Balancing Recreational Use:
Lessons Learned from Lake Ripley's Recreational Carrying Capacity Study
Paul Dearlove, Lake Ripley Management District
Presented at *Changing Lakes, Changing Policy: a Workshop for Lake Communities*
February 13, 2010

Recreational Carrying Capacity Concepts

Background
The concept of carrying capacity developed within the field of ecology where it was applied to wildlife management. It was originally used to determine the number of animals that could be maintained in a given habitat before undue biological or ecological impacts occurred. Carrying capacity was later applied to park management as increasing visitor numbers became a concern. This added human component broadened the concept of carrying capacity to include both ecological and social components.

What is "carrying capacity?"
Carrying capacity can be thought of as a threshold that, if exceeded, would lead to an undesirable set of conditions or problems. Carrying capacity can pertain to everything from pollutant loading, to habitat loss, to crowding. In our case, the threshold of concern relates to boat traffic—both in terms of its density and its mix of activities or speeds.

What measures can be used to define it?
A number of measures, or indicators, can be used to establish carrying-capacity thresholds. These indicators may be evaluated in isolation or in combination, depending on the particular problems needing attention or management goals pursued. Examples include:

- User perceptions of excessive crowding
- Public safety concerns
- Ecological or water quality impacts
- Economic and property value impacts (as users and home buyers seek out more optimal conditions elsewhere)

Is it possible to accurately measure "social" carrying capacity?
There is no easy answer to this question. One cannot just sit on a dock, count boats, and form a reasonable conclusion about carrying capacity. Rather, it requires assessing lake-user perceptions under a range of boating scenarios. Such perceptions can vary widely depending on the lake in question, the type and speed of boats using the lake, and the particular mix of activities pursued at any given time. It ultimately comes down to the tolerance levels, value judgments, experiences and expectations of each individual or user group. Since each lake and community is unique, it becomes problematic to find a one-size-fits-all formula that represents every situation. The best we can do—short of trying to directly measure these social factors on all our lakes—is to apply published figures and formulas from the literature that best approximate our particular scenarios.

What factors are used to derive a capacity estimate?
The literature provides many examples of how to determine the amount of area a given lake user needs to feel safe and minimally affected by other users. Research has also demonstrated the depth at which certain boating behaviors can negatively impact water quality and shallow-water ecology. Regardless of lake, there becomes a point at which a finite resource cannot safely or environmentally accommodate any more activity. The challenge is to identify that point with sufficient credibility to justify policy action.

Due to its complexity, carrying capacity is often reported in the form of a range of estimates, as opposed to an optimum or maximum value. Capacity will vary from lake to lake depending on local lake-use behavior, user preferences, and resource-management goals. Typical measures of analysis used to derive carrying capacity include the following:

1) **Lake-use characteristics**. Evaluating lake-use patterns involves collecting sufficient data to document how the lake is being used, and by whom. Various techniques are used to estimate the number and types of boats in use during peak and non-peak times, and the distribution of use between shoreline residents and visitors. Methods include on-the-water surveying, on-the-ground contact surveys, mail-back surveys, aerial flyovers, and parking lot vehicle counts.

2) **Usable lake area**. The amount of lake surface that can support a mix of boating activities is most often calculated by subtracting a *shoreline buffer zone* of predetermined width from the total acreage of the lake. This zone is generally off limits to high-speed boating due to shallow water depths, piers, swim rafts and other navigational hazards. Buffer zones can also include areas around emergent aquatic vegetation, marinas, public swimming beaches, and underwater obstructions.

3) **Boating density standards**. Boat density standards are represented in surface acres per type of watercraft or activity. Optimum densities depend on users' preferred setting types and site-specific attributes. Some studies provide aggregate densities, which are applicable to the entire lake and for a typical mix of uses. Others specify an optimum density for each type of watercraft or activity, or for particular areas of the lake.

4) **Riparian use rate**. This is a measure of the estimated proportion of lake use originating from private lakeshore facilities versus public access sites. For boats moored at existing shoreline developments, studies have estimated peak-use rates ranging from 3.6% (ERM, 2004) to 25% (Jaakson et al., 1990). On-lake boat counts combined with public launch data can often be used to generate more refined, lake-specific estimates.

5) **Boater's perceptions of crowding**. This social factor is measured through user surveys and interviews that address various crowding scenarios. Crowding is typically measured on either a 5- or 9-point Likert-type scale. Digitally-enhanced photographs can also be used to gauge perceptions of crowding.

Definition of Terms

Usable Lake Area

That part of the lake (measured in acres) that can support a mix of boating activities. Portions that are restricted by boat type or speed, or where conditions preclude safe boating, are subtracted from the total lake-surface area to arrive at a "usable" lake area. It is generally accepted that any water less than 5 feet in depth be included in this group.

Example: There is a 1,000 acre lake with 10,000 feet of shoreline, a 200-ft from shore no-wake zone, and 23 acres of water less than 5-ft. deep. The usable lake area is equal to 1,000 acres – (10,000 feet) x (200 feet)/ (43,560 sq. ft./acre) – 23 acres…. or 1,000 acres – 46 acres – 23 acres = 931 acres of usable lake area.

Area per Boat (or Boating Density Standard)

Describes the amount of lake surface a boat requires for safe operation at a certain speed or when engaged in a particular activity. A range of published area requirements can be found in the literature. Areas can be adjusted based on social perceptions held by particular user groups. For example, a fast-moving boat towing a skier might require 20 acres for safe operation and minimal interference. A pontoon boat out for a slow cruise might only require 7 acres per boat. An angler anchored outside a 200-ft. no-wake zone might require at little as 3 acres.

Area Required per Average Boat (or Aggregate Boating Density Standard)

This is a weighted average of the area-per-boat requirements for all boats actively using the lake. Boats are likely to be operating at different speeds while engaged in different activities. These different speeds and activities have unique area requirements. The weighted average is the number of each boat type (defined by its particular speed or activity category), times its area-per-boat requirement, and then divided by the total number of boats.

Example: If there are 10 boats engaged in a high-speed activity requiring 20 acres each, and 5 boats engaged in a passive activity requiring 5 acres each, then the weighted average would be: (10 boats x 20 acres/boat) + (5 boats x 5 acres/boat) / 15 boats = (200 acres + 25 acres) / 15 boats = 15 acres/boat.

Boat Carrying Capacity

This is the number of boats that can reasonably operate on the lake at the same time. It may be based on safety, environmental and/or other factors. It is determined by dividing the usable lake area by the sum of the areas required by each type of boat or boating activity using the lake.

Example: If the lake has a usable area of 1,000 acres, and all boats are presently engaged in an activity requiring 20 acres per boat, then the boat carrying capacity is 1,000 acres / (20 acres/boat) = 50 boats. Carrying capacity is often expressed as a percentage of the optimum boating density during peak use (# of boats on lake during peak use / optimum boating density x 100).

Shoreline Development Factor (SDF)

SDF is a size-independent description of lake shape that relates shoreline length to the circumference of a circle with the same area as the lake. SDF is equal to the shoreline length divided by the circumference of a circle with an area equal to the lake. A perfectly circular lake would have a SDF of 1.0. Higher values may imply greater safety risks as well as greater potential for adverse ecological consequences (i.e., closer proximity of shoreline, and more hidden corners and narrow thoroughfares that contribute to crowding or unsafe conditions).

Example: A lake is 332 acres and has 15,631 feet of shoreline. 332 acres x 43,560 sq. ft./acre = 14,461,920 sq. ft. Next, determine the radius (r) of a circle with the same area: 14,461,920 sq. ft. = 3.14159 x r^2, or 14,461,920 sq. ft./3.14159 = r^2, or 4,603,375 sq. ft. = r^2, or r = √4,603,920 sq. ft., or r = 2,145 feet. Now solve for the circumference of the circle to get the theoretical shoreline length: 2 x 3.14159 x 2,145 ft. = 13,480 ft. Then, SDF = actual shoreline/theoretical shoreline, or 15,631 ft./13,480 ft. = 1.16.

Shallowness Ratio Factor (SRF)

SRF is a description of lake shallowness. It is calculated by dividing the area of a lake less than 5-ft. deep by total area. High ratios imply shallow lakes and greater vulnerability to boating impacts.

Little Congestion Lake, WI

Lake size:	300 acres
Restricted areas:	50 acres (no-wake areas + buoyed swim zones + shallow water depths)
Boat count:	22 total boats (peak-use average)
Wake-producing/high-intensity uses:	25% of total (peak-use average)
Slow-moving/stationary/passive uses:	75% of total (peak-use average)
Optimal boating densities:	9 – 25 acres/boat
Avg. peak-use boat trailer count at launch:	13 boat trailers

Carrying Capacity Assessment (for average peak-use conditions)

1. Usable surface area: 250 acres
   (300 total acres – 50 restricted = 250)

2. Optimal boating density for observed user mix: 13 acres/boat
   (25 – 9 = 16-pt scale… 16 X 0.25 = 4… 9 + 4 = 13)

3. Estimated carrying capacity for observed user mix: 19 boats
   (250 usable acres/13 acres per boat = 19)

4. Observed carrying capacity (%): 116%
   (22 avg. total boats/19 est. capacity X 100 = 116)

5. Riparian boat contribution (%): 41%
   (22 avg. total boats – 13 boat trailers = 9… 9/22 X 100 = 41)

Tools for Managing Lake Use

There are multiple strategies that can address crowding and user conflicts on lakes. Many involve working with local governmental bodies to enact special boating ordinances, subject to DNR approval. Due to the inherent controversy associated with proposing new boating regulations, care must be taken to ensure that such action is well justified. Any strategy should strive to achieve a fair and balanced approach to managing lake use—one that recognizes community priorities and the physical limitations of the water body.

Examples of specific tools:

1) **Surface zoning.** Make areas of a lake available to only certain uses. Mark those areas with approved navigational buoys. Examples include boat-restricted swimming areas, no-motor locations, and slow-no-wake zones.

2) **Speed limits.** Must be applied to all boat types to be legally enforceable. Slower moving boats require less area, generate smaller wakes, and create fewer user conflicts. Actual speed can be difficult to gauge, which can lead to compliance and enforcement challenges.

3) **Time zoning.** Allocate timeframes when certain activities can occur. For example, special morning and evening slow-no-wake times can be reserved for quieter, more passive activities.

4) **Boat-launch restrictions.** Place a limit on the number of boats that can launch and therefore operate on the lake at one time. This may only be possible when there is a control point for boat access. Strategies include limiting parking spaces for cars and trailers, and designing launch facilities to accommodate only a certain type and amount of traffic flow.

5) **Traffic-flow policies.** Adopt boating rules that direct the flow of faster-moving traffic in a clock-wise or counter clock-wise pattern around the lake. This allows for greater predictability, and, consequently, more boats can use the lake at one time.

6) **Shoreland zoning.** Adopt land-use controls to manage the amount of development and boating access around the lake. Examples include restricting "keyhole" subdivisions that transfer private lake-access and boat-mooring rights to back lots located off the water. Limiting the number of public access points and their parking capacities is another example. However, the latter will disproportionately penalize visitors over riparian property owners.

7) **Launch fees.** Increase boat-launching fees to the maximum allowable rates as set forth in Wis. Stats. §30.77. Extra revenues can be reinvested back into maintaining the facility. Increased cost burdens may alleviate some boating pressure, but will disproportionately impact non-riparian visitors and lower-income users.

8) **Enforcement.** An increased law-enforcement presence would help improve safety and rule compliance, but would not control the number of boats on the lake.

9) **Monitoring.** Continued monitoring of boating activities is necessary to document long-term patterns and trends. This information can then used to evaluate carrying capacity and advocate for policy changes.

Quotes

"Free public resources like water may inevitably be trampled by too many users, by a single, well-organized group, or by inappropriate technology that simply overwhelms other uses and sometimes destroys the resource itself." (Lowell Klessig, 2001)

"The ability of a lake to accommodate a given number or users and mixed recreational uses depends on the compatibility of those uses." (William Jones, 1996)

"Carrying capacity should not be perceived as a measure but instead as a range of estimates which also reflects the demands of users and the level of environmental quality that they are willing to accept." (Jaakson et al., 1989)

"People often continue (or learn) to be satisfied even when conditions become more crowded, often to the detriment of the resource. This phenomenon results in more bodies of water being managed for higher densities. The acceptance of crowded conditions results in fewer opportunities to manage for lower use levels." (Dudiak et al., 2002)

"Perhaps the commonest circumstance under which societies fail to perceive a problem is when it takes the form of a slow trend concealed by wide up-and-down fluctuations… Politicians use the term "creeping normalcy" to refer to such slow trends concealed within noisy fluctuations. If the economy, schools, traffic congestion, or anything else is deteriorating only slowly, it's difficult to recognize that each successive year is on the average slightly worse than the year before, so one's baseline standard for what constitutes "normalcy" shifts gradually and imperceptibly… Another term related to creeping normalcy is "landscape amnesia": forgetting how different the surrounding landscape looked 50 years ago, because the change from year to year has been so gradual." (Jared Diamond, *Collapse,* 2005)

"While a local boating regulation need not solve all of the watercraft-related problems facing a lake community, a regulation must reflect a thoughtful effort to address an actual threat to public health, safety, welfare or the environment. Although the Courts will generally defer to the policy decisions of elected officials, they may not sustain regulations on the free use of public waters which impose unnecessary restrictions on one type of watercraft, if other watercraft types present similar threats to public health and safety and environmental resources." (William O'Connor, 1998)

Relevant Literature

Ashton, P. G. 1971. *Recreational boating capacity: A preliminary study of three heavily used lakes in southeastern Michigan*. Doctoral dissertation, Michigan State University. Dissertation Abstracts International*, 32*, 03-B (UMI No. AAI7123158).

NOTES: Personal interviews of boaters and self-administered questionnaires sent to shoreline property owners were used to evaluate user attitudes toward different levels of lake use. Aerial photography at one-hour intervals was used to quantify level of use. Based on these relationships, a range of satisfaction levels for various numbers/groupings of boaters was used to develop carrying capacity limits.

Boating Uses	**Suggested Densities**
All uses combined in Cass Lake	5 to 9 acres/boat
All uses combined in Orchard Lake	4 to 9 acres/boat
All uses combined in Union Lake	6 to 11 acres/boat

Asplund, Timothy R. 1996. *Impacts of motor boats on water quality in Wisconsin lakes.* Wisconsin Department of Natural Resources, Bureau of Research.

Asplund, Timothy R. 1997. *Effects of motor boats on submerged aquatic macrophytes.* Journal of Lake and Reservoir Management, 13(1): 1-12.

Asplund, Timothy R. 2000. *The Effects of Motorized Watercraft on Aquatic Ecosystems.* Wisconsin Department of Natural Resources.

Aukerman, R., Haas, G., Lovejoy, V., & Welch, D. (2004). *Water Recreation Opportunity Spectrum (WROS) users' guidebook*. Retrieved from www.usbr.gov/pmts/planning/wros/wros_report.pdf

Bosley, Holly E. 2005. *Techniques for Estimating Boating Carrying Capacity: A Literature Review*
Prepared for Catawba-Wateree Relicensing Coalition. North Carolina State University, Department of Parks, Recreation & Tourism Management.

Bureau of Outdoor Recreation, U.S. Department of the Interior. 1970. *Outdoor Recreational Space Standards*.

Clark, R. N., & Stankey, G. H. 1979. *The recreation opportunity spectrum: A framework for planning, management, and research.* Seattle, WA: Pacific Northwest Forest and Range Experiment Station, U.S. Department of Agriculture, Forest Service.

Dearlove, Paul and Molinaro, John. 2004. *Assessing a Lake's Recreational Carrying Capacity*. North American Lake Management Society, Summer 2004 LakeLine. Vol.24, No.2, pp.22-26. Retrieved from www.nalms.org/lakeline/ll24-02.htm.

Dillman, D. A. 2000. *Mail and Internet surveys: The tailored design method* (2nd ed.). New York: John Wiley & Sons, Inc.

Dirig, D., A. Lefevre, B. Mayer, P. Oakes, B. Schmidt and C. Van. 2006. *Full to Overflowing: A Study of Lake Carrying Capacity.* LaGrange County Lakes Council Inc. (LaGrange, IN) and Steuben County Lakes Council Inc. (Angola, IN).

NOTES: The authors apply the Warren et al. (1989) analysis to boat-area requirements that considers several additional factors influencing carrying capacity:

1) *Location of the lake to the population served.* Users from urban population centers are more accustomed to higher user densities than participants from rural areas. Also, users of lakes located near or within a metropolitan area expect to see more people and tend to be more tolerant of being closer to other participants. The opposite is true for people who travel to more remote lakes.
2) *Multiple use of water area.* Multiple-use waters generally have lower carrying capacities.
3) *Shoreline configuration.* A highly irregular shoreline with a high SDF value generally reduces carrying capacity (and vice versa).
4) *Amount of open water.* A lack of large open-water areas generally reduces carrying capacity (and vice versa).
5) *Amount of facility development.* Areas with a high degree of facility development (e.g., restrooms, launch ramps, marinas, etc.) can support a higher carrying capacity than a less developed area.

Pluses and minuses are assigned to each factor. A minus means that the factor being evaluated reduces carrying capacity, meaning more area is required than expected. A plus means that the factor increases carrying capacity, meaning less area is required than expected. Adding together the pluses and minuses yields a total score. A zero means the proposed areas for boats should not be altered. A negative number indicates that the area per boat needs to be increased, while a positive

number suggests the area could be decreased. These multipliers can be weighted to reflect the local importance of each factor. Additional factors can also be included and weighted accordingly. Lake depth is an example of such a factor, with shallower lakes being more susceptible to boat damage and consequently having reduced carrying capacities. The "shallowness ratio" (SR) can be used as a factor to account for these differences in lakes. SR would be equal to the area of the lake that is less than 5 ft. divided by total lake area. Ratios less than 0.1 were considered low, while ratios greater than 0.5 were considered high. The information is then used to make a site-specific determination of area required per boat. Using a hypothetical base area requirement of 12.7 acres per ski boat, and an accepted density range of 6-30 acres per ski boat…

Base value range

6 7.3 8.6 9.9 11.2 12.7 16.1 19.5 22.9 26.6 30.0

↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓

| Positive values | Negative Values |

+5 0 -5

Each point represents one plus or minus value. The scale spans the range of –5 to +5. These are the maximum values for the five factors considered. The span from minimum to base, 6 to 12.7, is divided into five parts to represent each possible plus score. The same is done on the minus value side. The range from maximum to base is different, 30 to 12.7, but it is divided the same way. For example, a lake receiving a –2 score would move two points on the negative side, resulting in a final value of 19.5 acres per boat.

Dudiak, Tamara. 2004. *How Much is Too Much? A Recreational Use Assessment.* North American Lake Management Society, Spring 2004 Lakeline. Retrieved from www.nalms.org/lakeline/ll24-01.htm.

Dudiak, Tamara and Korth, Robert. 2002. *How's the Water? Planning for Recreational Use on Wisconsin Lakes and Rivers.* University of Wisconsin, Cooperative Extension Service.

EDAW. 2004a. *Reservoir boating, Final R-7, Oroville Facilities Relicensing FERC Project No. 2100*. The State of California, Department of Water Resources.

NOTES: Analysis was applied to Shelby and Heberlein's (1986) four carrying capacity types: ecological, facility, physical/spatial and social. Goal was to determine the maximum amount of use of a particular type an area can sustain without excessive detrimental effects to the natural resource, facilities or visitors' recreational experience. For each lake zone, conclusions were made regarding which of the four capacity types is or could be a limiting factor(s). Authors acknowledge that boating density standards are lake-specific and must consider water depth, shoreline configuration, visitors' perceptions, number of accidents involving other boats, boat type and speed, dominant boating activities, and the types of activities that are popular on the water and shoreline. The fact that boat traffic and interactions were more often seen as problems during the non-peak season highlighted that social capacity issues are not solely related to high use levels but were also affected by the types of visitors present and their preferences. Social carrying capacity was assessed using a 9-point scale to measure crowding perceptions. Physical carrying capacity was determined for each zone using ROS and modified WROS methods outlined by Aukerman et al. (2004). Differentiation was made between active and inactive (non-moving) boats using the lake. Each zone was then assigned a level of management priority (high, moderate, low).

The researchers noted some high-traffic "pockets" within larger areas, even when the larger areas themselves are classified as below capacity. A high level of boat traffic did not in itself indicate a capacity problem. No attempt was made to develop a numeric capacity limit (i.e., boats at one time) for each zone for each factor. The data collected did not permit a direct relationship to be identified between levels of boating activity and the quality of the recreation experience or deterioration of natural resources.

Density Classification	**Density Range (acres/boat)**	**Physical Capacity Assessment**
Very high density	≤ 10.0	Exceeding capacity
High density	10.1 – 20.0	Approaching capacity
Moderate density	20.1 – 50.0	Below capacity
Low density	> 50.0	Below capacity

EDAW. 2004b. *Ririe Reservoir recreation carrying capacity study.* Prepared for U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Region, Snake River Area Office, Boise, Idaho. Retrieved from www.parksandrecreation.idaho.gov/Data_Center/PDF/2004_Ririe_RCC_Complete_Final.pdf

NOTES: Authors comment that surface water acreage per watercraft is not the only measure of carrying capacity. Overall surface water capacity is also dependent on the types of watercraft used, the natural topography and setting, safety conditions, and on-water crowding perceptions, among other factors. Study applied density figures taken from Aukerman et al. (2004).

WROS Class	**Low End of Range**	**High End of Range**
Urban	1 acre/boat	10 acres/boat
Suburban	10 acres/boat	20 acres/boat

Rural developed	20 acres/boat	50 acres/boat
Rural natural	50 acres/boat	110 acres/boat
Semi-primitive	110 acres/boat	480 acres/boat
Primitive	480 acres/boat	3,200 acres/boat

ERM, Inc. 2004. *Deep Creek Lake boating and commercial use carrying capacity study.* Prepared for Maryland Department of Natural Resources. Retrieved from dnrweb.dnr.state.md.us/download/dclfinalreport.pdf

NOTES: User surveys were combined with spot counts on the lake and at the public ramps to characterize lake use. On-the-ground observations and low-altitude aerial photography were also used. For monitoring purposes, the lake was divided into three different sections known to experience the greatest variations in boating use. Carrying capacity assessments were based on two study models: Urban Research and Development Corp. (1977) and Warren et al. (1989). Social carrying capacity was estimated using contact surveys to evaluate user tolerance on a 5-point scale with respect to different levels of crowding. Digitally-enhanced photos were used during the surveys to depict five different levels of crowding: 25%, 65%, 81%, 106% and 155% of estimated carrying capacity. Social carrying capacity was reached when one-third of the respondents indicated that use levels were sufficient to discourage them from boating. The authors caution that lake managers should not rely on boaters using the 100-ft. shoreline buffer for passive activities, and should not encourage use of this buffer for safety or environmental reasons. They also noted that recreational users, especially visitors, may be willing to tolerate crowded conditions for a short period on a high-use weekend without it adversely affecting their overall experience. It was recommended that isolated sections of the lake (bays, channels, etc.) be evaluated individually, since boat use is typically unevenly distributed.

Boating Uses	**Suggested Densities**
Waterskiing	12 acres/boat
Motor boating	9 acres/boat
Sailing	4.3 acres/boat
Fishing and paddling	1.3 acres/boat

Falk, J., Graefe, A., Drogin, E., Confer, J., & Chandler, L. 1992. *Recreational boating on Delaware's inland bays: Implications for social and environmental carrying capacity.* Prepared for the Inland Bays Estuary Program, Delaware Department of Natural Resources and Environmental Control, Division of Water Resources.

NOTES: Lake use rate was determined using six on-water observations, on-site surveys administered at boat ramps, parking lot counts, and mail-back surveys to shoreline property owners. Bay usages were examined by comparing aggregate boating density, in average acreage per boat, among all of the bays. Boating density was also compared among zones on each bay as an indication of highest use areas. Perceived crowding was measured on a 9-point scale.

Florida Department of Environmental Protection, Division of Recreation and Parks. *Visitor carrying capacity guidelines.* Retrieved from www.dep.state.fl.us/parks/planning/forms/CarryingCapacityGuidelines.pdf

Boating Uses	**Suggested Densities**
Limited power (10HP or less), sailing	5 - 10 acres/boat
Unlimited power	10 - 20 acres/boat
Waterskiing	20 - 50 acres/boat

Graefe, A., F. Kuss and J. Voske. 1990. *Visitor Impact Management: The Planning Framework*. National Parks and Conservation Association, Washington, D.C.

Herron, Elizabeth. 2004. *To Ban or Not to Ban? Assessing PWC Management in Rhode Island.* North American Lake Management Society, Fall 2004 Lakeline.

Hill, David and Michele Beachler. 2001. *The Hydrodynamic Impacts of Recreational Watercraft in Shallow Lakes*. Penn State University, Civil and Environmental Engineering.

Hill, David F. 2004. *Physical Impacts of Boating on Lakes.* North American Lake Management Society, Fall 2004 Lakeline.

Jaakson, R., Buszynski, M. D., & Botting, D. 1990. *Carrying capacity and lake recreation planning*. The Michigan Riparian, pp. 11-12, 14. Retrieved from www.mi-riparian.org

NOTES: Carrying capacity is more a value judgment and less a technical decision. It should not be perceived as a scientific measure but instead as a range of estimates which also reflect the demands of users and the level of environmental quality they are willing to accept. In determining useable surface area, the authors recommend including buffer zones around shorelines (200 ft.), emergent aquatic vegetation (100 ft.), and marinas and public swimming beaches (400 ft.). Conclusions about optimal densities were value judgments based on field observations, and may not be readily transferable to other lakes. Authors

recommended adjusting these general spatial standards according to the morphology of a given lake, cultural tolerances of density, and safety considerations regarding the manner in which water-oriented recreation activities are carried out. Overall carrying capacity can then be expressed as a range of estimates.

Boating Uses	Suggested Densities
Waterskiing and motorboat cruising	20 acres/boat
Fishing	10 acres/boat
Canoeing, kayaking, sailing	8 acres/boat
All uses combined	10 acres/boat

Jones, William J. 1996. *Balancing Recreational User Demands and Conflicts on Multiple Use Public Waters*. American Fisheries Society Symposium 16:179-185.

NOTES: Author notes that the ability of a water body to accommodate a given number of users and mixed recreational uses depends on the compatibility of those uses. Motorboating and waterskiing were identified as the most incompatible with other lake uses.

Klessig, Lowell L. 2001. *Load Limits for Lakes*. Article, University of Wisconsin Cooperative Extension.

NOTES: Provides a good philosophical argument as to the importance of setting recreational carrying capacity limits on lakes.

Kusler, J. A. 1972. *Carrying capacity controls for recreation water uses*. Upper Great Lakes Regional Commission.

NOTES: Author notes that the ability of a water body to accommodate particular types of uses and a given number of users within defined levels of ecological disturbance and inter-use conflicts may be termed its carrying capacity, which differs for each water body. It depends both upon natural characteristics and acceptable limits of environmental disturbance and activity conflict. Determination of the former requires objective factual studies, definition of the latter a subjective weighing of values. Author also notes that if the criterion for allocating bodies of water to particular uses is "the greatest good for the greatest number," in many instances space consumptive uses such as waterskiing will need to be restricted in favor of high intensity uses such as swimming.

Boat Uses	Suggested Densities
Waterskiing combined with all other uses	40 acres/boat
Waterskiing only	20 acres/boat
Coordinated waterskiing	15 acres/boat

Lake Ripley Management District. 2003. *Lake Ripley Watercraft Census & Recreational Carrying Capacity Analysis.* Cambridge, Wisconsin. Retrieved from www.lakeripley1.homestead.com/files/lake_ripley_carrying_capacity_report.pdf.

NOTES: Two different "usable area" scenarios were identified, resulting in alternate carrying capacities. A sliding scale of optimum boating densities was established, based on a range of published boat-area requirements taken from the literature. Boating activities involving slower and more passive uses translated into lower values on the sliding scale, while faster and more aggressive uses translated into higher values. Carrying capacity was then based on the usable area selected relative to the proportion of fast-moving versus stationary or slow-moving watercraft using the lake during peak-use periods. The procedure was partially modeled after the method described in the study below.

Mahoney, E.M. and D.J. Stynes. 1995. *Recreational boating carrying capacity: A framework for managing inland lakes*. Department of Park, Recreation and Tourism Resources, Michigan State University.

Manning, R. 1985. *Studies in Outdoor Recreation: Search for Satisfaction*. Covallis, OR: Oregon State University Press.

Manning, R. E., Lime, D. W., & Hof, M. 1996. *Social carrying capacity of natural areas: Theory and application in the U.S. National Parks*. Natural Areas Journal*, 16* (2), pp. 118-127.

McKnight, John. 2004. *Balancing Growth with the Environment in Recreational Boating.* North American Lake Management Society, Fall 2004 Lakeline.

Miller, Paul. 2004. *Dealing with User Conflict: Best Boating Practices in Ohio.* North American Lake Management Society, Summer 2004 Lakeline

National Park Service, U.S. Department of the Interior. 1987. *The Carrying Capacity of Lake Powell: A Management Analysis of Capacity for Boater Recreation*. Technical report prepared by the National Park Service: Glen Canyon National Recreation Area and Rocky Mountain Regional Office.

O'Connor, William P. 1998. *Local Boating Regulation in Wisconsin: A Guide for Lake Management Organizations*. Wisconsin Association of Lakes, Inc.

Progressive Architecture Engineering. 2001. *Four Township recreational carrying capacity study: Pine Lake, Upper Crooked Lake, Gull Lake, Sherman Lake.* Retrieved from www.kbs.msu.edu/ftwrc/publications/carryingcapacity.pdf

NOTES: Authors emphasize there is no single boating density standards that will satisfy all lake users in all situations. Lake size, shape and depth strongly influence carrying capacity. Study used on-the-ground surveys and two aerial flyovers to assess boating use. Moored boats and parked trailers at the public boating launches were counted to evaluate their relative contributions to lake use. Using published density figures from five studies, it was determined that 10-15 acres of water surface per boat represented a conservative, aggregate estimate of optimum boating density. The density estimate was adjusted, using a sliding scale, based on the proportion of fast and slow-moving watercraft using the lake. Carrying capacity is reflected as a percentage equal to the estimated number of boats at peak use divided by the optimal number of boats.

Schneberger, E. and C.W. Threinen. 1964. *Lake management for recreation uses*. Wisconsin Academic Transactions *(53)*, Part A.

Shelby, B., & Heberlein, T. A. 1986. *Carrying capacity in recreation settings*. Corvallis, OR: Oregon State University Press.

Stewart, Chris. 1993. *Recreational and developmental carrying capacity of coastal environments: A Review of Relevant Literature and Research*. Prepared for Atria Engineering Hydraulics, Inc. Mississauga, Ontario, CA.

The Lewis Berger Group, Inc. 2001. *Duke Power Company - Shoreline Development Plan, Catawba-Wateree River System.*

NOTES: The following base, boat-area requirements were proposed: fishing (4.3 acres), canoe/kayaking (1.3 acres), motor boating (9.0 acres), sailing (4.3 acres), PWC (4.3 acres), and waterskiing (12.0 acres). The above base values were then subjected to factor analysis to arrive at more-refined area requirements. This involved applying a multiplier to the base area requirements if the particular situation called for it.

Thorton, Jeffrey A. 2000. Personal communication. Southeastern Wisconsin Regional Planning Commission.

NOTES: Commission had recommended that about 17 acres per vessel was considered acceptable.

Threinen, C.W. 1964. *An Analysis of Space Demands for Water and Shore*. Wisconsin Conservation Department.

Boating Uses	**Suggested Density**
All uses combined	10 acres/boat

United States Coast Guard. 2000. *Factors Related to Recreational Boating Participation in the United States: A Literature Review.* Response Management, Harrisonburg, Va.

Urban Research and Development Corporation. 1977. *Guidelines for Understanding and Determining Optimum Recreation Carrying Capacity.* For U.S Department of the Interior, Bureau of Outdoor Recreation.

Boat Density Range (acres/boat)

Type	**Low**	**Base**	**High**	**Special Considerations**
Fishing	1.0	0.5	0.062	Boat size, fish availability, type of fishing
Non-power	2.5	1.3	0.5	Boat type and associated space needs
Unlimited power	18.0	9.0	3.0	Aquatic life, multiple use of lake, water depth, shore configuration, policing
Water ski	20.0	12.0	7.0	Multiple use of lake, shore configuration, policing, circulation patterns

NOTES: Developed a value for boat separation based on interviews with lake users involved in several different boating activities. Interviewed users were either involved in unlimited power boating, limited power boating, or non-motorized boating. It was concluded that the base separation, or the distance a boat would need to be from another involved in the same activity, was 626 feet for unlimited power boating, 433 feet for limited power boating, and 240 feet for non-motorized boating. This implied a separation "bubble" around each boat with a radius equal to each of the above values.

Urban Research and Development Corporation. 1988. *Recreation carrying capacity study and management guidelines for Deep Creek Lake NRMA, final report*. Bethlehem, PA: URDC.

U.S. Army Corps of Engineers. 1994. *Cumulative impacts of recreational boating on the Fox River Chain O'Lakes area in Lake and McHenry Counties, Illinois: Final Environmental Impact Statement*.

U.S. Army Corps of Engineers. *Lucky Peak Master Plan – Technical Report, Volume 2*. Retrieved from www.nww.usace.army.mil/planning/er/lpeak/sptdata/spt11.htm.

NOTES: Optimum recreational carrying capacity defined as the amount of use most appropriate for both the protection of the resource and the satisfaction of the participant. Used Urban Resource and Development (1977) model for optimum average densities. Did not adjust for actual density in some areas being much higher or lower than the average. Boating types classified as either low- or high-powered uses, with average relative proportion of uses estimated.

Wagner, Kenneth J. 1991. *Assessing impacts of motorized watercraft on lakes: Issues and perceptions*. In: Proceedings of a National Conference on Enhancing the States' Lake Management Programs, 77-93. Northeastern Illinois Planning Commission.

NOTES: Irregular shorelines, with their coves and inlets, may serve to isolate impacts, but also imply greater safety risks as well as ecological consequences. As the density of watercraft increases, the resource becomes less acceptable for certain users. Racers and waterskiers feel restricted at less than 10 acres per boat, and nearly all motorized watercraft users feel crowded at less than 5 acres per boat. The author notes that the density of motorized watercraft that resulted in unsatisfactory (water quality) conditions ranged from 14 to 50 acres per motor, which would generally be considered an acceptable ratio for motorized activity from the perspectives of safety and user satisfaction.

Boating Uses	**Suggested Density (Zwick, 1990)**
All boating activities	25 acres/boat

Warbach, J. D., Wyckoff, M. A., Fisher, G. E., Johnson, P., & Gruenwald, G. 1994. *Regulating keyhole development: Carrying capacity analysis and ordinances providing lake access regulations*. Planning and Zoning Center, Inc.

Boating Uses	**Suggested Density**
All motorized (>5 HP) uses	30 acres/boat

Warren, Roger and Rea, Phillip. 1989. *Management of Aquatic Recreational Resources.* Publishing Horizons, Inc., Columbus, Ohio.

Boating Uses	**Suggested Base Densities**
Motorboats	9 acres/boat (range: 3-18)
Canoeing, kayaking	1.3 acres/boat (range: 0.5-2.5)
Sailing, fishing, jet skiing	4.3 acres/boat (range: 2-10)
Waterskiing	12 acres/boat (range: 7-20)

Wisconsin Department of Administrative Code, NR 1.91 (public access standards for lakes)

NOTES: The DNR has determined that granting permits for boating access on bodies of water where the maximum access standards are exceeded will materially impair navigation and is detrimental to the public interest. DNR may not pursue public access development nor may it approve permits or provide financial assistance for access that exceeds levels described in this subsection, unless greater levels are established in a plan. DNR recommends 15-30 open-water acres/car-trailer unit (NR 1.91).

Inland Lakes (open water acres)	**Maximum Public Boating Access**
< 50 acres	One carry-in access site for 5 vehicles
50 – 99 acres	One or more access sites which in total provide 5 car-trailer units
100 – 499 acres	One or more access sites which in total provide 1 car-trailer unit per 15 open water acres
500 – 999 acres	One or more access sites which in total provide 1 car-trailer unit per 25 open water acres…
1,000 – 4,999 acres	One or more access sites which in total provide 1 car-trailer unit per 30 open water acres…
5,000 or more acres	One or more access sites which in total provide 1 car-trailer unit per 50 open water acres…