Cisco Chain Riparian Owners Association
Hazardous Wakes
Review of Published Studies
May 1, 2023

Compiled and edited by Steve Kessler, West Bay Lake Representative

Section A - Background:
Cisco Chain Riparian Owners Association (CCROA) Board Members were asked to review published studies relative to Wake/Surf Boats (WSB) during the winter of 2022 – 2023. The recommendations included in the attached position paper were made after a review of those studies.

We believe that our review was comprehensive and included most of the studies that are recent and relative.

On March 8, 2023 Vilas County hosted a "Local Regulation of Hazardous Wakes Workshop". Cathy Higley, Lakes Conservation Specialist, presented "Current Science Behind Hazardous Wakes". She presented and summarized ten different studies. We have reviewed all ten of those studies. We have also gained insight from a few noteworthy studies which were not included in her presentation.

The Wisconsin Conservation Congress (WCC) held a survey in mid-April of this year addressing many topics, one of which was WSB regulation. The 6 questions on WSB regulations were overwhelmingly (2 to 1 margins) in favor of greater regulation of WSBs operating in "wake surf mode". You can view the results here:
https://dnr.wisconsin.gov/sites/default/files/topic/About/WCC/2023/SpringHearing/2023_StatewideResults.pdf

Here we will summarize the findings of the published research. We will identify the authors and the funding source for each study. We will present many excerpts but encourage readers to read the reports in their entirety and we will provide internet links to help the reader find the presentations.

Section B - Overview White Paper:

In September 2022 The Fisheries Division of the Michigan DNR published *"Wake boats: concerns and recommendations related to natural resource management in Michigan waters"*. Here is the link:
https://mymlsa.org/wp-content/uploads/2022/09/DNR-Wake-Boat-Report.pdf

The authors of this report did no field work or basic research. They did an exhaustive review of studies performed by others, and distilled all that they learned down to six very readable pages. Here are key excerpts from the Executive Summary and from the Conclusion:

EXECUTIVE SUMMARY

The operation of wake boats in a manner that creates large waves and increases bottom scour is an emerging threat to natural resources in inland lakes. Wake boats can produce waves with 1.7–17 times the

energy of other comparable-sized powerboats and their propellers generate enough turbulence to resuspend bottom sediments in water up to 33 feet deep. The large waves generated by wake boats take between 225–950 feet to dissipate to heights and wave energies observed 100–200 feet away from similar boats operating at cruising speed. Further, the use of ballast tanks in wake boats results in a dramatic increase in risk for transporting Dreissenid mussels and other aquatic invasive species and pathogens among water bodies. The cumulative negative effects of wake boats on natural resources can lead to loss of habitat, resulting in the decline of aquatic ecosystems and angling opportunity.

CONCLUSION

Wake boats provide a means of outdoor recreation but the waves and propeller turbulence they generate can damage aquatic environments through a number of mechanisms. The cumulative effects of these damages will lead to loss of habitat and resulting declines in aquatic ecosystems and angling opportunity. The recommendations below are intended to provide guidelines under which the recreational opportunities that wake boats provide can be enjoyed in a manner that minimizes harm to the natural resources and property of Michigan citizens:

1. Boats operating in wake-surfing mode or wake-boarding mode, during which boat speed, wave shapers, and/or ballast are set to maximize wave height, should operate at least 500 feet from docks or the shoreline, regardless of water depth.
2. Boats operating in wake-surfing or wake-boarding modes should operate in water at least 15 feet deep.
3. Ballast tanks should always be drained prior to transporting the watercraft over land.
4. Regulatory authorities and the boating industry should implement an education and outreach campaign that targets wake boat operators to improve awareness and implementation of the best practices listed above.

Section C: Wave Energy, Shoreline Erosion, and Safety

Large wakes contribute to shoreline erosion, threaten the safety of other lake users, and can cause damage to moored boats and to shoreline docks. The potential for a wake to contribute to these threats is evaluated by the wave's energy. Wave energy is a function of wave height. Energy increases by the square of an increase in wave height. If wave height doubles wave energy increases by 4X. If wave height triples, energy increases by 9X. Hence the concern over the energy generated by big "hazardous" wakes.

Threats posed by large energy laden waves can be mitigated by increasing the distance between the source of the wave and the shoreline, other lake users and shoreline property. Current law requires only one hundred feet.

Surf boats generate big waves primarily by operating at slow speeds off plane (referred to as "plowing").

Are the waves generated by Wake/Surf Boats operated in "surf mode" a greater threat to shoreline erosion, to the safety of other lakes users and to the security of property, than the waves generated by pontoons, ski boats, and fishing boats? How about as compared to wave action driven by the wind? Does the surf mode generated wave require greater distances to dissipate than the ski boat generated wave? The following studies address these questions.

St. Anthony Falls Study. University of Minnesota College of Science & Engineering at St Anthony Falls Laboratory. Title*: A Field Study of Maximum Wave Height, Total Wave Energy, and Maximum Wave Power Produced by Four Recreational Boats on a Freshwater Lake.* Funded via crowd sourcing. Donors had no input. Peer reviewed. Link:
https://conservancy.umn.edu/handle/11299/226190

Key findings:

- The waves generated by test surf boats operating in surf mode (plowing) were compared to waves generated by test non-surf boats operating on plane. 100 feet from the boat, the plowing surf boat vs non surf boat measurements were: wave height: 2X to 3X, total wave energy: 3X to 9X, and maximum wave power: 6X to 12X.
- A surf mode generated wave must travel more than 500 feet before its height, energy and power decreases to the height, energy and power of a non-surf boat generated wave 200 feet from the boat.
- The wave generated by a non-surf boat when the boat transitions from "still" to "on plane" is larger than the wave it generates once on plane (the transition wave). Even so, surf mode plowing generated waves had substantially more energy than the transition waves generated by non-surf boats. Surf boat generated plowing waves must travel more than 425 feet before dissipating to the energy levels of transition waves generated by non-surf boats.

Lake Rabun and Lake Burton Study. Work performed by Water Environmental Consultants. Funded by respective lake associations. Link: https://docslib.org/doc/12378144/boat-wake-impact-analysis

Key Findings:

- Surf Mode generated waves required 950 feet to dissipate to the wave heights observed 100 feet from the same boat in cruising mode.
- The height of waves generated by surf mode plowing were 2X the height of waves generated by on plane operation of other recreational boats.
- Measurements were taken of the horizontal force hitting a shoreline vertical wall by a wave generated 500 feet from shore. The force generated by plowing surf boats was 100% greater than the force generated by cruising/waterskiing boats on plane.
- 66% of lake association member survey respondents reported frequent or occasional swamping cause by surf boat plowing waves. (57% response rate in survey, total of 486 responses).
- The maximum wave energy from wind was calculated for two locations on Lake Rabun and compared to the wave energy hitting those locations from surf mode waves generated by a surf boat 100 feet from shore. The wave energy produced by the surf mode wave was 2,546% higher than the monthly maximum energy from wind driven waves.

Considerations in assessing shoreline and near shore impacts of wind-driven waves vs motorboat waves in Vermont. Author: Responsible Wakes for Vermont Lakes, July 9, 2022, Link: https://dec.vermont.gov/sites/dec/files/wsm/lakes/docs/Additional%20supporting%20Information%20submitted%2007292022.pdf

Key Findings:

- The authors are a citizen group, founded in March 2021 by citizens concerned about the environmental impact of enhanced waves created by surf boats on Vermont lakes. While this group is hardly "unbiased", their study is nonetheless interesting.
- The study uses publicly available, archived wind speed and wind directional data from the Automated Surface Observing System (ASOS) at Vermont airports (every pilot is familiar with this data).
- The study challenges conclusions contained in the Goudey Study (funded by the Water Sports Industry Association) that the impact from surf boat generated waves is no more damaging than that from naturally occurring wind.
- Actual historical wind data reviewed demonstrated that the wind speeds and directions assumed in the Goudey Study hardly ever occur. Additionally, shorelines not in line with prevailing winds are not subject to erosion from wind driven waves. "For most Vermont inland lake shorelines, wave-driven shoreline erosion will be dominated by motorboat waves".

Numerical Study of the Impact of Wake Surfing on Inland Bodies of Water, Authors: Endicott M. Fay, Andrew Gunderson and Arden Anderson, March 23, 2022. Link: https://www.scirp.org/journal/paperinformation.aspx?paperid=116094

The following summarization of this study borrows heavily from wording used by Cathy Higley, Vilas County Lakes Conservation Specialist, in her presentation "Current Science Behind Hazardous Wakes".

Background:

- Study funded by the National Marine Manufacturers Association (NMMA). Gunderson and Anderson are Mercury Marine employees, Endicott Fay is a former Mercury Marine employee.
- The study used physics theories and modelling to create conclusions (no field data collection)
- Study investigates wind waves and wake surfing waves and models their potential to impact lake bottoms and shorelines.
- Study is not peer reviewed.
- Study finds conclusions that are quite different from the other studies available.
- The study has received significant criticism. Four critiques can be found at the following link: https://dec.vermont.gov/sites/dec/files/wsm/lakes/docs/Critiques%20of%20NMMA%20CFD%20Study%2020220419.pdf

Findings:

- Bottom and shoreline impacts from surf boats are minimal if operated 200 feet from shore and in water at least 10 feet deep.

Section D: Phosphorous

- A discussion about phosphorous is necessary to understand why we should care about "Sediment Resuspension", the subject of the next section.
- The Cisco Chain saw extensive blue green algae growth on West Bay Lake during the summer of 2022. East Bay, Mamie, and Big Lakes had algae blooms as well, but they were not as significant as the bloom that occurred on West Bay.
- While surf boats have a role in triggering algae blooms there are many other factors as well. No one is asserting that there is a direct causal factor between surf boat operation and the algae blooms that occurred last year; it is not that simple.
- Algae blooms occur when lake nutrient levels increase. Nutrient levels for the individual lakes in the Cisco Chain can be found in the published reports of the Cooperative Lakes Monitoring Program. Cisco Chain lakes, except for Thousand Island Lake, have relatively high nutrient levels. Nutrient levels in Fishhawk and West Bay are about the same. Mamie, East Bay, Cisco, and Big Lake all have higher nutrient levels than West Bay.
- Per a published report authored by Cathy Higley, a study of 88 Vilas County lakes during the period 1990 to 2019 indicated 27 with statistically significant trends. 74% of the lakes in transition were moving to higher concentrations of phosphorus.
- The following is excerpted from the book *Ripple Effects* by Ted J. Rulseh":

  Excess nutrients in lakes come from sources that include polluted runoff from farmland upstream and from improperly designed, poorly maintained, or failing septic systems. Other sources include stormwater carrying all manner of dirt, chemical, and debris from urban streets, over application of lawn fertilizers; and rainfall runoff from lakefront lots carrying leaves, pet waste, and other nutrient-rich materials.

The nutrient of greatest concern for most inland lakes is phosphorus. By its nature, phosphorous is essential; it supports the production of plant roots, flowers, and fruits and gives strength to stems and stalks. But in excess, it is destructive to lake ecosystems. Phosphorous is known as the limiting nutrient in lakes-among Nitrogen, Potassium, and Phosphorous, it is the nutrient typically in shortest supply. The issue is not that plants and algae need a great deal of phosphorous. The issue is that in most lakes, phosphorous is comparatively scarce. But when more phosphorous is added to the water, the algae have a feast and reproduce with abandon.

Section E: Sediment Resuspension

When propeller downwash stirs up the lake bottom bad things happen. Aquatic plant life can be damaged. Fish eggs can be covered. Propeller downwash can blow phosphorous off the lake bottom up into the water column providing the "fertilizer" necessary for an algae bloom.

Excerpts from the Michigan DNR Report:

- Sediment resuspension decreases water clarity in lakes, subsequently reducing the ability of fish to find food, the depth to which aquatic plants can grow, and the dissolved oxygen content within the water.
- In addition, as sediments are resuspended and nutrients become available in the water column, excessive algae growth can occur.
- Boat wakes resuspend sediments, especially fine substrates such as silt or sand, in shallow waters and this resuspension increases with wave energy. Existing studies have shown that resuspended sediments caused by powerboats increase turbidity and phosphorus concentrations in rivers, lakes, and shallow experimental ponds.
- Wake boats have greater potential to exacerbate sediment resuspension through increased wave energy and propeller turbulence. Mercier-Blais and Prairie (2014) determined sediment resuspension was significantly higher than background conditions up to 492 feet from wake boats operating in wake-surfing mode and 656 feet from wake boats operating in wake-boarding mode and was highest when wake boats were operated in wake-surfing mode at a speed of 10 mph… Field testing by Raymond and Galvez (2015) found that wake boat propellers generated water velocities with the capacity to resuspend unconsolidated sand, silt, and smaller organic materials at a depth of 15 feet while the boat was in wake-boarding or wake-surfing modes. Ray (2020) estimated that modern wake boats can cause sediment resuspension in water up to 33 feet deep.

A Phased Study of the Water Quality and Wave Propagation Dynamics Currently Impacting a Small Southeast Wisconsin Freshwater Lake in Waukesha County, WI, June 2022. A collaborative effort between Carroll University (Chemistry, Environmental and Aviation Sciences), Southeastern WI Regional Planning Commission, and Terra Vigilis Environments Services. Funded by the North Lake Management District and a grant from the WI DNR. You Tube Video Link: https://www.youtube.com/watch?v=t3KpNPlGyw0

Findings:

- This is a sophisticated scientific study utilizing extensive field work, water quality measurements of phosphorous, suspended solids, dissolved oxygen and water temperature. Aerial drones were used for imagery depicting plume development and wave features. Submersible Drones were used for observing propwash depths and impact on aquatic plants. Submersible cameras and engineered submersible measuring devices were utilized. Test boats included surf boats, personal watercraft, pontoons and fishing boats.
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- Edited Excerpt from Phase 2 Principle Findings:
    - There are significant differences noted between the wave characteristics and impacts of wave action from various powered vessels. Less impactful wave effects are noted from Pontoon boats, fishing vessels, and PWC compared to Wakeboard Boats in "Surf Mode". Wakeboard Boats in surf mode have both surface and subsurface impacts.
    - Propeller downwash characteristics have been measured showing significant bottom effects from Wakeboard boats in "surf mode" **at depths greater than 20 feet.** This depth effect is not observed from the other three categories of vessels owing to reduced engine power, propeller angles, hull design, lack of ballasting, and the mode of operation ("planing").
    - Near shore impacts from wave propagation show significant differences between vessel type and distance from shoreline. At measured distances from shoreline (300') Wakeboard boats in surf mode produce wave oscillations larger than all other categories with bottom impacts including scrubbing and re-deposition of sediments…
    - Bottom impacts from Wakeboard boats in surf mode have a significant impact on sediment redistribution and nutrient release into the water column after periods of less than 30 minutes (25% increase in phosphorous). This effect was measured in depths of 5-8'.
- Comment on final bullet point above: Analysts measured water chemistry in samples taken before and after completing two passes by a single wakeboard boat in surf mode. Test results included a 33% increase in phosphorous when the two passes were completed over a course in 15 feet of water. At a second site in 25 feet of water, a 25% increase in phosphorous was noted after two passes and at a third site, also in 25 feet of water, a 17% increase in phosphorous was noted after two passes.

University of Laval Study commissioned by the "Coalition of Sustainable and Responsible Navigation". Link: https://www.documentcloud.org/documents/6801170-SéBastien-2015-English-U-of-Laval-1.html

- Used an Acoustic Doppler Current Profiler installed on the lake bottom to collect data on the water depths impacted by the propeller wash of non-surf boats and by wake boats in surf mode.
- Water column disturbances from a pontoon with a 100hp motor at 3mph, 6mph, and max speed were seen at 3-6 feet deep.
- Water column disturbances from a wake surf boat was up to 16 feet.

Section E: Aquatic Invasive Species

The relationship between wake/surf boats and aquatic invasive species is an evaluation of risk. No one can cite a specific example of a wake board ballast tank transporting an invasive aquatic species to a specific inland lake. Likewise, no one can tell you the day, week and year, nor name the boat model and owner, responsible for the transfer of Eurasian milfoil to any local lake.

Excerpts from the Michigan DNR Report:

- The State of Michigan's AIS Management Plan (MDEQ 2013) prioritizes the need for preventing accidental AIS introductions, which may be greatly increased by wake boats due to the presence of large ballast tanks that can be filled from or emptied directly into the water body they are operating on.
- Research has shown that ballast tanks from wake boats operated on a lake infested with the Zebra Mussel *Dreissena polymorpha* typically carried 247 Zebra Mussel veligers per sample (Doll 2018), which was much greater than stern drive motor compartments (13 veligers per sample), outboard motor lower units (1 veliger per sample), live wells, or bilges.
- Although wake boat ballast tanks are typically emptied before trailering, they are rarely ever completely dry which increases the survival time for invasive species potentially trapped inside. Doll (2018) found that 5% of zebra mussel veligers remained alive in ballast tanks after 48 hours.

Volume and contents of residual water in recreational watercraft ballast system. Author: Tim Campbell and others. Campbell employed by University of Wisconsin. Supported by the University of Wisconsin Sea Grant Institute and the University of Wisconsin Extension Environmental Resources Center. Link: https://www.reabic.net/journals/mbi/2016/3/MBI_2016_Campbell_etal.pdf

Findings:

- Wake/Surf boats ballast systems differ from boat to boat. These ballast systems take on hundreds of gallons of ballast and have the potential to transport large volumes of residual ballast water. The ballast systems can be difficult, if not impossible, for a boater to drain completely.
- Thirteen wakeboard boats were sampled at Ft. Fremont Marine in Fremont WI. Only boats with ballast bags as opposed to hard ballast tanks were chosen for sampling. Before the ballast bags were removed for sampling, they were drained using existing pumps to ensure that only water that could not be drained was used for test measurements.
- The average residual ballast water in the thirteen watercraft examined was 8.3 gallons.
- Nine of the thirteen watercraft tested had viable organisms present in the residual ballast water, with thirteen different families of zooplankton and macroinvertebrates observed. Dreissenid veligers were detected in two samples, with 9 and 47 veligers present in those samples.
- The simple actions that drain water on other types of watercrafts (e.g. fishing boats, cruisers) such as pulling the drain plug and emptying the bilge, will not achieve the same risk reduction in wakeboard boats with ballast water systems.