analysis of the smallest and largest islands which are the extremes of the study. An average 1.23 craft per beach was noted by this study. This "real world" estimate of boats is less than the minimum number of craft established for both density standards. It also implies an average under-use of beach space by boaters. Because this number is simply an average, it is important to keep in mind that it is not beach specific, and therefore does not take into account beach attributes and size. This mode of predicting use also assumes that beaches are equally utilized, and this may not be an accurate assumption.

### *Boating Capacity*

Given the results of comparing beached and moving craft percentages in this pool, (Table 7) it was evident that great yearly variation is inherent. Because the inability to predict variation from one year to the next, the observed moving craft numbers were used for analysis. The raw data was analyzed to determine the number of moving craft based on zonal delineations and years the aerial surveys were taken. The resulting numbers of craft were then applied to a formula which estimated, based on a flexible scale, the number of acres required for certain categories of craft. Based on the results of estimated acreage ranges for craft type, it can be concluded that use of the river was not exceeding its physical capacity within the main channel and the main channel border. The moving craft category of cruisers/houseboats was closer to capacity within zone 1, than all other craft for all other zones. This may be attributed to the fact that the category of cruisers and houseboats was determined to utilized only the main channel the majority of the time. The high number of moving craft in zone 1 could also signify a rush of boats or waiting line at the Lock and Dam. Exceedence in 1989 on the other hand may be due to the unseasonably warm and dry year, which made boating conditions optimal.

### *Considerations*

There was a great deal of difficulty associated with a project of this nature. Some of the problems have been touched upon in previous sections of the paper. The most obvious and difficult of these was finding suitable methods on how to develop a model for the physical boating capacity study. Much of the difficulty comes from the great variation from one water body to the next, which makes determination of formulas from these sources seem rather arbitrary. There are also a large number of variables that can be taken into account, and trying to work with them all results in an extremely complex analysis situation. Values, and social data have been proven inconclusive in countless other studies and likely would have in this study too. The study on Lake Mead for example collected social data that was so inconclusive it could not be used for analysis (National Park Service, 1980). Cost and time constraints were also a factor in eliminating this type of data collection and analysis. Therefore, studies of recreational craft types and the amount of space available to them that would allow for a safe recreational experience took priority.

In the literature that was consulted to develop the model used for analysis, there was a large variance in the amount of acreage that was estimated for the various watercrafts. This is due to the fact that this information was collected from all across the U.S. and took into account various water body types. Some literature was collected that contained calculations for boating capacity and beach recreation capacity however, none of this information was specific to the Mississippi River, which can vary greatly in it's composition even within pools. A study involving recreational boating capacity on inland bays by the University of Delaware gave the best examples of how to calculate capacity (Falk et al, 1992). This study lists the acreage estimations from several different agencies. However, even this source was lacking craft specific information for cruisers, houseboats, pontoons, and personal watercraft. Conformity between the numbers which were sometimes ranges, and other times singular acreage standards was also not present. Included in the agencies listed were the WiDNR, the MnDNR and Army Corps of Engineers, which are the governing agencies for this area of the Mississippi River and pool 6 in particular. With the idea that agencies would have the best information dealing with boating capacities for the Mississippi River, their numbers were modified to develop the density ranges used in this study. An attempt was made to contact members of each of the different agencies to find out more specifics, including how the numbers were determined, however this was unsuccessful. The ranges were developed in order to add flexibility to the model allowing for more or less crowded situations, but allow for any future discrepancies in the estimates.

Another problem encountered was related to watercraft classification. Because classifications were based mainly on use the determination was made to calculate and consider personal watercraft separately from other craft. This is attributed to the fact that personal watercraft have the ability to travel unlike any other craft (through backwater areas, although only the main channel and border use was considered here) in this study. Additionally, personal watercraft were not present in any data prior to 1993 and therefore had a small impact on the chi square tests conducted.

Along similar lines, absence of other types of craft in this study adds a small element of variability that was not accounted for. Towboats and canoes are seen less frequently than other boat types on this pool of the Mississippi and comprise an extremely low percentage of the craft that were observed for this study. It is for this reason of significance that they were eliminated from this study. Although data on barges was unavailable, this too is another factor that requires more attention.

The subject of beach area calculation, is an additional item that should be more thoroughly visited. The methodology used, which measured the length of the beach, excludes several factors and implies others. This model is highly dependent on the accuracy of the length data which in this scenario may have caused some misrepresentation. It also expects that people will disperse themselves evenly and linearly when this may not always be the case. Every group cannot be expected to regard others space or privacy similarly. In addition, group size and type may play a role in this as well as the depth of the beach; these are two factors that were not accounted for. Other influences that were not addressed in this specific analysis include boat type and access problems. Certain boats may or may not be able to successfully access and "park" themselves depending on the characteristics of the beach. This is something that can vary seasonally due to water depth and sedimentation and therefore could not realistically be examined.

Once the data were properly analyzed and the problems that were encountered were given consideration, it was possible to look at the information on a spatial level by implementing it into a GIS. Up until this point, in neither the beach recreational use analysis nor the boating capacity, did the study take into consideration any sort of social value of the variables. However, once contained within a GIS it was possible to buffer beach polygons for distances to take into consideration how near landings and other facilities were. It is hypothesized that this could be a determining factor in which beaches were most often used. Other studies have shown "distribution of boats is directly related to lake services (National Park Service, 1982)." Some marinas offer services such as gas, food, ice, repairs, and temporary dockage. Being close to these particular amenities would be more desirable than beaches that may not be within a given distance of a marina.

In addition to taking into consideration amenities of nearby landings and marinas a GIS made it possible to represent analysis findings within a view. Rather than looking strictly at numbers, visual representation can aid managers in decision making and give insight to ideas and patterns that would otherwise be un-observable.

### *Future Studies and Management Implications*

Additional research and analysis in this study could have provided information and views on the current situation. Time of day information, had it been consistently complete in the data set could have been utilized to further pinpoint peak periods and look at distribution for different boat types. Information on launch rates and types from marinas, and boat ramps within the pool could also have been utilized to determine facility capacity and the approximate percentage contribution of each to river traffic. This approach was used in another Mississippi River study where the purpose was to develop a means for manipulation of boat access development and resulting effects on summer boating patterns (Kelly, 1993). The same study also interviewed boaters which would prove to be valuable as well in determining the views of a larger population of boaters, and the effects of the current river situation on their actions and enjoyment. An origin-destination model could also be established with survey information, and could help to determine the areas that are most heavily populated, or are most popular as a target. The heavily populated areas in particular could then be further analyzed for cases where the capacity is not within the devised limits. Determination of future trends based on the current information is another option of study that was not carried out this project but could easily be considered.

Overall, as numbers of boaters increase on the river, comfort, safety and solitude collide. Determining the capacity, and current levels of use can be found scientifically, however when it comes to establishing optimum number of users subjective notions and values come into play (Heberlein, 1986). This is something that may also be established in the future and could be aided by management objectives. Once the optimum number of users is determined, measures aimed at maintaining those levels may be undertaken. These may include encouragement of use during non- peak times, restricting parking space, closing ramps or limiting use on peak weekends.

Other management suggestions for this area, considering that it is not physically over capacity relate more to boater behavior. Conflict between certain boat types in narrow areas or specific spaces may be leading to the observation that the area is exceeding capacity. Enforcement and reminders of safety while boating may be all that is required at this point in time for this area. This approach was utilized for Lake Powell where speed limits and safe operating codes were recommended to reduce hazards and encourage a change in behavior (National Park Service, 1982). Zoning for specific uses is also an option that will end conflict between groups, but is insignificant when it comes to stopping problems that occur within boating categories or groups. Falk et al, (Falk et al, 1992) also recommends boater safety education to fill this gap.

Although percentages of river users in regards to density may not be useful to managers by itself, when associated with a set of evaluative standards and management goals the maximum use levels for a variety of conditions can be determined (Tarrant, 1996). The fact that this portion of the Mississippi River has no standards or goals however makes it difficult to make management implications based on the results of this study. Still, being aware of the "change in the quality and quantity of recreational use can be useful in planning efforts and can lead to specific management actions and policies (Robertson, 1994)." With a growing base of information and completed analysis, changes may now be determined and managed.

## Conclusion

In a book about recreational carrying capacity, Thomas Heberlein and Bo Shelby (Heberlein, 1986) appear to understand well, the nature of these studies. They seemed to be speaking particularly to this situation when they said " often there are no widely shared and acceptable values about safety, no universal straightforward sampling techniques, and physiological attributes are individualistic and complex at best." Aside from all the complexities, this study attempted to find a method of analysis and display for physical boating and beach capacity.

Although the hypothesis that pool 6 of the Mississippi river was at or above safe recreational capacity limits based on the views and observations of local boaters, the physical capacity evidence shows that this idea was unfounded. It is important to keep in mind that this is true only for the current situation, data, and methods of analysis. The need for continued research, observation, and improved methodology still remains. Recreational changes may occur quickly and it is best to plan ahead rather than be caught trying to make drastic changes that may not be well accepted by the public. Alternative recreation, the focus of second portion of this project, is also an important option to consider if boating appears to be unsafe or does not meet the users expectations. There are various coping mechanisms to crowding, and it has been suggested that some boaters will avoid specific areas due to high use levels (Robertson, 1994). The database that was created kept this in mind and gave recreationalists the option of doing other activities while still being near the river.

" In 1996, the U.S. Coast Guard reported that 4442 persons were injured and 709 persons died in boating related incidents in the United States. (Department of Transportation, 1998)." Although this project and model only dealt with a small area, pool 6 of the Upper Mississippi River, it is still important to realize the need for safety measures to curb the number of people getting hurt. The model that was developed for this study kept boater safety in mind by looking at the physical aspects of the boat movement potential and the space required. Once analysis and calculations were completed, GIS was used for quantification and visualization purposes. Putting this information into an easily accessible and usable system makes understanding current use levels more feasible. Overall, GIS can be a very powerful tool for analysis and spatial display of information and is an asset when used by managers and visitors alike.

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