Full To Overflowing

A Study of Lake Carrying Capacity

LaGrange County Lakes Council Inc., LaGrange, Indiana
Steuben County Lakes Council Inc., Angola, Indiana

May 23, 2006

Acknowledgements

The committee would like to thank the staff of the Fremont Public Library for their efforts in obtaining copies of many of the sources used in this study. Thanks to the staff's efforts and the interlibrary loan program, several sources that were critical in the writing of this report were available to the committee.

The committee would also like to thank Chad Hoover of the Steuben County Geographic Information System Office for his help in determining lake areas and shoreline lengths.

A major thank you to Susan Anderson for reviewing this report and making it both more readable and eliminating many errors in grammar, spelling and structure.

The committee, which gathered the information and wrote the report, consists of:

Dick Dirig – Big Long Lake
Allen Lefevre - Lake Gage
Bob Mayer – Oliver Lake
Paul Oakes – Ball Lake
Bill Schmidt – Lake James
Corkey Van – Lake James

Table of Contents

Executive Summary

A joint committee was formed in May of 2005 by the LaGrange County Lakes Council (LCLC) and the Steuben County Lakes Council (SCLC) to investigate lake carrying capacity. There is a perception by the members of these two organizations that overuse is degrading the safety and enjoyment of our lakes.

Jacquie Colburn[1] has defined carrying capacity as, "The amount of development and activity a body of water can handle before it starts to deteriorate." When carrying capacity of the lake is exceeded, the lake's ecology can deteriorate, it can have reduced enjoyment potential, increased safety issues and property values can decrease. The State Comprehensive Outdoor Recreation Plan observes, "Recreation opportunities also benefit the economy. Property values increase when there are ample outdoor leisure opportunities available."[2] Lakes that exceed their carrying capacity can negatively impact the economy by discouraging their use and driving the lake recreationist to other areas or states. The Economic Study commissioned by the SCLC clearly shows the positive impact made by lakes on the economy of Steuben County.[3] Exceeding the carrying capacity of the lakes could negatively impact this positive contribution.

The literature on lake carrying capacity makes clear that there is no easy answer to the question of carrying capacity. The question is social in nature. One can not just sit on a dock, count boats and make a determination. The pleasure capacity of a lake is exceeded when there is deterioration in the enjoyment of the lake by the user. This can be caused by the perception of too many boats, overcrowding, too many fast boats, reduction in safety, or just a feeling that this is not a place I want to be.

What a user would perceive as overcrowding on Bitter Lake N.W.R. outside of Roswell, New Mexico would be considered the wide-open spaces in New York City. The users' idea of what is too close and what is enough space to feel safe is dependent on the users' experiences and expectations. The literature has many examples of how to determine the amount of area a lake user needs to feel safe and secure. While the actual study process is long and arduous, the concept is simple. Ask the people who use the lake what their needs and expectations are, do a statistical analysis and generate a result.

Having generated results, then what? How much area does a user need to feel safe and have no reduction in enjoyment caused by other users? The IDNR and the laws of the State of Indiana control the lakes. No Lake Association can make a rule limiting the number of boats on the lake or their activities. There is one exception in Steuben County

---

[1] New Hampshire Department of Environmental Services, Lakes Coordinator – NHPR June 18, 2004
[2] SCORP-2000. Indiana Department of Natural Resources, Chapter 1 pg. 6
[3] Steuben County Lakes Council, Inc. *An Economic Impact Analysis of the Lakes in Steuben County, Indiana* October, 2003

where specific laws are in place to control boating activities;[4] this was by special legislation and affects only two lakes. The answer to preventing overcrowding on a lake is by action through the legislature or other law making groups. An effort by individual lake residents through their elected representatives is the only way to see that site-specific capacity laws are in place.

The conclusion that the committee reached, based on both the literature sources and its own work, is that the lakes studied exceed their carrying capacity on most, if not all summer weekends. The committee recommends further study using an existing methodology that allows for the lake specific determination of carrying capacity. The study would require an investment of time, but the results could be used for planning, policy and legislative action.

These are the recommendations of the Carrying Capacity Study Committee:

1) That there be a study of the environmental impact of over capacity use on the lakes. The committee feels that the impacts of boating on the environment of a lake needs study, and the fact that the lakes seem to exceed their carrying capacity by multiples, means that the study needs to be undertaken soon.
2) That two lakes be selected on which to do a carrying capacity study. An in depth study using the methodologies cited in the literature will serve as an experience guide for others who wish to determine the carrying capacity of their lake.
3) That the results of this study be disseminated to the individual lake associations. The study should be distributed to governmental bodies, the press, or anyone who would have an interest in or the power to determine the levels of lake usage.
4) Work with government agencies to enact laws that will positively impact the health, safety and enjoyment of the lake resources. An example of this would be a maximum speed limit for boats on inland fresh water lakes. Less area is required for slower moving boats, generated waves are smaller for slower moving boats, and there should be fewer user conflicts if the speed of boats is controlled.
5) Use this study to influence authorities to include lake carrying capacity as one of the factors when considering the approval of projects that will place more boats on the water.

[4] IC 14-15-3-9. This was enacted for the users of Lake George and any other qualifying lake by P.L. 1-1995, Sec. 8.

Introduction

Carrying capacity is the term used for the amount of development and activity a body of water can handle before it starts to deteriorate.
Jacquie Colburn

While you were boating or fishing, did you experience any interference by other recreationists that took away from your enjoyment?
Steven J. Basell

Jacquie Colburn[5] has clearly delineated the point at which the carrying capacity of a body of water is exceeded. Carrying capacity is exceeded when ecological deterioration is experienced by the body of water or the recreational experience is degraded by the actions of other recreationists. Steven J. Basell [6] asks the question that determines when recreational deterioration begins. Deterioration in enjoyment begins when the resource user feels that another has negatively impacted the recreational experience.

This study of a fresh water lake carrying capacity was begun to address the perceived problem of over crowding on the lakes in LaGrange and Steuben counties. This over crowding manifests itself in several ways. The ecological degradation of the lakes by prop wash, wave action and chemical pollution is one facet of the problem. The reduced enjoyment of the boating or fishing experience is another. Increased safety issues with overcrowding is a third. This study will limit itself to the second and third items, enjoyment and safety. The impact of overcrowding on ecological issues is a major concern and needs to be addressed in a separate study.

Enjoyment of a lake is a perceptual concept. The safety of a lake is perceptual as well as factual. Typically, the enjoyment of a lake is negatively impacted by over crowding. The waves generated by some boating activities also has a negative impact. The comment heard many times, " I did not go out today because there were too many boats on the lake", is an example of perception. Another way to state this perception is, "The carrying capacity of the lake was exceeded and I feel this will reduce my enjoyment of the lake." Safety also enters into the decision of lake usage. An uncrowded lake can be perceived to be unsafe if those using the lake are operating at high speed or in close proximity to the casual boater or fisherperson or statistics may show that a lake has experienced many accidents and that the lake user is in more danger than the user is willing to accept.

This study will explore some of the work that has been done on Lake Carrying Capacity. There are many scholarly works on the subject. The Federal Government has done much work in the area. Lake Associations and other special interest groups have also addressed the subject. The electrical power industry has also done much work on the subject. While not every source was probed, the committee feels that enough sources were reviewed to give a solid basis on which to base its recommendations.

---

[5] See foot note 1
[6] Factors relating to the recreational boating participation in the United States

Definition of Terms

There are several terms that are important in the discussion that will follow. These terms are defined as follows:

Usable Lake Area –That part of the lake that can be used for boating activity. In the State of Indiana, boats are not allowed to operate at a speed greater than idle speed within 200 feet of the shoreline.[7] The shore line length multiplied by 200 feet and divided by 43,560 square feet gives the area excluded from use by law. This area must be subtracted from the total lake area. Also, any shallow area of a lake that does not lie in this 200-foot exclusion needs to be deleted. It is generally accepted that any water less than 5 feet be included in this group. Example : if there is a 1000 acre lake with 10,000 feet of shoreline and 23 acres of water of less than 5-foot depth, the usable lake area is 1000 acres – (10,000 feet)x(200 feet)/ (43,560ft.sq./acre) – 23 acres = 1000 acres – 46 acres – 23 acres = 931 acres of usable lake area.

Area Per Boat - The amount of lake surface a boat requires for safe operation. A boat that is towing a water-skier might require 20 acres for safe operation. A pontoon boat out for a slow speed cruise might only require 7 acres per boat. A fisherperson anchored in water outside of the 200 foot exclusion zone might require 3 acres. The type of activity that a boat is engaged in determines the amount of area that is required for each boat.

Boat Carrying Capacity – The number of boats that can safely be using a lake at the same time. This number is determined by dividing the usable lake area by the area required per average boat. If the lake has an usable area of 1000 acres and the average area required per boat is 10 acres, then the boat carrying capacity of the lake is 100 boats. Calculation: 1000 acres/(10 acres/boat) = 100 boats

Area Required Per Average Boat – A weighted average of the area per boat for the boats active on the lake. Most all lakes are used for many different activities at the same time. There are water-skiers, boats cruising at slow speed, boats cruising at high speed, anchored fisherpersons, tubers and sailors on the water at the same time. Each of these has different area requirements. The weighted average is the number of each usage times its area/boat requirement then divided by the total. number of boats. Example: If there were 10 boats doing an activity requiring 20 acres each, and 5 boats doing an activity that requires 5 acres each the weighted average would be 15 acres/boat. Calculation : (10 boat x 20 acres/boat) + (5 boats x 5 acres/boat) / 15 boats = (200 acres + 25 acres) / 15 boats = 15 acres/ boat

[7] IC 14-15-3-18

Fetch – The maximum open water distance across a lake. The higher the ratio of the fetch to the theoretical diameter of the lake, the more irregular is the shoreline. This would lead one to expect more safety issues and greater potential for ecological damage.

Shoreline Development Factor (SDF) – Relates shoreline length to the circumference of a circle with the same area of the lake. A circular lake would have a SDF of 1.0. According to Wagner, high values may imply greater safety risks as well as adverse ecological consequences.[8]

Definition of Problem

It is the perception of many lake residents and lake users that the lakes are becoming more crowded with each passing year. This increase in lake usage is causing both safety problems and reducing the enjoyment of the lake by many of its users. Today there are many large, high-speed boats on our lakes. There are water-skiers, knee boarders, wake boarders, tubers, fisherpersons, cruisers, sailors, sunbathers, personal water craft riders, and any number of other recreational water activities happening on the lake at the same time.

While none of these uses are mutually exclusive, many have a negative impact on the enjoyment of the lake by other users. Any high-speed water activity is an annoyance to a fisherperson who happens to be anchored in the area where the high-speed activity is occurring. The fisherperson's boat is getting rocked, reducing his/her enjoyment of the lake. The pontoon boat's passengers are aggravated by the PWC that is trying to jump over its wake. The pontoon driver gets mad and goes home. Clearly reduced enjoyment. The water-skier can not ski because the waves are too high due to heavy lake usage. No enjoyment. Boaters feel unsafe due to the many watercrafts going every-which-way at break neck speed with what seems to be little regard for the rights or safety of others.

How many is too many? What is unsafe? From a use perspective, is the lake full or overflowing? These are the questions that this study will try to answer. The problem is to determine at what point the lake becomes saturated from a use standpoint. The common sense answer is that there must be a point at which the lake can not safely accommodate any more activity. The problem is to identify that point with sufficient credibility that action can be taken to control the usage of the lake.

There are many strategies that have been used to address user conflicts on other lakes.
1) Making certain areas of a lake available only to certain uses. You can fish here, but you can not water-ski here.
2) Limiting speeds at which boats can operate.

[8] Wagner, Kenneth J. 1991. *Assessing Impacts of Motorized Watercraft on Lakes: Issues and Perceptions.* Proceedings of a National Conference on Enhancing States' Lakes Management Programs. Northeast Illinois Planning Commission

3) Limiting the time when certain activities can occur. You can not wake board between the hours of 10:00 a.m. and 5:00 p.m.
4) Limiting the number of boats that can use a lake.[9] This is possible when there is a control point for boat access. On the lakes in our area, boaters access the lake from public ramps but also from pay ramps, marinas, other lakes and from homes along the shoreline.
5) Directional boating. Directional boating is basically one-way boating on a lake, either clock-wise or counter clock-wise.

The challenge is then to identify when the lake is at capacity. As stated above, there are two issues: safety and enjoyment.

Study Lakes

For this study, the lakes that were used as examples are Lakes Gage and James. These lakes were chosen because the Steuben County Geographic Information System (GIS) site makes measurements of these lakes easiest.

Table 1
Physical Dimensions of the Lakes

	Area (acres)	Shoreline (feet)[10]	Excluded area (acres)	Usable lake area (acres)
Lake Gage	332[11]	15,631	72	260
Lake James	1039[12]	66,000	303	736

As can be seen from Table 1, both lakes are significantly reduced in usable area when the 200 foot no wash-no wake area is deducted. The above table also assumes that there are no areas of less than 5 feet outside of the 200-foot from shore zone. This assumption is false, but will be made for the study.

[9] This approach is used on some inpoundments in the west where there is access by ramp only. The carrying capacity of the lake is determined and when that number is reached, no more boats are allowed on the lake. The boater is directed to other lakes in the area for use.
[10] The shoreline measurement was made using the Steuben County Web Site. The G.I.S. feature was chosen and the lakes identified and measured.
[11] Anchor Publishing, 2005. *Steuben County Lakes Map.* pg. 9
[12] The area for Lake James is that from the DNR office at Pokegon State Park. The map was created by Kendallville Publishing Company in 2000. Some sources site Lake James as having an area of over 1400 acres. This value includes Snow Lake in the total area of Lake James. It has been stated that Snow Lake has been considered as Snow Bay of Lake James. This is because there is no difference in lake elevation between James and Snow and for it to be considered a separate lake there must be an elevation difference. For this study, the lakes will be considered separate.

Table 2
Shoreline Development Factor (SDF)

	Area (acres)	Circular Shoreline (feet)	Actual Shoreline (feet)	SDF
Lake Gage	332	13,480	15,631	1.16
Lake James	1039	23,840	66,000	2.76

The calculation for the SDF for Lakes Gage and James can be found in Appendix 1.

In August, 2005, a count was made of all watercraft docked or on shore on Lakes Gage and James. These counts were one time counts and were done during weekday mornings. The committee felt that there would be few boats on the water at this time and any boats that were gone from their slips would not be statistically important. There was no attempt to break down boats by horse power although some literature sources have made that distinction.

Table 3
Boat Populations on the Study Lakes

	Speed Boats[13]	Pontoon Boats	PWC	Manual[14]	Total
Lake Gage	230	70	125	131	566
Lake James	749	439	352	402	2032

It is interesting to note that, on a docked boat basis, there were roughly 20% more boats per usable acre moored on Lake James than on Lake Gage.

Review of the Literature

The review of the literature will be divided into two parts. The first will address the area requirements for different types of boats and the second will address the method for determining, from the lake users, the area requirements for the safe and enjoyable use of the lake.

The question of how much area is required for each boating activity has been actively researched. The problem is the sources vary greatly in their evaluation of the area requirements. As can be seen from Table 4, the results vary greatly. P.G. Ashton in his 1971 Ph.D. thesis generated the lowest area values. Ashton states that the density should be, averaging his results from the three lakes, 7.4 acres / boat for combined usages. J.D. Warbach and his co-authors reached a conclusion that was several multiples of Ashton's

[13] Speedboats include all powered boats excepting pontoon boats. Ski boats, deck boats, fishing boats, cabin cruisers, etc. are included in this category.
[14] Manual includes all person powered craft as well as sailboats. Canoes, kayaks, rowboats, pontoon paddleboats, etc. are included in this category.

values. Warbach states that the figure should be 30 acres / boat for all motorized uses where the boat exceeds 5 horsepower. Others show values in between.

Table 4
Area Requirements for Different Water Use Activities[15,16]

Source	Boating Use	Suggested Density
Ashton (1971)[17]	All combined uses in Cass Lake All combined uses in Orchard Lake All combined uses in Union Lake	5 to 9 boats / acre 4 to 9 boats / acre 6 to 11 boats / acre
Kusler (1972)[18]	Water-skiing combined with all other uses Water-skiing only Coordinated water-skiing	40 acres / boat 20 acres / boat 15 acres / boat
Jaakson *et al* (1989)[19]	Water skiing and motorboat cruising Fishing Canoeing, kayaking, sailing All uses combined	20 acres / boat 10 acres / boat 8 acres / boat 10 acres / boat
Wagner (1991)[20]	All boating activities	25 acres / boat
Warbach *et al* (1994)[21]	All motorized uses greater than 5 h.p.	30 acres / boat

[15] This table was reproduced from the "Lake Ripley Watercraft Census and Recreational Carrying Capacity Analysis" Lake Ripley Management District, December 2003
[16] See Footnote #13, pg. 13
[17] Ashton, P.G. 1971. *Recreational boat carrying capacity: A preliminary study of three heavily used lakes in southeastern Michigan.* Doctoral Thesis, Department of Resource Management, Michigan State University.
[18] Kusler, Jon A. 1972 *Carrying Capacity Controls for Recreational Water Uses,* Upper Great Lakes Regional Commission
[19] Jaakson R, *et al* 1990. *Carrying Capacity and Lake Recreational Planning*. The Michigan Riparian, November 1989, pg. 11-12,14
[20] Wagner, Kenneth J. 1991 *Accessing the impacts of motorized watercraft on lakes*. Northeast Illinois Planning Commission
[21] Warbach, J.D. *et al* 1994 *Regulating keyhole development: Carrying capacity analysis and ordinances providing lake access regulations*. Planning and Zoning Center, Inc

In 2001, Progressive Architecture Engineering stated, "Based on these various criteria and considerations, 10 to 15 acres of water surface per boat is recommended as a conservative, aggregate density for all types of boating activities. A boating density greater than 10 to 15 acres per boat would create a potential for safety problems, multi-use conflicts, or environmental degradation."[22] This study was made on four lakes located to the northeast of Kalamazoo, Michigan. The lakes were similar in size and shoreline development to the lakes in this study. The largest was Gull Lake with 2,047 surface acres; the smallest was Sherman Lake with 153 surface acres. While Gull Lake is somewhat larger than Lake James and Sherman Lake is somewhat smaller than Lake Gage, the lakes are equivalent for this study. It can be extrapolated that the carrying capacity for the lakes studied are applicable to Lakes Gage and James.

In the Lake Ripley study,[23] the researchers reached a different conclusion. They identified two different conditions of lake usage and assigned boating areas for each. One condition was passive boating activities. Lake usage was dominated by stationary and slow-moving boats in this condition. The other condition was aggressive boating activities. When the lake usage was predominately fast moving watercraft. They concluded that an area of 10 acres per boat is required during passive boating periods and 30 acres per boat during periods of aggressive boating activities. They concluded that a mean optimum density of 20 acres per boat was a good value assuming that there was a relatively equal mix of the two types of boating activity. They also observed that this value could move up or down depending on the mix of lake usage.

In the Duke Power Shore Line Management Plan for the Catawba-Wateree[24] river system, another set of areas was suggested. They proposed that fishing required 4.3 acres, canoe/kayaking required 1.3 acres, motor boating required 9.0 acres, sailing required 4.3 acres, PWC required 4.3 acres and water skiing required 12.0 acres. They subjected these base values to factor analysis (the second part of this review) and developed final numbers.

The United States Bureau of Outdoor Recreation (BOR) has developed a value for boat separation based on interviews with resource users involved in several different boating activities. The contractor for this study interviewed users who were involved in unlimited power boating, limited power boating, and non-power flat water boating. The report suggests that the base separation, the distance a boat would be from another involved in the same activity, is 626 feet, 433 feet, and 240 feet respectively.[25] This would mean that there is a "bubble" of a radius of one-half of each value around each boat.

---

[22] Progressive Architecture Engineering May 2001, *Four Township Recreational Carrying Capacity Study* Project #51830106 pg. 14
[23] See footnote #13, pg. 37
[24] The Lewis Berger Group, Inc. 2001 *Duke Power Company-Shoreline Development Plan, Catawba/ Wateree River System* Table 2.5-3
[25] Urban Research and Development Corporation, January 1971 *Guidelines for Understanding and Determining Optimum Recreational Carrying Capacity* U.S. Department of the Interior, Bureau of Outdoor Recreation. Contract #5-14-07-5 pgs. III-16,17,18

The committee then utilized the above information to develop its own separation distance The BOR distance was modified by considering several factors that the committee felt were important. These additional considerations are as follows:

1) Boats are required to stay 150 feet from a down diver[26] (it is reasonable to assume that a skier or a boater would require the same clear space), they are also excluded from a 5-foot radius around a person in the water. This is a total exclusion of 160 feet. Adding a 25% safety factor gives an exclusion zone of 200 feet around the boat as well as any towed persons.
2) The suggested distance to stay behind another moving vehicle on the road is two seconds.[27]
3) Around each boat is a "bubble". These bubbles may touch, but not overlap.

The "bubble" for a boat in motion developed by the committee, based on their considerations, would be 200 feet plus two seconds. This number is below the values generated by the BOR study of 216 feet for limited power boating and 318 feet for unlimited power boating. The committee feels it is better to be conservative in the "bubble" than to be aggressive and used a value of 200 feet.

As an example, a boat pulling a skier. The skier is on a 75-foot long rope. The boat is 22 feet long. The boat is traveling at a speed of 30 miles per hour. The following calculation shows the area required for this usage:

A circle of 200 foot radius has an area of Π x r x r = 3.14159 x 200 ft. x 200 ft = 125,663 sq. ft. = 2.9 acres.
The boat has a length of 22 feet and has a total of 400 feet of safe space. The rope is 75-foot long. The area in this rectangle is 75 ft. x 400 ft. = 30,000 sq. ft. = 0.69 acres. The area in this rectangle is 22ft. x 400 ft. = 8800 sq. ft. = 0.20 acre
A boat traveling at a speed of 30 miles per hour covers 44 feet per second.[28] If a boat has a two-second safety bubble around it, which means that there is a 4-second minimum separation between boats. The boat has traveled 88 feet in two seconds.
The area traversed is 88ft. x 400 ft. = 35,200 sq. ft. = 0.81 acres.
Therefore, the area required for a boat pulling a skier at 30 miles per hour is the total of the above three numbers. Without consideration of SDF or wave height, the minimum area required is 4.60 acres.

The SDF of a lake, in the opinion of the committee becomes important at this point. A SDF of 1.0, a perfectly round lake, should have the minimum number of obstructions, no hidden corners, no unobservable areas, a minimum number of factors which could cause crowding or unsafe conditions. The higher the SDF, the more irregular is the shoreline with coves, side basins, elongate areas, etc. There is more probability of user crowding in the reduced useable area of water due to increased shoreline. If the SDF is applied to the 4.60 acres generated above, a figure is obtained that considers the shape of the lake as a

[26] IC 14-15-9
[27] Indiana Bureau of Motor Vehicles. *Indiana Drivers Manual.* pg. 41
[28] 60 mph = 88 feet per second

part of the usage area requirement. The SDF for Lake Gage was 1.16; the value for Lake James was 2.76. Multiplication of the SDF for each lake by the generated area calculated results in the following:

Table 5
Boating Area Requirement When SDF Is Factored

	SDF	Area (acres)	Boating Area Requirement (acres)
Lake Gage	1.16	4.60	5.3
Lake James	2.76	4.60	12.7

The value for Lake Gage seems to be low in relation to the values suggested by others, but the SDF describes the lake as being nearly round. An aerial view shows that the SDF has correctly predicted the shape of the lake. The area value calculated for Lake James is in the range suggested by others. The SDF for Lake James predicts that the lake is irregularly formed and has many twists and turns. Again, an aerial view confirms this prediction.

Using this analytical approach, area requirements for each type of watercraft traveling at a given speed can be calculated. The calculated values are presented in Table 6. These values are again less than suggested by other literature sources but when the SDF is applied, they come closer to suggested areas.

Table 6
Committee's Calculated Area Requirements for Various
Water Craft[29] (acres)

	Speed Boat	Pontoon Boat	PWC	Manual
Lake Gage	4.5	3.8	4.3	3.5
Lake James	10.8	9.1	10.2	8.0

The question of wave height generated by a boat is complex and has many proposed solutions. For this study we will use Bhowmik's [30] (1975) equation. David F. Hill[31] has suggested that for illustrative purposes that this equation has good predictive value. The following equation can be used to describe the wave height generated by a boat traveling at a certain speed:

[H/d] =√ [[0.0345 x VExp1.74[X/L]]

Where H is the wave height, d is the draft of the boat, V is the speed of the boat, X is the perpendicular distance from the sailing line of the boat and L is the length of the boat. A boat traveling at 20 miles per hour with a draft of 1.5 feet and a length of 20 feet is predicted to generate a wave height of 1.06 feet at a distance of 50 feet, a height of 0.75

[29] The calculations for each type of craft and the assumed speed can be found in Appendix II.

[30] Bhowmik, N. 1975 *Boat generated waves in lakes.* Technical Notes, Journal of the Hydraulics Division, 101. pg. 1456 - 1458

[31] Hill. David F. Fall 2004. *Lakeline* pg. 16

feet at 100 feet and a wave height of 0.50 feet at a distance of 250 feet. The equation has several interesting predicted results:

1) The less draft a boat has at a given speed, the smaller the wave. This would imply that a boat on plane would generate a smaller wave than the same boat at the same speed not on plain. It also explains why boats with inflatable bladders used for wave generation in wake and knee boarding generate larger waves. While the speed is slower, the boat draft is much deeper and thus larger waves.
2) The shorter the boat, the smaller the wave.
3) The equation also generates the expected result that when on plane, the faster the boat travels, the larger the wave generated.

The predictive value of this equation can be used to evaluate the assumption that the boats have a protective bubble of 200 feet. As can be seen from the above results, at a distance of 200 feet, the wave generated by the 20-foot long boat would be about 0.6 feet, or just more that 7 inches. Such a wave should cause no problem for anyone.

The effect of speed and distance is clearly demonstrated by the Table 7. At a water skiing speed of 30 miles per hour, the 50-foot distance wave is 11 inches, nearly a foot, and at 200 feet, the extent of the exclusion bubble, the wave has degraded to a height of 6 inches. This gives further credence to validity of the 200-foot exclusion zone. The table clearly shows that at 200 feet the waves have subsided to the point that they should not adversely impact other recreationists on the lake.

Table 7
Wave Height, in Feet, Generated
By a 20-foot Long Boat at Various Speeds
Boat Draft of 1-Foot

Boat Speed (MPH)	10	20	30	50
Wave @ 50 feet	0.47 feet	0.71 feet	0.90 feet	1.22 feet
Wave @ 100 feet	0.35 feet	0.52 feet	0.64 feet	0.88 feet
Wave @ 200 feet	0.24 feet	0.37 feet	0.48 feet	0.65 feet
Wave @ 250 feet	0.22 feet	0.33 feet	0.43 feet	0.58 feet

Bhowmik's equation also demonstrates why a properly trimmed boat on plane has very little wake. When on plane the area of the boat hull that is in contact with the water, the effective boat length, is much shorter than the waterline length of the boat at rest. The effective draft of the boat is also reduced. This combination of reduced effective draft and hull length results in a smaller wave being generated than one would expect for the same boat traveling at the same speed and not on plane and trimmed.

One observation on wave perpetuation is in order. A single boat generating a wave of 1-foot interacts with other boats to generate larger waves than any single boat. The action of the generated waves are additive. This means that if the peak of a 1-foot wave meets the peak of a 6-inch wave, the resultant wave height is 18 inches. This interaction between waves is how such large waves are generated on the lakes by the boats using the lake. The wave size is also magnified by the waves rebounding form solid sea walls. Glacial rocks on the shore break up the wave and almost eliminates rebounded energy.

The second part of determining the area requirement for safe and enjoyable use of the lake by recreationists is to evaluate the user expectation for the lake and use that expectation to modify the area results that were generated above.

The literature is clear; there are two sources that are the foundation of the analysis. They are *Guidelines for Understanding and Determining Optimum Recreation Carrying Capacity*[32] and *Management of Aquatic Recreation Resources.*[33]

Warren and Rea (*Management of Aquatic Recreation Resources*) take the values that they have identified for boat area requirement and apply an analysis that considers several factors influencing carrying capacity.[34,35] These factors are then applied to the area requirements to give the suggested actual area needs per boat.

Warren and Rea identify five factors for their analysis. These five factors are:

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, a user at a recreational area located near or within an urban/metropolitan area expects to see more people and tends to be more tolerant of being closer to other participants. The opposite is true for people who travel to remote recreation areas.
2) *Multiple use of water area.* Multiple use (mixture of different activities) of a lake generally causes the capacity level of a lake to be lower.
3) *Shoreline configuration.* A highly irregular shoreline generally results in a lower carrying capacity. This shoreline configuration is the SDF. A high value of SDF is a negative factor. The fetch ratio can also be used in this assessment.
4) *Amount of open water.* Large, open areas are necessary to safely accommodate sailboats, unlimited powerboats, and water-skiing. Thus open area increases capacity. Fetch ratio can be used as one measure of open area. In a round lake, the fetch is the same as the diameter or the fetch ratio is 1.0. If the fetch ratio is either very high or very low, indicating irregular shoreline with many bays or long fetches with many areas connected by narrows gives an idea of open water. The SDF is part of this assessment.
5) *Amount of facility development.* Areas with a high degree of development (restrooms, launching ramps, marinas, etc.) can carry a higher capacity than a less developed area.

---

[32] Urban Research and Development Corporation, January 1971 *Guidelines for Understanding and Determining Optimum Recreation Carrying Capacity* U.S Department of the Interior, Bureau of Outdoor Recreation. Contract BOR # 5-14-07-5

[33] Warren, Roger and Rea, Phillip, 1989. *Management of* Aquatic *Recreation Resources,* Chapter 8.

[34] See footnote 30, pg. 117

[35] Warren and Rea will be used extensively in this analysis; every quote will not be foot noted. The reader is directed to the source.

With the five factors identified, the authors then give pluses and minuses to each factor. A minus assigned means that the factor being evaluated has a negative connotation. A plus means that the factor is a positive influenced. Table 8 shows how each factor[36] is scored for the studied lakes. The total score was then totaled and a factor determined. If the factor is negative, more area is required than expected; if zero, the expected area would be acceptable; and if the factor were positive, less area than expected would be required.

Using the five factors identified by Warren and Rea, Lakes Gage and James score as follows:

Table 8
Lake Factor Scores

	Lake Gage	Lake James
Location	0	0
Multiple use	-	-
Shoreline configuration	+	-
Open Water	+	-
Facility Development	-	+
Total Score	0	-2

Lake Gage was scored 0 for location. While close to some large cities, the area is considered semi-rural. There are many uses of the lake at the same time so a minus is assigned. The low SDF indicates a near circular lake with few points or bays so a plus is scored. While there is open water, the usable lake area is less than 300 acres and this is on the small side of water area for a ski lake. It is scored a plus since there is open water. There are few facilities on the lake so this is a minus score. The total being zero, Warren and Rea would suggest that the proposed areas for boats not be altered.

Lake James was scored 0 for location the same as Lake Gage, a semi-rural area. This is a multi-use lake and a minus is assigned for this factor. A minus is assigned for shoreline configuration, as the SDF is high. A minus is assigned for open water. This is the result of the high fetch ratio and SDF. A plus is assigned for facility development. There are several marinas and the State Park has public facilities. There are also public and pay ramps with developed facilities. The total score for Lake James is a minus 2. This indicates that the area per boat needs to be increased.

The BOR suggests that these ratios can be weighted to reflect the importance of each factor to the evaluating party.[37] One factor could be twice as important to the group that is doing the study as any other factor. Such an example would be that the lake is multi-

[36] See footnote 30. pg. 118, Figure 8.1
[37] See footnote #29 pg. III-5

use. A multiplier could be assigned to this factor so that it will be more heavily weighted in the evaluation. These local preferences can easily be factored into the ratings.

The BOR then gives a detailed description of how to put all this information into a format which will allow a site specific determination of area required per boat.[38] There are two ways to do this analysis. One would be to take the range of areas suggested for skiing and then use the number generated by this committee as a base. Let us assume that maximum value from the literature was 30 acres per boat and the minimum was 6 acres per boat. The area requirement determined in Table 5 is 12.7 acres per boat. This number then becomes the base from which the variance is calculated.

Example 1
Optimum Boating Area Selection for a Ski Boat on Lake James

					Base					
6	7.3	8.6	9,9	11.2	12.7	16.1	19.5	22.9	26.6	30.0
↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓

+5	Positive values	0	Negative Values	-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 is different, 12.7 to 30, but it is divided the same way. Lake Gage received a 0 score. Such a factor analysis could also be constructed for Lake Gage. The factor value generated for Lake Gage was 0 and the factor analysis would yield the area value as the base value of 5.3 acres per boat. Lake James received a –2 score. Going to the line score, move two to the negative side and a value of 19.5 acres per boat is the required area.

Any group doing the analysis can choose as many factors as they wish. There can be nine factors and the factors can be weighted as the group sees fit. This allows the tailoring of the study to each individual situation and complete customization to the situation that exists on each lake.

The second approach to generating this value is to survey the lake users and develop the range based on the input received. This approach assumes that the lake user has the ability to judge distances on the water, which can be deceiving, and can assign a numerical value to the separation required.

A survey of the users can also be used to assign the + and – to the factors. Ask them if they feel crowded. Ask if they have ever left a lake because of safety concerns. Ask if they feel crowded even though they still use the lake. Such questions can help make the scoring of the factors more fact based, and as such, more objective.

[38] See footnote #29 pg. III 5 - 8

The proper weighting of the lake usage can only be accomplished by the collection of a large mass of data. The Ripley Lake report serves as an example of how extensive this data collection needs to be.[39] The more data that is collected, the more valid is the value for each use of the lake. This is the most difficult part of the study. For Lake Gage it is easier as there are many points on the lake from which the whole lake can be observed. Lake James is another story all together. No basin can be observed from another. The third basin can be observed from one point, the second from one point, the first seems to take at least two points and perhaps three. Coordinating and analyzing these observations is a time consuming labor. The group could assume boat group usage, but unless the assumption has some basis in generated data, the results are open to question.

Surveying Assessment

As implied above, the most important part of customizing a capacity study to a particular situation is developing and weighting the questionnaire. The questionnaire can be used to determine the attitude of the recreationists. Are they concerned with the safety and crowding on the lake? Are they concerned about environmental impacts on the lake caused by over use? The questionnaire can also be used to get information for other uses. How far have you traveled to use this lake? What is the maximum distance that you would travel to use a lake? How many times a year do you visit this lake? How many other lakes do you visit for recreation in a typical year? Economic data can be generated by this survey as well. Money spent on a typical visit for meals in restaurants and nights spent in motels would be examples of data that could also be collected.

These surveys can also be used to help decide what weighting should be assigned to the factors chosen. If there is an overwhelming concern for safety and closeness, this could be more heavily weighted. If interference from PWC is an important issue for those surveyed, then this can be weighted accordingly.

The important concept is that a proper and complete carrying capacity study is not possible without an intensive collection of data on actual usage of the lake by boat type and input by survey of the lake user for their attitudes and concerns. With the above two items completed, a carrying capacity assessment is possible.

[39] See footnote #13 Appendix B. There are over 800 lake observations recorded.

Conclusions

This report has identified the parameters that affect the determination of a lake's carrying capacity. Many values of area requirement per type of boat activity have been suggested. The committee calculated the area requirement for skiing given certain assumed parameters.

So are the lakes exceeding their carrying capacities? Tables 9 and 10 answer this question for each of the areas proposed by the cited sources:

Table 9
Lake Gage Carrying Capacity

Source	Recommendation, Acres per Boat	Usable Lake Area Acres	Carrying Capacity
Ashton[40]	7.5	260	35
Kusler[41]	40	260	7
Jaakson[42]	20	260	13
Wagner[43]	25	260	10
Warbach[44]	30	260	9
Duke Power study[45]	8	260	33
BOR[46]	7	260	37
Average			21 boats

Table 10
Lake James Carrying Capacity[47]

Source	Recommendation Acres per Boat	Usable Lake Area Acres	Carrying Capacity
Ashton	7.5	736	98
Kusler	40	736	18
Jaakson	20	736	37
Wagner	25	736	29
Warbach	30	736	25
Duke Power Study	8	736	92
BOR	7	736	105
Average			58 boats

[40] See footnote #15
[41] See footnote # 16
[42] See footnote # 17
[43] See footnote # 18
[44] See footnote #19
[45] See footnote #21
[46] See footnote # 29, Figure is the average of limited power boating, III-16, and unlimited power boating, III-18. Limited was 4.3 apb and unlimited was 9.0 apb.
[47] So as not to be too repetitive, the footnotes are the same a Table 9.

The carrying capacity for Lakes Gage and James, based on the areas recommended by the literature, is revealing. The capacity of Lake Gage is 21 boats when there is mixed activity present. The capacity of Lake James is 58. If the extreme value by Kusler is taken, the capacities are only 7 and 18 respectively.

These values clearly show the necessity of a custom capacity study for a lake. If the average is true, the study lakes are well beyond their carrying capacity during times of high use. There are times, weekdays, before Memorial Day and after Labor Day, when these boat numbers are not exceeded, but on most every summer weekend, these numbers are exceeded. On one August Sunday afternoon, 45 boats (a mixture of power, pontoon and PWC) were observed entering Lake James through Jimmerson Creek in one 30 minute period. While this snapshot picture is not statically valid, it does give some indication of the number of boats going on to Lake James. The literature has suggested that the typical use of a lake by its resident boat population varies from 2.3% [48] to 8%.[49] Averaging these values would give an average usage of 5%. If you only include powered boats, this would mean that on Lake Gage residents have 21 boats on the lake during peak usage hours. For Lake James, this number would be 77 boats. Both of these generated values exceed the theoretical carrying capacity of the lake and do not included boats entering from public access sites or from other lakes.

The boating use of the lakes will also increase as more multi-family developments are placed around the lakes. The vast majority of these developments will be large condominium developments. The most likely buyers of these units are nonresidents of Steuben County. Most of the buyers will use the units as second homes. They will be at the lake in order to be on the lake. Back lot funneling to the lake and the increased boat traffic associated with funneling is an on going concern to both the LCLC and the SCLC. It is expected that the percentage of moored boats that are using the lake will increase as a result. It is estimated that there have been about 125 units approved for construction by Steuben County zoning control authorities for Lake James. There are also proposals for units on Crooked Lake, Lake Gage and others. This influx of lake users will have a negative impact on the lakes.

The conclusion of this study can be summarized in one sentence. **Both Lake Gage and Lake James exceeds its carrying capacity on the typical summer weekend.**

---

[48] See footnote # 13, pg. 28
[49] See footnote #12, pg.15

Recommendations

These are the recommendations of the Carrying Capacity Study Committee:

1) That there be a study of the environmental impact of over capacity use on the lakes. The committee feels that the impacts of boating on the environment of a lake needs review, and the fact that the lakes seem to exceed their carrying capacity by multiplies, means that the study needs to be undertaken soon.
2) That two lakes be selected on which to do a carrying capacity study. An in depth study using the methodologies cited in the literature will serve as an experience guide for others who wish to determine the carrying capacity of their lake.
3) That the results of this committee study be disseminated to the individual lake associations. The study should be distributed to governmental bodies, the press, or anyone who would have an interest in or the power to determine the levels of lake usage.
4) Work with government agencies to enact laws that will positively impact the health, safety and enjoyment of the lake resources. An example of this would be a maximum speed limit for boats on inland fresh water lakes. Less area is required for slower moving boats, generated waves are smaller for slower moving boats, and there should be fewer user conflicts if the speed of boats is controlled.
5) Use this study to influence authorities to include lake carrying capacity as one of the factors when considering the approval of projects that will place more boats on the water.

Bibliography

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

Warren, Roger and Rea, Phillip. 1989. *Management of Aquatic Recreational Resources* Publishing Horizons, Inc., Columbus, Ohio (Available from the Indiana University Library, Bloomington. Call number GV 191.67.W3 W36 1989)

Dearlove, Paul and Molinaro, John. 2003. *Lake Ripley Watercraft Census & Recreational Carrying Capacity Analysis* Lake Ripley Management District

Dearlove, Paul and Molinaro, John. 2004. *Assessing a Lake's Recreational Carrying Capacity*. Summer 2004 Lakeline.

Bureau of Outdoor Recreation, U.S. Department of the Interior. 1977. *Guidelines for Understanding & Determining Optimum Recreational Carrying Capacity.* Urban Research Development Corporation, Bethlehem, Pennsylvania. (Available from the IUPUI Library, Indianapolis, call number GV 182.15.U73)

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

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

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

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

Dudiak, Tamara. 2004. *How Much is Too Much? A Recreational Use Assessment.* North American Lake Management Society Spring 2004 Lakeline

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

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

Progressive AE. 2001. *Four Township Recreational Carrying Capacity Study.* Four Township Water Resources Council, Inc.

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.

Note : Most everything listed above can be found on the Internet. Using "boat carrying capacity" or "Bureau of Reclamation" in the search engine will generate many more sources than are listed here. Some of the above were not cited in the report, but are good sources of information and insight on the question of carrying capacity.

Abbreviations

BOR – Bureau of Outdoor Recreation, United States Department of the Interior

GIS – Geographic Information System

IDNR – Indiana Department of Natural Resources

LCLC – LaGrange County Lakes Council, Inc.

PWC – Personnel Water Craft

SCLC – Steuben County Lakes Council, Inc.

SDF – Shoreline Development Factor

Appendix 1
Shoreline Development Factor Calculations

Shoreline Development Factor (SDF) determination for Lake Gage.

Area of Lake Gage = 332 acres X 43,560 sq.ft./acre =
= 14,461,920 sq. ft.
Circle area = 14,461,920 sq.ft. = 3.14159 x r x r
= 4,603, 375 sq. ft. = r x r
r = √ 4,603,920 sq. ft.
r = 2145 feet

Circumference = 2 ∏ r = 2 x 3.14159 x 2145 ft. = 13,480 ft. This is the theoretical shoreline.

SDF = actual shoreline/ theoretical shoreline = 15,631 ft./13,480 ft. = 1.16

Shoreline Development Factor (SDF) determination for Lake James.

Area = 1039 acres X 43,560 sq. ft./acre = 45,258,840 sq. ft.
r x r = 45,258,840 sq. ft. / 3.14159 = 14,406,348 sq. ft.
r = 3,796 ft.

Circumference = 2 x 3.14159 x 3796 ft. = 23,851 ft.

SDF = 66,000 ft./ 23,851 ft. = 2.76

Appendix II
Calculation of Area Requirements for Various Boats

Ski Boats

From page 12, the calculated value of a ski boat with a 75-foot long rope was 4.60 acres. For a speedboat from this number subtract the area for the 75-foot long rope. This is 0.69 acres. The area for a speed boat traveling at 30 mph is then 4.60 acres – 0.69 acres = 3.91 acres. This number is multiplied by the SDF for each lake, 1.16 for Lake Gage and 2.76 for Lake James. The result is :
Lake Gage : 3.91 acres x SDF = 3.91 acres x 1.20 = 4.5 acres
Lake James : 3.91 acres x SDF = 3.91 acres x 2.76 = 10.8 acres

Pontoon Boats

For a 24-foot pontoon boat traveling at 6 mph the area requirement is :
6 mph = 8.8 feet/sec. With 400-foot clear zone and 2 second separation :
8.8 ft/sec x 2 sec x 400 ft = 7040 sq.ft. = 0.16 acre.
The 200-foot radius circle around the boat has an area of 2.9 acres.
The 24-foot length x 400 ft = 9600 sq.ft. = 0.22 acres
The total area required is : 2.9 + .16 + .22 = 3.3 acres
Lake Gage : 3.3 acres x SDF = 3.3 x 1.16 = 3.8 acres
Lake James : 3.3 acres x SDF = 3.3 x 2.76 = 9.1 acres

Personal Water Craft

For a PWC : For the sake of this calculation, it will be assumed that the PWC is a point, has no effective length. Assume a speed of 30 mph = 44 fps.
44 ft/sec x 2 sec x 400 ft = 35,200 sq.ft. = 0.81 acres
The 200-foot clear radius = 2.9 acres
Total area required = 2.9 + 0.8 = 3.7 acres
Lake Gage : 4.0 acres x SDF = 3.7 x 1.16 = 4.3 acres
Lake James : 4.0 acres x SDF = 3.7 x 2.76 = 10.2 acres