

RUNNING HEAD: ENVIRONMENTAL IMPACTS OF WAKE BOATS ON DEEP CREEK

**Environmental Impacts of Wake Boats on Deep Creek Lake with Consideration of
Recreational and Social Benefits**

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Executive Summary

Wake boats are designed to create a large and specifically shaped wake through the use of ballast tanks and hull design. They are an increasing concern to water resources and their surrounding environment. After reviewing literature and data from California, Michigan, Nevada, New Hampshire and Maryland, this report documents findings and recommendations for recreational usage of wake boats, and their environmental sustainability in Deep Creek Lake. The goal of this paper is to link and identify wake boat connections to the local economy and the surrounding environment. Through a third-party overview of current policies and economic/environmental impacts, this study provides recommendations for the future of recreational wake boating in Deep Creek Lake. No scientific evidence from other states was sufficient to directly determine the extent of environmental damages provoked from wake boats. Until further research is conducted and analyzed, wake boats users should follow existing best practices of their local jurisdictions.

Wakeboarding is a water sport that combines water skiing, surfing, and snowboarding in which the rider is fastened to a board and towed behind a boat. The rider can ride the surface of the water, as well as perform wakeboarding and surfing tricks behind the boat (Boyd, 2016). The type of boat that is used has a big impact on the wake boarding experience and wakeboarders are looking to enhance their experience by creating the biggest wave possible. Wake boats, with specially designed wave-enhancing devices, create large wakes that appeal to wakeboarders and wake surfers (Discover Boating, n.d.). These boats have come a long way over the years, creating bigger waves that make the sport more extreme.

Recreational wakeboarding and wake surfing have gained a lot of popularity in the last few years. As a result, the wake boat industry has seen an increase in demand and is more competitive

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and innovative than ever (Discover Boating, n.d.). But what are the environmental implications of these boats and their wakes? And do the economic and social benefits outweigh the environmental consequences? Because this is a relatively new technology, the environmental impacts of wake boats are still being examined and considered. Wake boat policies and regulations are still in rudimentary phases in only a few areas of the country.

Wake boats are of growing concern due to their rising popularity and ever-increasing wave technology. They also impact a variety of stakeholders including the boating industry, local residents, the government officials who implement and enforce laws, recreational users, waterfront property owners and Marinas. When considering what types of wake boat policies should be implemented, it is important to consider all interested parties and both the positives and negatives of wake boats.

Deep Creek Lake

Deep Creek Lake is located in the western mountains of Garrett County, MD and spans about 3,900 acres (Deep Creek Watershed Plan Steering Committee, 2016). It is the largest freshwater lake in Maryland. The Deep Creek watershed is entirely within Garrett County and covers approximately 41,435 acres and is divided into several sub-basins (Figure 1). Most exposed geological formations around the lake are composed of sandstone and shale (Deep Creek Science, 2018).

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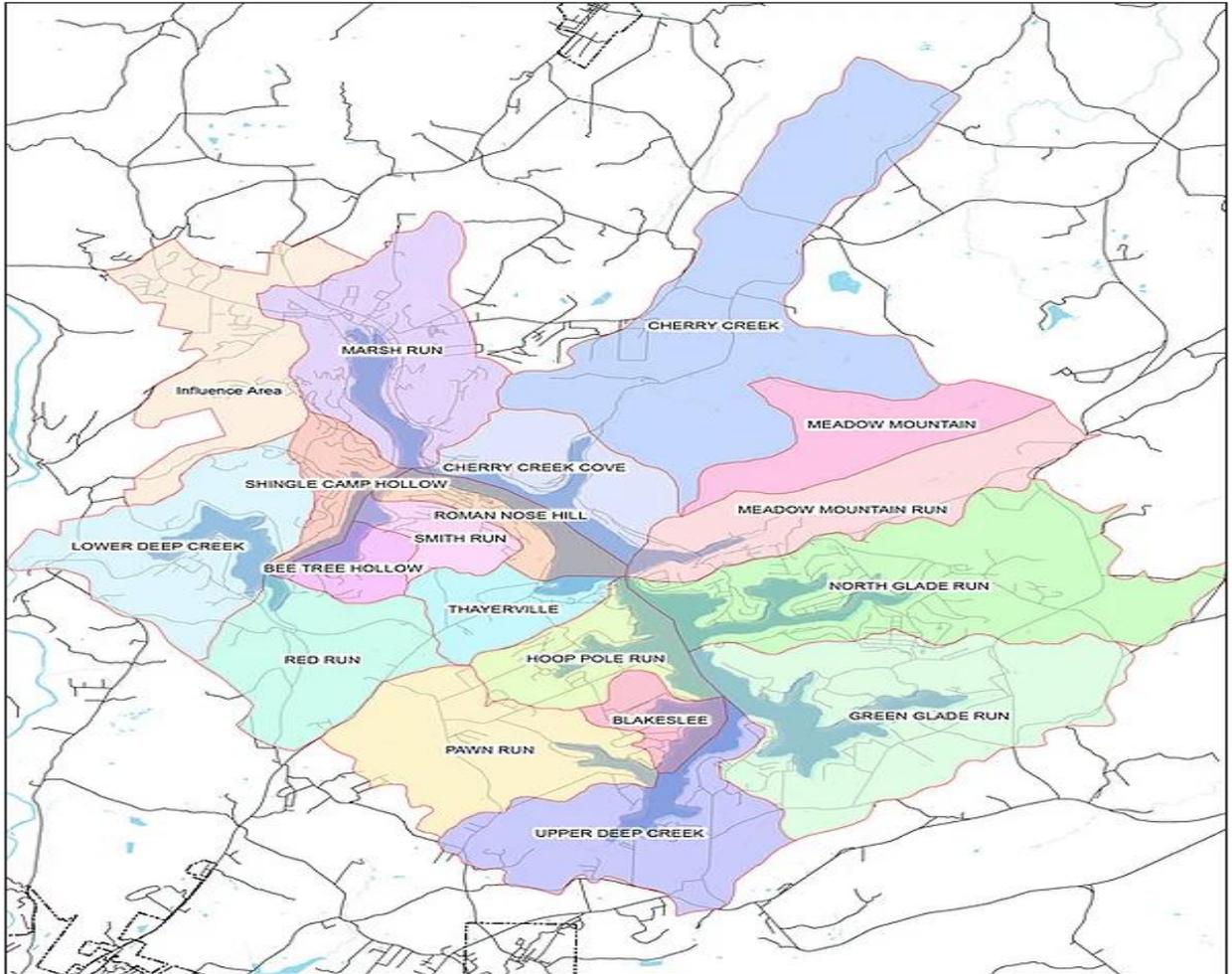


Figure 1. Deep Creek Sub-basin.

Retrieved from: <https://www.deepcreekwatershedfoundation.org/the-watershed>

The lake has evolved into a primary recreational destination and is the economic engine for Garrett County. It boasts a variety of recreational activities including boating, skiing, hiking, whitewater rafting, camping, and fishing (Garrett County Chamber of Commerce, n.d.).

In recent years there are growing concerns about the overall health of the watershed; apprehensions among community members, Garrett County, and the Maryland Department of Natural Resources (MD DNR), among others. There are growing concerns about reduced sediment in coves, submerged aquatic vegetation (SAV), lower water quality, lake level fluctuations, and other issues (Deep Creek Watershed Plan Steering Committee, 2016). There is a need to ensure the

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quality of the lake is preserved and recreational value is maintained. Some of these concerns extend beyond the authority of state-owned property and involve extensive cooperation between industries.

Historical Statistics

In 1922, Deep Creek was surveyed and identified as suitable site to construct a dam to generate electricity. Construction began in 1923 and was completed in 1925 by the Pennsylvania Electric Company, also known as Penelec (Deep Creek Watershed Plan Steering Committee, 2016). The reservoir was created by capturing the water in the existing creek, creating Deep Creek Lake and a two-unit, 20MW hydroelectric generation system known as Deep Creek Hydro (Brookfield Renewable Partners, 2018). Penelec was the long-time owner and manager of the lake and the lands surrounding it but over the years sold much of that land with the exception of a single buffer strip that circles the lake (Myerberg & Shepherd, 2014). By the mid-1900s the dam became a recreational spot; recreational activities, as well as public access, were managed by MD DNR.

In 1999, Maryland negotiated with General Public Utility, Inc. to purchase the lake bottom, buffer zone properties, and other parcels owned by the power company. The purchase was completed in 2000 for \$17 million and did not include the dam, intake, tunnel, or power plant (Deep Creek Watershed Plan Steering Committee, 2016). Later, General Public Utility sold the rest of the property to Brookfield Renewable Energy Partners who still owns it today. In 2000, the state of Maryland purchased the lake and its buffer zones, and the MD DNR manages it.

Community Involvement, Governance, Ownership

An Administrative Council, consisting of three main agencies (Garrett County, Maryland Department of the Environment (MDE), and the MD DNR) coordinate efforts to manage Deep Creek Lake and its watershed. This council is designed to facilitate coordination, cooperation and

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distribution of information between all three agencies to ensure that the Deep Creek Watershed Management Plan is implemented and managed properly and that project design, funding, and oversight are provided by the appropriate individuals (Garrett County Government, n.d.a). The Garrett County Watershed Coordinator, Gary Aronhalt II, assists with the implementation of the Deep Creek Watershed Management Plan and serves as the liaison between the Administrative Council and local stakeholders.

Stakeholders of the watershed include local residents and property owners, tourists and consumers with an interest in using the lake for recreational purposes, citizens with environmental concerns, affiliates with the power company, and government agencies tasked with managing the watershed. The Administrative Council works closely with the Educational Advisory Committee to include input from private citizens and promote communication through public outreach and education. This committee is comprised of volunteers representing various interests such as agriculture, business, education, forestry, marketing, recreation, and property owners within the watershed (Garrett County Government, n.d.).

Current Lake Usage

Deep Creek Lake started as a way to harness electricity and transformed into a popular location for water recreational activities. Deep Creek Hydro generates electricity but is also permitted by the MDE to manage water levels to support fisheries as well as white water recreation (Brookfield Renewable Partners, 2018). This helps the lake offer year-round recreational opportunities. Hydro maintains reservoir levels, particularly in periods of high run-off or extreme drought. Water releases may be a constant flow or variable flow with releases dependent on existing river and energy market conditions (Brookfield Renewable Partners, 2018).

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Wake Boats

Wake boats are designed to create a large, specially shaped wake. Boat manufacturers have developed systems that not only create large wakes but also enhance the shape of the wakes. The quality and size of the wake is largely a function of the hull design and ballast weight of the boat. Wake boats are specifically designed V-drive boat, meaning they are an inboard boat with the engine placed backward in the rear of the boat (Boyd, 2016). This design keeps more weight in the back of the boat and creates larger wakes. Some boats even use a stern drive design with propellers in the front (Discover Boating, n.d.). The more stern sitting in the water, the bigger the wave it can create. In addition to engine and propeller placement, most wake boats have ballast, hydrofoil, and hull technology that help create large wakes.

The depth and shape of a boat's wave are mostly decided by the amount of ballast, or weight, in the boat (Hughes, 2018). Most wake boat manufacturers have installed factory ballast systems but sometimes wakeboarders want more weight. In these cases, the ballast can take the form of hard tanks or soft bags which are filled with ambient water. Ballast tanks add extra weight in certain areas of the boat to create larger wakes.

The hull design also plays a major role in the size of the wake. A company called Malibu Surfgate created a two-gate system that sits on the back of the boat hull. As the gates turn left or right, the weight of the boat is shifted from one side to the other allowing the driver to make minor adjustments to the wave cresting (Hughes, 2018). Some boats have an integrated wake shape plate as well as "dynamic reduction of pressure zone wake-enhancing technology" (Boyd, 2016). In these boats, the hull is specifically molded to displace large amounts of water. Wake plates and trim tabs, as well as some type of ballast system and other devices, allow the driver to create an ideal wave for wakeboarders.

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Many wake boat manufacturers operate on one central truth – more displacement equals a bigger wave. One company, Centurion Surf System, capitalizes on this theory by advertising a power wedge that sits deep in the water with a shaped arc to create a massive wave (Hughes, 2018). A wedge is a hydrofoil device that can be extended or retracted. When it is extended it creates a downward force that pulls the stern of the boat lower in the water creating a larger wave. Some boats use an "attitude adjustment plate" which is a large trim tab that allows the boat to be trimmed- enhancing the wake. Other boats use a "hydrogate" that creates a small channel along the stern of the boat. When the hydrogate is open, it creates a higher velocity of water through the trough, creating a region of lower pressure, causing the transom to settle lower, creating a larger wave (Boyd, 2016).

Environmental Impacts

The larger waves from wake boats result in accelerated erosion in the shorelines, making a major impact in water bodies such as Deep Creek Lake. Erosion and deposition are naturally occurring but are a slow process and wake boats accelerate their occurrence, affecting the natural timeline. Any boating activity interferes with the natural process of erosion, and this is proven by sheltered systems where there should be minimal shoreline erosion without boating activities, meaning waves that occur by boats does accelerate erosion, there has been studies in which sheltered areas with no boating recreational activity have not shown accelerated erosion (Bilkovic et al., 2019).

The velocity and impact of waves produced by wake boats are believed to be stronger than other recreational boats on shorelines (Bloom, 2017). A combination of factors influences the extent of the boat wake energy: water depth, vessel length, boat speed and channel shape. The wave energy from boats is different from waves produced by wind, particularly in terms of

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influence in erosion, due to higher wave height and wave period (Bilkovic et al., 2019). The following diagram shows possible effects on water bodies produced by boat wakes (Figure 2).

The impact on shorelines can be hidden by some coastal infrastructures, these impacts can be seen in habitat heterogeneity in sediment systems (Hedge, Dafforn, Simpson & Johnston, 2017). By the constant impact of these waves, the shoreline vegetation gets affected which works as an attenuator to the wave to avoid major erosion (Bilkovic et. al, 2019). Also, as a result of these waves, erosion creates mini cliffs at the “leading edge of mudflats”, which is a matter of concern for vegetated mudflats, resulting in sediment being transported (Wollanski & Elliot, 2016).

Wakes produced by boats are affecting the environment in theory; the challenge is to provide complete scientific evidence to correlate wake boats with erosion to the shoreline. There are many contributing factors to erosion; making it event independent will entail further research than a literature review and to separate each variable.

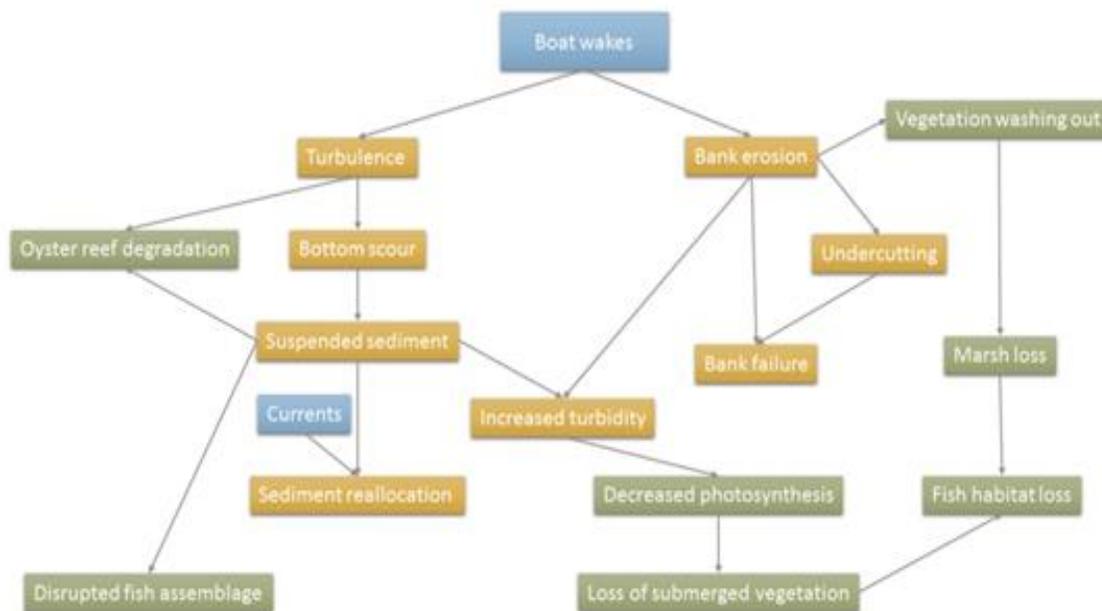


Figure 2. Potential boat wake impacts. Blue boxes are changing factors, yellow are changing factors in the ecosystem and green boxes impacts on living sources.

Source: Scientific and Technical Advisory Committee, Chesapeake Bay Program,

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Water Quality

Another major environmental concern from wake boats is reduced water quality. One manifestation is increased turbidity. Boat activities already affect turbidity by stirring sediments and preventing them from settling out (Alexander & Wigart, 2013). Studies have correlated recreational boating activity and nearshore turbidity. High recreational boating activity was linked to elevated turbidity in the Chesapeake Bay (Bilkovic et. al,2019). Considering the mechanical aspects of the wake boats including the hull design and ballast weight, their impact should be greater on water turbidity.

Contaminants

Other potential impacts on the environment are contaminants. Recreational boating re-suspends sediments in the water column (Sagerman, Hansen, & Wikström, 2019); with suspended sediment high concentrations of phosphorus are also possible. High-activity boating areas such as marinas and ports in Australia showed a high sediment metal concentration, probably occurring from boat coating and vessel hulls (Hedge et al., 2017). Another potential contaminant is chemicals from lubricants and fuels from boat engines (Sagerman et al., 2019). As mentioned previously boating activity including mooring is linked with high turbidity which affects water clarity hence aquatic vegetation, which would disturb the sediment nutrients (Figure 3).

Studies suggest an elevation of metals and phosphorus in areas where mooring and recreational boating activities such as wake boats occur (Hedge et al., 2017). For contaminated sediments, multiple types of research have been conducted in terms of possible remediation technologies, however, the drive of such research was not due to wake boat contamination. Remediation techniques such as dredging and in-situ are often used for contaminated sediments, but they are expensive, complex and work better in some situations than others (Zheng, Ying Lin,

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Chiueh & Lo, 2019) Because wake boats are a new phenomenon, their potential contaminant contributions haven't been addressed.

Implementing policies and monitoring in Deep Creek Lake could prevent the need for remediations. Whitney, Bailey, Cox & Magnan (2013) recommended continuous monitoring of Deep Creek Lake for shoreline erosion, stream erosion, and all developments as best management practices to ensure there is no decline on the Lake's health. They also recommended strict guidelines for agricultural fields and implementation of buffer zones in the lake.

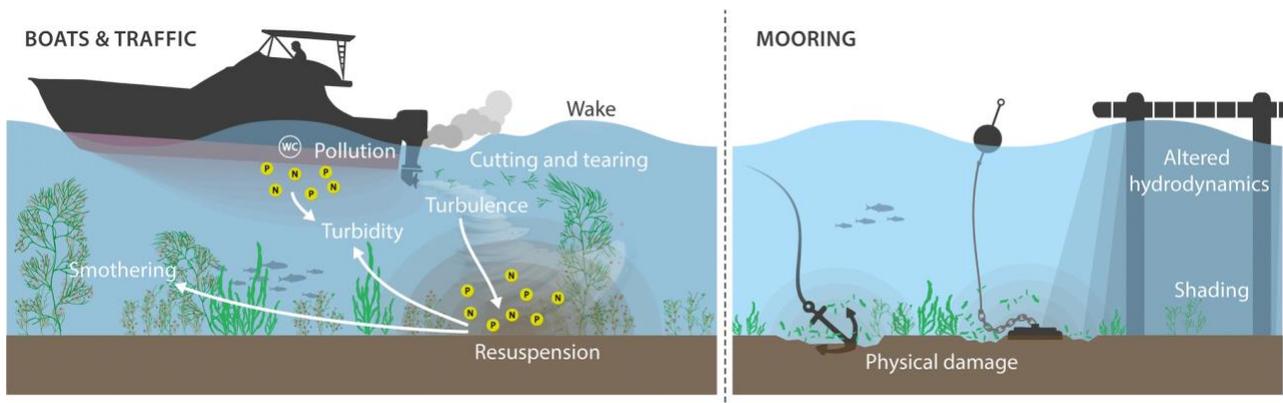


Figure 3 The effects of recreational boating activities in water, sediment, and vegetation. Source: Sagerman, Hansen & Wikström (2019).

Federal Policies

Federal policy guides “no-wake zones”, but there are currently no federal policies specific to wake boats. The major concerns around wake boat usage are the potential damage to lakefront property and docks, which lake managers have gathered from local residents at Deep Creek Lake and throughout the country. Another concern and an area that needs more research is whether the enhanced wake from wakeboard boats is causing erosion to the shoreline and shoreface.

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Throughout the United States, local property owners have filed complaints about the noise and the safety issues caused by improper operation of wakeboard boats.

Current Regulations in Maryland

Like all motorized watercraft, wake boats must obey “no wake” speed limits in protected areas (VDGIF, 2019). Most of the regulations currently in place are designed to promote the safe operation of conventional boats. In Deep Creek Lake, all motor craft are prohibited from producing large wakes in certain areas. Vessels 26 feet long and up are prohibited from using the lake with the exception of pontoon boats, which may be up to 30 feet. All vessels, including wake surfing boats, must not exceed a speed of 3.5 mph within 100 feet of the shoreline on the lake, with the exception of towing a water-skier away from any restricted area (MDNR, 2017). This regulation is to accommodate the narrow footprint of the lake to minimize shoreline erosion and excessive wake energy on boat docks. The 100-foot rule applies to marine structures including docks, piers, bridges, and swimming or water-skiing floats as well channel markers and regulatory buoys (MDNR, 2017). All portable ballast tanks must display maximum capacity in gallons and/or maximum weight in pounds. This will help to determine the maximum weight and ensure it does not exceed the maximum weight capacity for any given vessel (MDNR, 2017). When wakeboarding, water skiing or tubing, there must be both an operator and an observer in the boat 12 years old or older. Wake boat operators must obey the current regulations in place for all motorized watercraft. Some localities are creating stricter regulations for wake boats ahead of formal studies and research.

Wakeboard boats are very expensive at around \$200,000 for a new boat versus \$20,000 for a regular speedboat, which is likely the limiting factor in the number of boats on the lake. Property owners began filing complaints about the boats three years ago and the complaints have increased

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over the years along with boat use. Large wakes can damage docks and moored boats, but most reports are filed as a result of negligent operations such as boats operating too close to docks or passing too closely to other watercraft or fishers. Deep Creek Lake is a long, narrow lake, so the large waves produced from ballast boats do not have much time to dissipate before reaching the shoreline or docks. The current “no wake zone” or limit on wake surfing is 200 ft from any untethered structure or 100 ft from any structure, object or vessel once the wake surfer is tethered to the boat. The effect of a larger wake on the shoreline of the lake is exacerbated during times of high water as the wake is able to travel higher up on the shoreline, which is documented in anecdotal accounts (Eric Null, personal communication, October 30, 2019). Deep Creek Lake has begun negotiations with the power company to keep the lake water level down.

Deep Creek Lake managers are concerned about the potential of wake boats to spread aquatic invasive species due to the design of ballast tanks. The current invasive species program invested \$200,000 a year for hydrilla, zebra mussels and spiny water flea control (Eric Null, personal communication, October 30, 2019). Maryland DNR cannot move forward on regulations for wake boats without data to support the decision.

The Deep Creek Lake Policy and Review Board was formed to document citizen complaints and determine when to move forward with regulatory suggestions. The Maryland Boat Act Advisory Committee consists of 21 members of the public appointed by the Maryland DNR Secretary to serve a term of three years. The group meets six times per year to manage community input and regulations for lake usage on active lake areas and advise the secretary on proposed changes to boat regulations (Eric Null, personal communication, October 30, 2019).

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Wake Boat Policies Elsewhere

Lake Tahoe, CA

In California, Lake Tahoe is similar in size but much wider, to Deep Creek Lake with a width of 12 miles and a length of 22 miles north to south. Lake Tahoe has 72 miles of shoreline and a maximum depth of 1,645 feet. The Tahoe Regional Planning Agency (TRPA) regulates activity on Lake Tahoe and while they do not have rules or policies specific to wake boats, all motorized watercraft are required to obey the required 600 ft “no wake zone” around all aspects of the Lake. The remaining water in ballast tanks can harbor juvenile stages of invasive aquatic species, so ballast tanks must be decontaminated every time they exit the water using hot water. All motorized watercraft are also required to undergo inspection prior to every launch for invasive species control. Wake boats can cause additional strain on the aquatic invasive species control program because their ballast tanks never completely drain (Dennis Zabaglo, personal communication, October 21, 2019). The Tahoe Regional Planning Agency (TRPA) reasons that wakeboard boats do not differ significantly from other motorized boats, so their impact on Lake Tahoe in terms of erosion or sedimentation does not cause great concern. However, the possibility of harboring invasive species in the ballast tanks of wake boats is a great concern. The TRPA requires that wake boats decontaminate ballast tanks with hot water to limit the spread of aquatic invasive species. They and others are working with boat manufacturers to determine if there is a way to design ballast tanks to release all water and eliminate the standing water left behind.

Lake Mead, AZ

Wake boats are popular in Arizona. Lake Mead is a frequented destination for wake boat users, and they are welcomed by lake support staff. Lake Mead is a reservoir so the volume in the lake varies year to year based on mostly on snowmelt, precipitation and increased demand from

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residential and commercial users due to the increasing population in the area. The boats do not present a concern to the shoreline or ecosystem any more than any other motorized watercraft.

Lake Mead has a very large open basin area and wake boats are usually operated in the open area giving waves plenty of time to disperse before reaching the shoreline. The shoreline changes every year with the lake depth or elevation. This year, the elevation is down 120 feet from its highest capacity, which is a large number, but not abnormal. Even at the end of a 20-year drought, Lake Mead has 3 trillion gallons of water, 32% of the maximum capacity of 9.3 trillion gallons (Christie Vanover, personal communication, October 30, 2019). Wake boats are required to maintain a safe distance from other vessels and structures and obey “no wake zone” speed limits.

Similar to Lake Tahoe, the design of wake boat ballast tanks is a concern for the spread of invasive species in Lake Mead. Aquatic invasive species control is very important at Lake Mead and there is an active control program to ensure quagga mussels, which were introduced from the Great Lakes, are not able to spread to or from the Lake. Boats that are docked for more than 30 days require mandatory inspection and decontamination, which includes the ballast tanks of wake boats. Interstate boats also have to be inspected before entering the water and this inspection is provided free of charge for lake users (Christie Vanover, personal communication, October 30, 2019).

Oregon

Managers in Yamhill, Marion, and Clackamas counties in Oregon have taken steps to limit wake boat use. Wake surfing should be conducted 200 feet from the shore, other boats in the water and docks because the wave energy from a WakeSurfing boat is 4 times as strong as a Wakeboarding wake (OSMB, 2018). This regulation will likely exclude wake surfing in small coves or bays. The OSMB (2018) referenced two studies on how wake size can affect shoreline

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erosion to determine how to limit wake boat use. Figure 4 shows a boat's speed in relation to the height of the wave it produces.

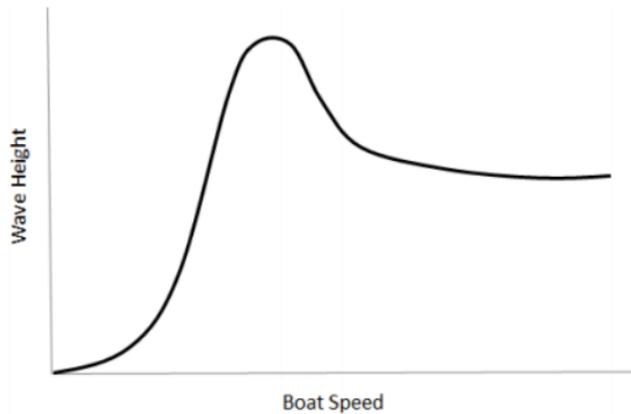


Figure 4. Relation of Wave Height to Boat Speed. Source: Oregon State Marine Board (OSMB, 2018).

Some localities in Oregon have tried restricting the use of wake enhancing devices and wake boats, but law enforcement has experienced difficulty enforcing the restrictions. Law enforcement officers cannot search boats for wake enhancing devices without probable cause. Boat design can mask wake enhancing devices as wake can be shaped by a boat's hull and trim tabs rather than visible wake-enhancement devices such as ballast tanks. Oregon established Personal Watercraft Rules in 1990 for speed and proximity rules for all motorized boats to enhance safety on the water and minimize conflict between boaters. These rules are similar to other localities throughout the country and are listed below:

1. Do not exceed no wake speed of 3.5 mph within:
 - a. 200 feet of a boat launch, any fixed structure, any other motorized boat or person on the water such as a swimmer or angler
 - b. 100 feet of any paddle powered or anchored vessel

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- c. 200 feet of shoreline (OSMB, 2018).

Lake Norman, NC

Lake Norman in North Carolina has 520 miles of shoreline and is in a heavily populated area just north of Charlotte, NC. In the past 2 to 3 years, wakeboard boat use has increased significantly, which has led to an increase in complaints from local property owners and other boaters on the lake about wake surfers and boarders showing a lack of consideration for property owners and other boaters. John Gerke, the Assistant Executive Director and Morris Sample, the Executive Director of Lake Norman Marine Commission (LNMC) shared their experience with wakeboard boats on Lake Norman. North Carolina has a “no wake zone” 150 ft away from docks and other boats which works well for conventional boats, but not for the 4 ft wakes generated from wake boats. Increasing the restriction on the wake zone will need more state-level guidance, according to Gerke and Sample. The North Carolina Wildlife Resources Commission is interested in beginning a study of wake boats in the state. The commission would like to limit wake boat use in the smaller coves along the lake as the large wake creates disturbance in these areas.

Control and enforcement on the lake can be complicated and everyone has a right to use the resource. There are 15,000 private and commercial docks on the lake, and most of the shoreline is privately owned. There is significant law enforcement presence on the lake, but the “no wake zone” is difficult to enforce. Buoys can be placed in the water to give boaters a visual idea of their distance from the shore. The commission hopes to limit lakeshore erosion by limiting the number of passes a boater can make in one area before moving on to a new section of the lake. The commission hopes to prohibit wake boats from entering any cove less than 600 feet wide. In North Carolina, if a wake damages structures or other people’s property, the boater is responsible to pay for that damage, but this is difficult to enforce and difficult to determine where the damage

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originated (John Gerke and Morris Sample, personal communication, November 7, 2019). The commission feels that wake boats do lead to erosion and contributed to the disappearance of several small islands in Lake Norman. The commission would like to see representatives in favor of a ban on wake boats as well as those opposed on an exploratory committee.

Bone Lake, WI

In Wisconsin, some districts are limiting wake-board boat usage. In Sawyer County, the Land, Water and Forest Resources Committee proposed a county-wide ordinance prohibiting watercraft from creating wakes more than 50 feet long and two feet high within 700 feet of any shoreline, dock, pier, raft or other restricted areas on all lakes. The wake size detailed in this ordinance directly relates to the larger wake created by ballast boats and is intended to limit their use. This will apply to all wake-enhancement watercraft whether they employ ballasts, mechanical hydrofoils, uneven loading or operation at transition speed (Boettcher, 2018). The ordinance is designed to minimize shoreline and lakebed erosion and is supported by many lake associations.

Bone Lake District is also taking steps forward to limit wake-enhancement watercraft (Cary Olson, personal communication, November 6, 2019). Cary Olson has been one of five commissioners for Bone Lake District, WI for the past 17 years. Bone Lake is 3.75 miles wide and 5 miles long with an average depth of 25-30 feet and a maximum depth of 42 feet. Like many lakes throughout the country and in this study, wake boats on Bone Lake are increasing in popularity in recent years. There would likely be even more boats on the water if not for their high price tag of \$100,000 for a new boat. The main complaints from property owners and other boaters are the noise, loud music and the proximity of wake boats to other boats on the water. Summer 2019 was a particularly difficult season for property owners because water levels were elevated 14 inches due to heavy precipitation. Since the water level was higher than normal, the wake from wake boats

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came up higher onto the shoreline and caused more problems for lakeside property owners. Bone Lake freezes in the winter, so all docks are removable and held in place with a suction system. The wake from wake boats was large and powerful enough to dislodge the suction system on the mobile docks and property owners were left to reposition the docks and fill in the land where dock pilings scraped the lakebed. If wake from a boat causes property damage, the boat owner is responsible to repair this damage, but this is difficult to enforce particularly during the summer season where 70% of lake users do not live locally. It is difficult to find suitable landfill for filling in dock walk-in areas. Riprap, loose stone placed along the shoreline as a foundation, works well to fill in areas dredged by loose docks, but it decreases the boater's ease of entering the water.

Bone Lake District established a committee to investigate ways to implement reduced-wake rules when lake water levels are high compared to a historic high-level date. Wake boats are not restricted by a "no wake zone" at Bone Lake, but jet ski use is restricted along the shoreline for noise control. Bone Lake is managed by the county, and they could set regulations at times of high water and put into place "no wake" or "reduced wake" zones to minimize damage to docks and shoreline property. Other concerns the committee would like to research are whether large wakes erode the shoreline and shoreface. The effect of wake boats on turbidity is visually evident and an observer can see the water turning murky (Cary Olson, personal communication, November 6, 2019). The committee would like to research what damage the lake basin may be facing from wake boats.

The committee is tasked with finding out if the county will allow the restriction, how the restriction can be patrolled and how to enforce such a rule. The process is in the beginning stages and the Board of Commissioners is seeking attendees and committee members from local property owners as well as wake boat owners and users. The Board of Commissioners has an annual

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meeting in August 2019 and the committee wants to have a recommendation ready by then for the Board. In the meantime, Bone Lake managers are beginning a public awareness campaign reminding users that the lake is for everyone and all have a right to use (Cary Olson, personal communication, November 6, 2019). The campaign is designed to encourage users to be courteous to others and be particularly mindful to canoes, kayaks and other small watercraft.

Lake Squam, NH

Lake Squam in New Hampshire is 6,791 acres in area with a length of 7.0 mi, a width of 4.6 mi and a maximum depth of 99 ft. Lake Squam is a popular destination for boaters and others looking for recreation, but also is a nesting site for loons, bald eagles, and great blue herons. The community surrounding Lake Squam believes it is important to balance tourism and recreational opportunities with ecological and environmental protection. HB137 seeks to establish a commission to study the impact of wake boats in the state of New Hampshire and received bipartisan support with Representative Suzanne Smith [D] as the primary sponsor, and Representatives Dan Wolf [R], Linda Tanner [D] and Senator Martha Fuller Clark [D] as cosponsors. The panel will include environmental groups as well as the Water Sports Industry Association for a balanced plan to limit the negative effects of wake boats while also maintaining the rights of the public to use the lake for water sports (H.B. 137, 2019). The bill passed on June 20, 2019 and the deadline for the commission to report its findings along with any recommendations for the proposed legislation is June 30, 2020.

Michigan

Michigan encourages lake users to follow best practices, but no formal policy exists regarding wake boat regulation. Like many other localities, wake boaters are responsible “for any damage to life or property resulting” from a wake as described in section 80158 of the Maritime

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Safety Act (Smith & Jarvie, 2015). Boaters are encouraged to follow best practices listed below and set forth by the nonprofit organization, Michigan Lake and Stream Associations (MLSA), to avoid causing damage to life or property:

1. “Reduce speed within 300 feet of shore
2. Do not add ballast water or other extra weight to wake boats
3. Do not operate wake boats near sandy areas, wetlands or lakefront residences
4. Avoid turning wake boats in tight circles (tight circles increase wave height and frequency)
5. Avoid operating wake boats in shallow water or near natural shorelines” (MLSA, 2015).

In addition to the MLSA guidelines, the National Marine Manufacturers Association (NMMA) recommends boaters maintain a distance of 150 feet or more from other vessels, swimming areas and fishers. Boats should always use a “no wake speed” when passing others within 150 feet and avoid operating in water less than 2.5 feet (Smith & Jarvie, 2015). Scientific data on the impacts of wake boats is very limited and more research and data collection is necessary before any regulations are made but maintaining and enforcing best practices while operating is essential to prevent damage while research is in the development phase. Wake boat enthusiasts will do well to enjoy their sport responsibly and consciously to ensure their safety and the safety of others (Smith & Jarvie, 2015).

Vermont

Senator John Rodgers introduced SB69 in Vermont to create local boating ordinances for wake boats throughout Wisconsin. SB69 was introduced last year, which is the first year of the biennium, so if the committee takes up the bill, it will be read in January or February of 2020

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followed by testimonies. The bill stems from a need to limit the spread of aquatic nuisance species such as Eurasian watermilfoil. The concern in Vermont is the same as in Lake Tahoe and Lake Mead; the water ballast tanks of wake boats can harbor juvenile stages of aquatic nuisance species. The bill calls for a ban of wake boats from all inland lakes in the state. The effect of wake boats on erosion is a secondary concern to the threat of AIS (Senator John Rodgers, personal communication, November 20, 2019).

Environmental and Social Cost-Benefit Analysis

Comparing the economic benefits of wake boat usage to the environmental cost of their usage can help decision-makers address future policies and propose new projects.

Economic Benefits/ Impacts

Lodging currently provides the largest tourist revenue in Western Maryland (Table 1). The Maryland Department of Commerce-Office of Tourism Development provides annual data based on recreational and lodging/accommodation sales tax revenue brought into the state. This data is further broken down by county. The state of Maryland is divided into five regions, with Garrett County residing within Maryland's Western region. Visitor spending accounts for a significant amount of county revenue. In 2010, a Maryland State Park visitor study from May-October was conducted by the Appalachian Regional Commission (ARC). The average daily spending for a family of three visiting the western region was \$239 (ARC, 2009). This figure included spending on lodging, retail, and food/beverage. Seventy percent of the economic impact in the Western region is generated in local communities within 20 minutes of a state park entrance. Sanctioned lake events also bring crowds to the area through events such as "Wake for Warriors". Wake for Warriors is a national wake boat event touring the nation aiming to connect military veteran family and friends together sharing a love of water sports whose website has since been deleted. The national tour

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hosted a two-day event this year at Deep Creek Lake on June 21st-June 23rd. Events such as this bring participants from around the Eastern seaboard of the United States if not further. Large crowds cheer on wounded veterans with amputated limbs and PTSD as they wake surf. Sanctioned events fuel the economy by making overnight accommodations, hosting parties at local pubs, purchasing food and beverages to sell for event concessions, and selling T-shirts made locally.

Table 1. Garrett County-Tourist Generated Economic Revenue.

Unquantified Economic Revenue Generated from Tourism.(Garrett County)	Economic Revenue Generated from State Park Admissions & Boating Source:(2019 Deep Creek Lake State Park)	Economic Revenue Generated from Wake Boat Rental Source: Life Lake Boat Rentals
Lodging/Accommodations	In-state parking admission- \$3	2 hr wake boat rental- \$539
Food & Beverage Industry	Out-of state parking admission- \$5	4 hr Wake Boat Rental- \$669
Retail Industry (Grocery/Clothing)		Daily Wake Boat Rental- \$1,059
Marine Engineering (Boat Maintenance)	In-State Boat Launch Fee- \$10	
Attractions	Out-Of-State Boat Launch Fee- \$12	Wake Surf Board Rental 2 hrs- \$40
Private Marina Docking Fees		Wake Surf Board Rental 4 hrs- \$75
		Wake Surf Board Daily Rental- \$100

Sources: Lodging Report Archives | Office of Tourism Development. (n.d.). Retrieved from <http://industry.visitmaryland.org/research/lodging-reports/lodging-report-archives/>
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Social Benefits of Wake Boating

Parks and outdoor recreational activities have known social benefits. Studies from the California Parks and Recreation Department have shown public health improvements. Wake boats may have the potential to improve social bonds, relieve stress, enhance physical health, and re-adjust a person's quality of life for wake boating participants (California State Parks, 2005).

Social Costs of Wake Boating

Tourism is a million-dollar industry in Garrett County that is vulnerable to the availability of recreational activities offered at Deep Creek Lake State Park (Table 2). As of yet, there is no recreational data to quantify wake boat usage in Garrett County. Though, you could generally state that a multitude of county economies could potentially be affected by the loss of wake boating. The brunt of recreational costs associated with the decline of wake boating would be tourism. Tourists flock to Maryland's Western region from around the country to experience recreational activities specifically at Deep Creek Lake. Costs associated with tourism include lodging accommodations, the food and beverage industry, retail sales, social attractions like clubs and bars, and State Park annual revenue.

Table 2. Fiscal Revenue Generated from Tourism.

<i>Fiscal Year Revenue</i>	<i>Revenue From Admissions & Amusement Taxes</i>	<i>Revenue From Hotel Taxes</i>
2014	\$808,839	\$2,282,190
2015	\$816,385	\$2,369,239
2016	\$819,688	\$2,404,619

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Education and Outreach

Community Involvement/Engagement

Development and expansion of collaboration within the community is critical for getting the community on board with understanding the impact wake boats have on the environment, current regulations surrounding wake boats, and education pertaining to wake boats. Waterfront property owners in particular are seeing the impacts of wake boats firsthand. Property owners, such as Richard Matlick, Gary Shafer, or Bob Sutton, who are local Deep Creek Lake property owners and part of the Educational Advisory Committee engaged with industries such as the Water Sports Industry Association can lead to more community involvement. In order for outreach to be consistently effective, there must also be a collaboration between the Garrett County Government, the Policy Review Board, the MD DNR, MDE, the US Army Corps of Engineers, the Property Owners Association (POA), internal and external organizations. external organizations such as the Water Sport Industry Association can give an outside perspective, and promote collaboration with passionate wake boat enthusiasts, and lead toward possible successful results for property owners. In doing so, regulations, policies, and environmental concerns can be prioritized and addressed.

Having a wide range of individuals and organizations on board will make stakeholders more aware of the environmental effects that wake boats create. Reaching out can be a challenge and targeting specific groups and populations through environmental campaigns can and should be very beneficial. In some cases, many passionate recreational water sports enthusiasts simply do not recognize the environmental concerns surrounding wake boats. Being unaware of these issues does not mean that they will not make efforts to lessen the effects, but they likely lack the knowledge to make changes. Spreading knowledge does not have to include expensive or time-

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consuming methods but can be done using a variety of platforms to target specific audiences. Social media, for example, can quickly reach a lot of people and help them become aware of specific issues (US Environmental Protection Agency (EPA), 2019). Most water sport enthusiasts and visitors will likely check out social media platforms, brochures and web pages related to the lake, recreational activities, and/or topics of interest for the area they are visiting. In particular, the Facebook group, “Friends of Deep Creek Lake” has over 1,000 followers. This group voices their concerns regarding wake boats, and the environmental issues that wake boats may cause. Promoting this group could help spread the word and could be as simple as acknowledging the group in Deep Creek Lake brochures or communicating with the group about updated concerns. Potentially the WSIA could even become part of the Facebook group for expansion.

The EPA’s “Getting in Step Guide” (2019) provides details regarding approaches and strategies for watershed management and outreach. Although it outlines the basics of a water quality improvement effort, the same principles can be applied for outreach in regard to wake boat environmental concerns. The six steps for outreach include defining what's driving the concern (wake boats effect on the environment), goals, and objectives. Next, who are we trying to reach, followed by what message is being sent? Finally, create/implement the message, ending with continuous evaluation of the message being sent. When successfully implemented, the audience should be motivated to use behaviors that promote wake boat responsibility and growing the watershed planning efforts, implementing continuous regulatory requirements, and ultimately building strong partnerships through the community (USEPA, 2019).

“Social Marketing 101”, in the Getting in Step Guide, discusses how using commercial marketing principles regarding social issues is beneficial for outreach and education. As opposed to

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selling services or merchandise, think of selling ideas, attitudes, and behaviors. In this case profit is not the goal, but instead improving the environment. Slogans and catchphrases are a cheap and effective way to reach out and educate society. Designing a slogan could guide individuals who normally are not aware of the environmental concerns surrounding wake boats and educate them on the matter. According to social marketing experts Philip Kotler, Nancy Lee, and Michael Rothschild, the process of social marketing must include marketing principles/strategies that reflect communication and value, which influences the audience behaviors and benefits society. A slogan, brochure, or radio broadcast is not nearly as effective alone but together they can be very beneficial.

Tourists, in general, are not as knowledgeable as residents and locals about the impact of wake boats on Deep Creek Lake. Outreach regarding these local concerns can be included within brochures, local gift shops, and word of mouth to target tourists. Residing in another area, likely one without a lake, tourists likely do not consider wake boat concerns or take part in lessening the potential consequences. Encouraging alternative water sports activities, providing wake boat etiquette tips, and advertising with slogans will help reach tourists. Informing tourists in brochures of basic wake boating tips such as staying 150 feet away from shorelines, making less repetitive passes, maintaining in a predictive path, and other methods that will reduce wakes could be beneficial (Fort, 2019).

Education

The Water Sport Industry Association (WSIA) promotes wake responsibility and could be beneficial for future collaboration on education and outreach. Having the WSIA who are water sport enthusiasts, playing a role with wake responsibility can open doors to the public across the country. They have a “wake responsibility” pledge in place, geared toward peaceful watersport

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play. The WSIA also works with homeowners and boating enthusiasts towards encouraging and partaking in etiquette boating behaviors. Unsuccessful past experiences where homeowners have tried shutting down water sports across the country because of negative environmental effects and damage, the WSIA decided to collaborate and continues to educate all over the country. Communication with this organization would allow them to see the growing interest for wake responsibility at Deep Creek Lake. WSIA can be reached at: Phone- 508-507-WISA; Email- info@wsia.net; Address- P.O. Box 568512, Orlando, Florida 32856-8512.

Mitigating and Managing Detrimental Impacts

Below are management strategies that could help identify and alleviate potential issues related to wake boats at Deep Creek Lake. These recommendations can help gain knowledge about wake boats and may facilitate the preservation of the Deep Creek watershed, providing direct benefits to the surrounding environment, as well as patrons, residents, and stakeholders of Deep Creek Lake. It is important to seek out management strategies that minimize environmental impacts with careful consideration to retaining recreational benefits.

Comprehensive Monitoring

Because there is not enough evidence to directly link wake boats to negative environmental impacts, Deep Creek Lake may benefit from developing and implementing a comprehensive monitoring plan with clearly defined goals and objectives. This plan would seek to establish baseline conditions that will serve as reference points for comparison in the future (for example, determine a baseline of shoreline data to use as a reference point when establishing whether erosion is occurring, considering changing water levels from controlled water releases). Baseline water quality is already being monitored in the summer months at Deep Creek Lake as well as Cherry Creek, but more data is needed to directly link wake boats to changes in water quality and erosion.

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Identifying and Prioritizing Environmentally Sensitive Areas

Environmentally Sensitive Areas are locations that contain rare species and ecologically significant natural communities. Sixteen of these areas have already been identified in and around the Deep Creek Lake Watershed. This can be a tool to locate areas that are particularly vulnerable to large wakes and target areas for no wake zones, etc. as well as knowing their vulnerabilities and the best strategies to protect against them.

Many of the ecologically significant areas in the Deep Creek Lake watershed harbor rare species and habitats that are directly dependent aquatic systems. Therefore, it is important to control erosion and maintain good water quality by limiting disturbances as much as possible and stabilizing the soil. Steep slope areas (15% slope or greater) and areas of highly erodible soils should be identified and monitored continuously if not already being done. Special attention should be made to retain fine particulate silt, sand and clay, and provide a minimum 100-ft undisturbed forested upland buffer to permanent and intermittent streams and nontidal wetlands, as well as identifying the most vulnerable shorelines and creating no-wake zones, limiting boat speeds, and placing restrictions on tight boat turns.

Other Management Strategies

To maintain and improve the current conditions of Deep Creek Lake the following management strategies should be considered:

- Provide education on the potential environmental impacts of wake boats and other anthropogenic activities that affect aquatic resources and their surrounding habitats to residents as well as visitors of the lake. Brochures, slogans, social media, etc. can all reach the public and should offer tips and suggestions for how to minimize impacts

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- Consider expanding vegetation around shorelines to minimize shoreline erosion. Consider how vegetation would impact recreational users
- Anticipate and address the future growth of Deep Creek Lake. This includes further land development, if any, increased property (such as docks), as well as increased recreational use of wake boats. Identify how and where growth will occur as well as its environmental impacts. Manage existing resources and current land use as much as possible.

Policy/Regulation Changes

It is important to promote policies that balance environmental and economic sustainability. Other lakes and their policies can be models to help establish policies and regulations in Deep Creek Lake. There are wake boat policies emerging in some areas such as Wisconsin's strategy of trying to limit the size of the waves and not necessarily eliminate the boats themselves. This could be an inclusive strategy for Deep Creek Lake to consider that would not necessarily eliminate wake boats and their economic benefits but just limit their capabilities.

Funding and Resource Allocation Changes

Funding management strategies present a challenge, particularly when there are several management approaches to consider. It is important to create rank how to alleviate concerns with consideration to the maximum benefit, particularly when there are limited funds (Klauda, 2014). This means concentrating efforts and funds on the most crucial environmental concerns first. In order to know which concern the most vital, environmental analysis is needed to help identify problem areas, prioritize which ones are the most critical, and ultimately which ones will have the highest economic benefit. Allocating resources to watershed preservation and restoration should consider the value of the system, its current state, the benefits if restoration is successful, the probability of success, and the total costs (Klauda, 2014).

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Consistent monitoring is expensive and limited funds can be a challenge, however, it helps to define clear, quantitative goals. Short-term variability cannot be captured and addressed by monthly samples. Monthly monitoring provides basic water quality information and a general picture of the overall health of the lake, whereas continuous sensors with real-time data can potentially provide information specific to wake boats. Continuous water quality monitors provide quantitative estimates that can ultimately address short-term issues, such as frequency/intensity of nearshore wake events. Long-term monitoring will help define trends in water quality as water use changes occur in Deep Creek Lake.

Another challenge to consider is enforcement and all the logistical and financial concerns that come along with it. Using other states as models, it is easy to see that implementing policies is a lengthy process and enforcing these regulations presents its own challenges. When imposing new regulations, it is important to consider how these regulations will be enforced and whether there are enough resources to do so.

Conclusion

It is difficult to conclude that wake boats damage the environment more than other motorboats. There is simply not enough evidence at this time to directly link wake boats to negative environmental impacts. That is why committees at many lakes are tasked with investigating wake boat impacts and exploring the possibility of imposing regulations. Deep Creek Lake managers are advised to do the same and collect evidence to investigate claims of accelerated erosion near shorelines, increased turbidity and sedimentation and as well as changes in water quality due to increased wake boat usage. It is advisable to continue to collect first-hand accounts of damage to personal property, impacts on other small boaters, as well as noise pollution and safety concerns in an effort to directly link these issues with wake boats. However, Deep Creek

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Lake could benefit from implementing policies such as limiting wake size, as a precautionary measure to preserve its resources and minimize potential impacts of wake boats.

Wake boats have a variety of economic and social benefits. Tourism is a million-dollar industry in Garrett County and Deep Creek Lake depends on recreational activities, such as wakeboarding, to thrive. Wake boats contribute to the tourism industry and may continue to gain revenue as wakeboarding becomes more popular. When regulating wake boats, it is important to consider if the positive benefits of wake boat specific to Deep Creek Lake, and how to balance these benefits with potential negative environmental impacts.

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