Lake Windermere Recreational Impact and Sediment Quality Assessment

Lake Windermere, BC

Prepared By:
Ecoscape Environmental Consultants Ltd. &
Larratt Aquatic Consulting Ltd.
Prepared For:
Lake Windermere Ambassadors

August 22, 2024

LAKE WINDERMERE

RECREATIONAL IMPACTS 2024

Prepared For:

Lake Windermere Ambassadors
Lake Windermere, BC

Prepared By:

Ecoscape Environmental Consultants Ltd.
#102 – 450 Neave Court
Kelowna, B.C.
V1V 2M2
&
Larratt Aquatic Consulting Ltd.
#105-2081 McDougall Rd.
West Kelowna B.C.
V1Z 4A2

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EXECUTIVE SUMMARY

Lake Windermere is unique, with an average depth of only 3.4 m and littoral zones that cover 95% of the lake area. This lake is a widening of the Columbia River and part of the Columbia wetlands, one of the longest intact wetlands in North America. The current and projected boating use of Lake Windermere has potential to harm lake water quality, habitat values, domestic water intakes, tourism and the local economy.

This report assessed recreational impacts on Lake Windermere BC by compiling 2022 and 2023 aquatic sampling programs, FIM/FIMP data, boat density surveys, a Lake Windermere Ambassadors resident survey and existing reports. Previously collected sediment cores and lake data were used to understand long-term threats from power boating activity to source water protection and habitat values on Lake Windermere. Ironically, the most popular boating type found on Lake Windermere is the least suited to this shallow lake.

The boat tally component of this study demonstrated that powerboating and particularly wake-surfing exceeds the safe boating capacity of Lake Windermere on summer weekends when tourism peaks. Criteria for the most appropriate Play Zone areas were developed with wake-surfing in mind because it was the most common boat type on the lake and the boat type with the greatest potential to harm Lake Windermere. Power craft have more potential for harm than paddle/sail craft, the latter preferred by most respondents in the LWA community survey. Segregating the power craft from the paddle craft would ensure the safety and enjoyment of recreators.

This study confirmed that intensive boating simultaneously impacts Lake Windermere in the following ways:

- sediment resuspension releasing nutrients and contaminants back into the water column from places where they were no longer biologically available
- accelerated algae growth and algae blooms resulting from increased nutrient concentrations
- increased exposure to the ongoing threat of invasive mussel introduction
- increased shoreline erosion of fine sediments by boat wakes
- increased potential for impacts to fish, mussels, birds, and aquatic life
- safety risks to the community from an exceedance of safe boating capacity during peak season

As the watershed and lake pressures mount on Lake Windermere measurable symptoms of overall lake health are likely to worsen. That change is needed to address the escalating recreational pressure on Lake Windermere was confirmed by all components of this study. Lake Windermere is unlikely to withstand increasing power boat and especially wake-surf pressure without harm to its ecology, water quality and aesthetic value.

Lake Windermere is not suited to heavy power boat usage, particularly wake-surfing vessels. A boating capacity number should be assigned with a mechanism to limit the number and horsepower of power boats operating on Lake Windermere through the summer. Further, formalizing a carrying capacity for the lake should also consider important periods where vessel numbers may need be limited through periods critical to Indigenous-led fisheries cultural considerations, such as fishery access or the reintroduction of salmon.

We provide a table of recommendations and next steps for improved boating regulation on Lake Windermere designed to protect lake values including cultural use and the work of Indigenous stewards on the reintroduction of salmon.

In discussions with Lake Windermere Ambassadors, two protocols with potential for broad application to many BC lakes were developed during this project:

- Ecoscape developed standardizable methods for boat survey data collection, analysis, and mapping (see Methods Appendix).
- LAC developed a Lake Suitability Index for power boating (See attached Excel Spreadsheet "Lake Suitability Ranking").

Acknowledgements

We would like to gratefully acknowledge funding from Lake Windermere Ambassadors. Their assistance and passion for Lake Windermere is responsible for the success of this project. Pam Saunders and Amy Baxter were instrumental. Amy Baxter's dedication to the execution of this project from start to finish was exemplary. We would also like to acknowledge the Ktunaxa and Secwépemc Nations on whose traditional lands Lake Windermere functions. We recognize local Bands - the Shuswap and the Akisq'nuk as the original and ongoing stewards of Lake Windermere, BC. Finally, we want to conclude with a thank you to all persons involved in lake protection work. Without you, lake deterioration would be certain and rapid at too many lakes in BC.

Preferred Citation

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Acronyms

EPH	Extractable petroleum hydrocarbons
IHA	Interior Health Authority
LAC	Larratt Aquatic Consulting
LWA	Lake Windermere Ambassadors
MAR	Mass accumulation rate (g/cm^2 per year)
OBWB	Okanagan Basin Water Board
PAH	Polycyclic aromatic hydrocarbons
QEP	Qualified Environmental Professional

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1.0 INTRODUCTION

Ecoscape Environmental Consultants Ltd. (Ecoscape) and Larratt Aquatic Consulting Ltd, (LAC) were retained by Lake Windermere Ambassadors (LWA) to provide an assessment of watersport impacts on sensitive environmental values and sediment quality at Lake Windermere, BC (Figure 1). This report is bound by the general Terms and Conditions, found in Appendix A: General Terms and Conditions.

This project was designed to investigate the long-term threats from boating activity to lake health, source water protection and habitat values on Lake Windermere.

1.1. Study Objectives

- Establish the theoretical boat capacity of Lake Windermere using metrics/modelling developed for Kalamalka and Wood lakes and compare against current use patterns (Schleppe et al. 2017).
- Determine power boat wake impacts including sediment disturbance, shoreline erosion, aquatic plant damage, and incorporate their significant potential to move invasive mussel larvae in ballast tanks or engine cooling systems.
- Determine the likelihood of sediment resuspension causing damage to water quality and releasing nutrients that lead to accelerated algae growth and algae blooms
- Develop recommendations on steps moving forward including where to boat and ranges of boat carrying capacity.

1.2. Background

Lake Windermere is a very large widening of the Columbia River. The lake is shallow, with an average depth of 3.4 m and maximum depth of 6.4 m. About 95% of the lake is classified as littoral, meaning light can penetrate to the lake bottom, allowing aquatic macrophytes to grow (Hildebrandt 2022). It has 36 km of shoreline and has a surface area of 16.1 km^2 (1,610 ha). Lake Windermere is part of the Columbia wetlands, one of the longest intact wetlands in North America.

Lake Windermere is a popular tourist destination for aquatic recreation. Previous studies found that heavy boating traffic in summer can cause increased turbidity levels, fuel emissions, and spills (Neufeld et al. 2010; Schleppe & McPherson 2021; Schleppe & McPherson 2021). The current and projected boating use of Lake Windermere has potential to influence lake water quality, habitat values and domestic water intakes, and exceed established metrics for boating safety.

Boating styles and behaviors vary, and so does the demand for supporting facilities such as launches and marinas. Large power boats > 15 ft (3.4 m) in length are most likely to adversely impact Lake Windermere. Large boats influence lake dynamics by displacing water and producing wakes. Large wake boats create wake turbulence that can reach 8 meters into the water column, with boat traffic correlating with up to 50 % increases in turbidity and accelerated shoreline

erosion (Self and Larratt 2020; Raymond and Galvez-Cloutier 2015; Francis et al. 2023; Asplund 2000; Mastran et al. 1994; Schleppe et al. 2017; Mercier-Bliase and Prairie 2014; Raymond and Galvez-Cloutier 2015; Francis et al. 2023).

Wake turbulence in Lake Windermere is particularly concerning given the extensive shallow littoral areas. Fine organic and silty sediments accumulated on Lake Windermere shallows are easily re-suspended with wake turbulence from prop wash, particularly for ballasted wake boats creating large wakes.

MacFarlane found wave energy from ballasted wake boats was 5–17 times higher than a benchmark speedboat (2018). Marr et al. (2022) found waves produced by wake boats were 2–3 times higher, had 3–9 times more energy, and were 6–12 times more powerful than a typical motorboat. Wake boat waves require at least 120–310 m to dissipate to energies of a typical motorboat at 30–60 feet from the sailing line, and to have minimal resource impacts (Francis et al. 2023).

Boating studies conducted by LAC showed significant potential for boat generated wakes to physically disturb sediment (Self & Larratt, 2020). Impacts from boat wakes were identified to depths of 8 m in LAC studies. In depths of 2 – 3 m, major impacts from wake-surf waves causing sediment resuspension and environmental disturbances were detected. Wake surfing in <5 m depth caused significant sediment resuspension migrating towards deeper water where intakes were positioned (Self and Larratt, 2020). Studies in Kalamalka and Okanagan Lake by LAC concluded that depths between 0 – 5 m are at extreme risk of boating impacts; this represents most of Windermere Lake.

Based on their experience in Lake Windermere during Foreshore Inventory Mapping 2020 (FIM), Ecoscape forecasted the following power boating risks:

- to water quality: spills and sediment disturbance, particularly in shallow areas
- to habitat values: longshore current disruption, shoreline wake erosion and spills or discharges from marina/docks
- to drinking water intakes: turbid plumes that include contaminants can travel from disturbed areas to intakes

2.0 RESULTS AND DISCUSSION

2.1. Boat Survey study

Lake Windermere Ambassadors undertook boat surveys on 31 days across 2022 and 2023 combined (Table 1; Figure 1).

Table 1: Summary of Survey period by day type

Survey day type	Number of survey days	Earliest – latest survey times	Number of vessels observed	Maximum count on single survey
Weekday	17	9:30 – 20:00	325	70
Weekend	9	9:30 – 20:00	862	210
Long Weekend	5	10:00 – 17:00	421	148

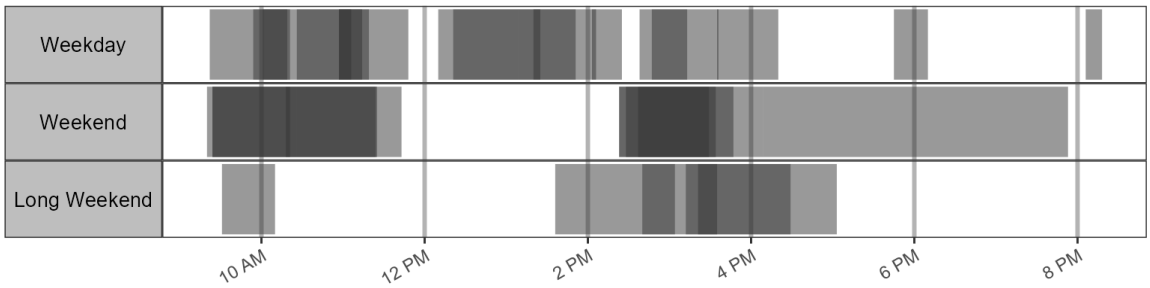


Figure 1: Representation of boat survey time spans broken up by day type.

Each Individual survey is indicated by a translucent grey ribbon; darker grey indicates overlapping survey time spans. For a more detailed representation of individual survey timespans, see Appendix B.

Boat survey data is presented in Figures 2 and 3 as maximum vessel density by boat type and in 4 as boat type by time of day. Additional metrics such as mode of operation during the survey period are provided in Appendix B. Note that descriptive summaries are representative of vessels observed during boat survey events. Survey events occurred at varied times and over varied lengths of time (Appendix B); this variety enabled the capture of a wide overall timespan that details boat presence over most of the available daylight hours but does not necessarily translate to direct one-to-one comparison of time spans. For example, multiple surveys occurred on weekdays between 12:00 PM and 2:00 PM, but that coverage was not mirrored on weekends or long weekends (Figure 1).

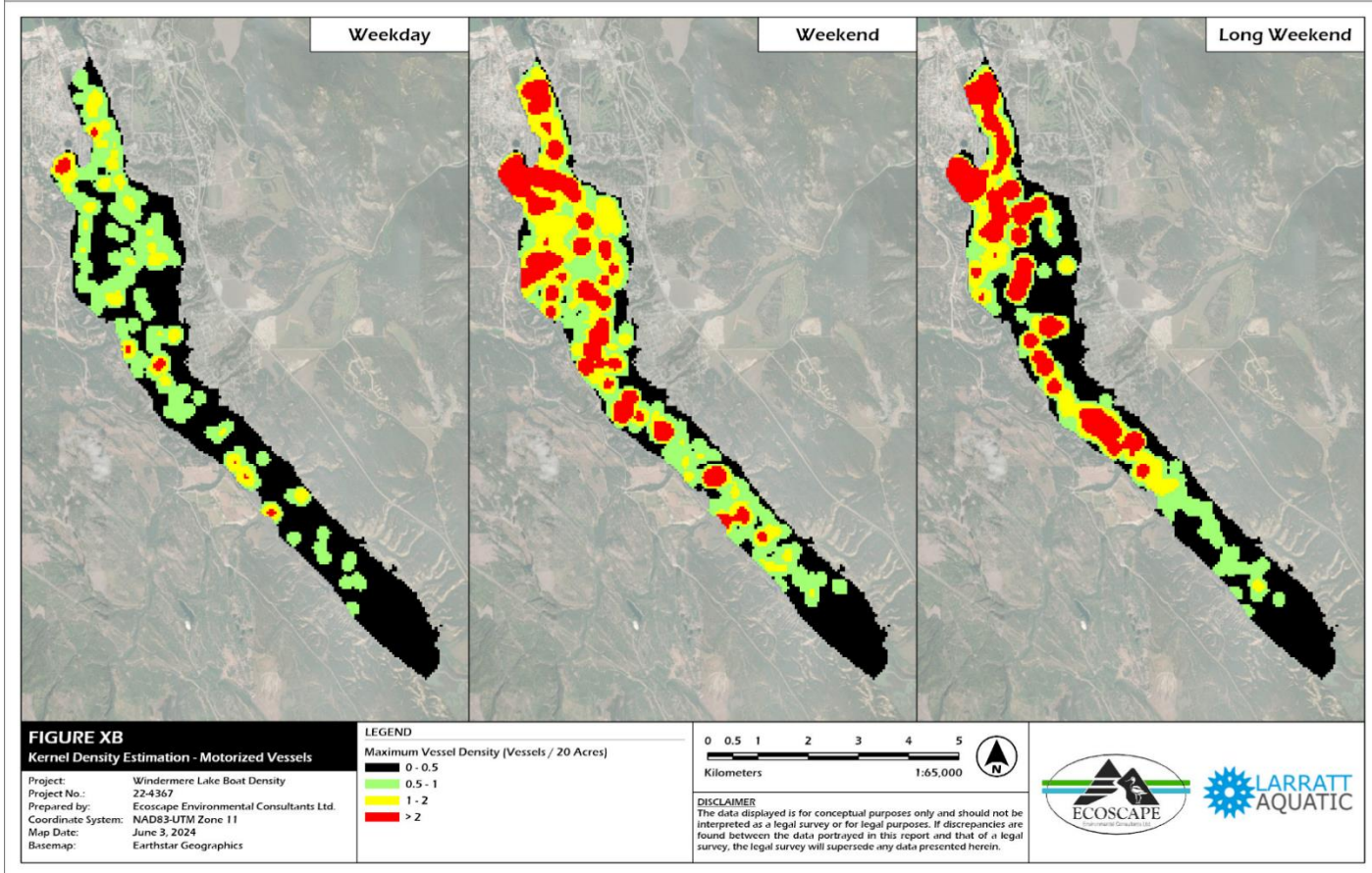
The key finding from the boat survey data corroborates the resident survey; popular portions of Lake Windermere regularly exceeded the local Safe Boating Capacity on summer weekends and

long weekends (1 power boat/20 acres or 8 ha[1]; Figure B-1, Figure 2). This included near-shore areas throughout the North end.

Additional findings from the boat survey data included:

- Wake-surf boats were the most prevalent boat type on Lake Windermere and were usually generating wakes (Figure 2; Figure 4, Appendix B). They were most prevalent on weekend afternoons. Up to 28% of the lake surface locally exceeded the safe boating capacity of Lake Windermere on summer weekends and especially on long weekends. This is a large percentage of the lake, especially considering that much of the southern end is too shallow for power boating.
- Motorized boats of all types accounted for 477 boats, and they were usually under power. They were most prevalent on weekend afternoons (Figure 2; Figure 4).
- Paddle craft were less abundant than powerboats (264 counted; Figure 3 and Figure 4) and operated throughout the day, with a noticeable pause during peak powerboating hours. Long weekend surveys showed fewer paddle craft than weekdays, suggesting avoidance when Lake Windermere exceeds the Safe Boating Capacity. Paddle craft use was more consistent between days of the week than power craft use.
- Fishing boats and sailboats accounted for the fewest boats in this study at 13 and 4 boats, respectively.
- The very shallow South end discouraged boaters. Aquatic plants entangling props and paddles helped protect the important habitat values of that area (Figure 2; Figure 4, Figure 3). However, this concentrates power boating and affects the Safe Boat Capacity of other areas of the lake.

[1] Safety standards for boat density vary, however, two common standards are 20 acres per boat (8 ha/boat) on lakes with high-speed watercraft and 9 acres per boat (3.6 ha/boat) on small lakes with low-powered watercraft



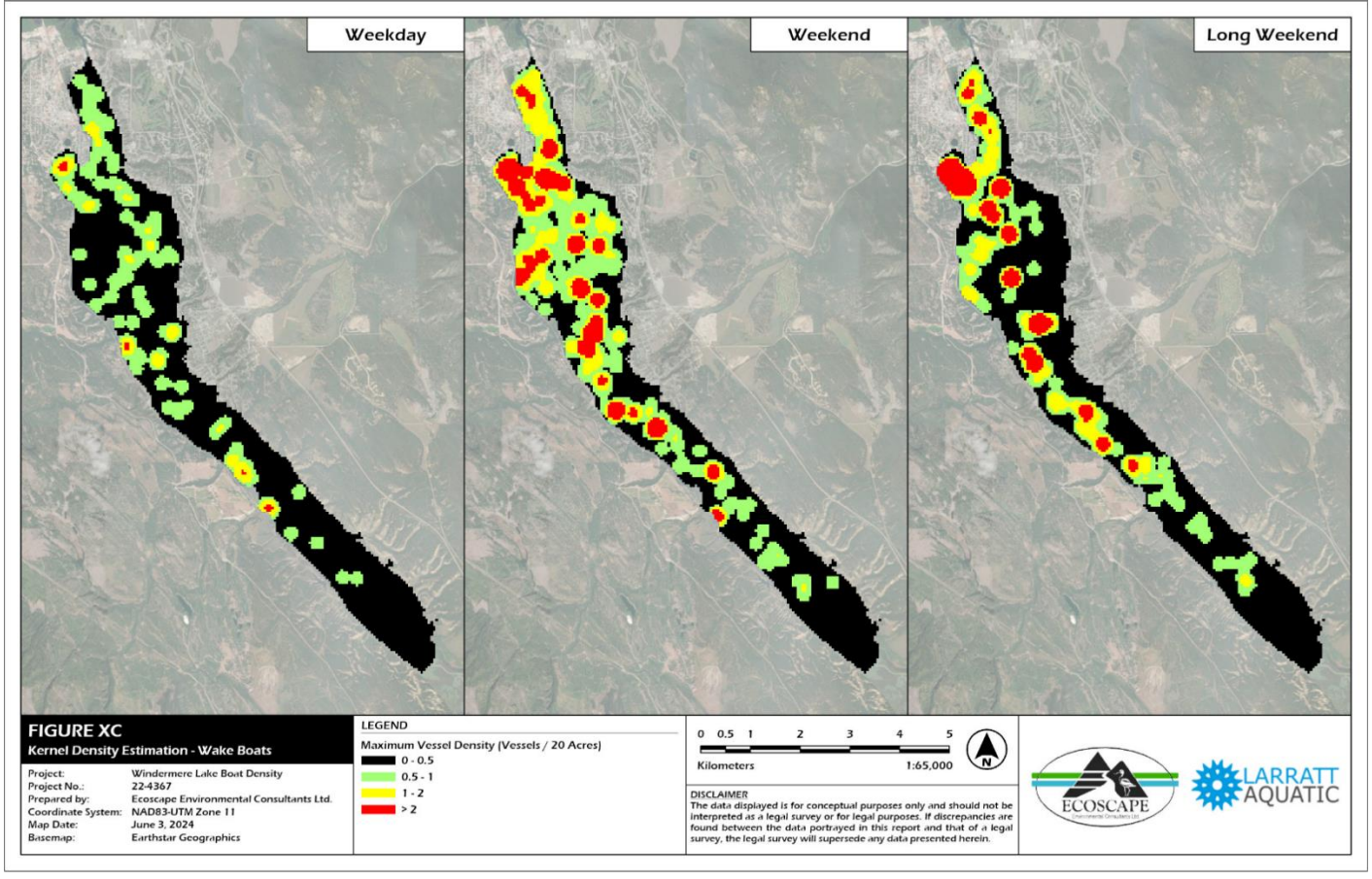


Figure 2: Areas of Windermere Lake where maximum safe vessel density was reached for: all vessels (A), motorized vessels (B) and wake boats (C) on summer weekdays, weekends, and long weekends.

These figures show regions where local density exceeded safe boating capacity (1 powered vessel / 20 acres) on any individual survey event. For sample exceedance densities from individual survey events, see Appendix B.

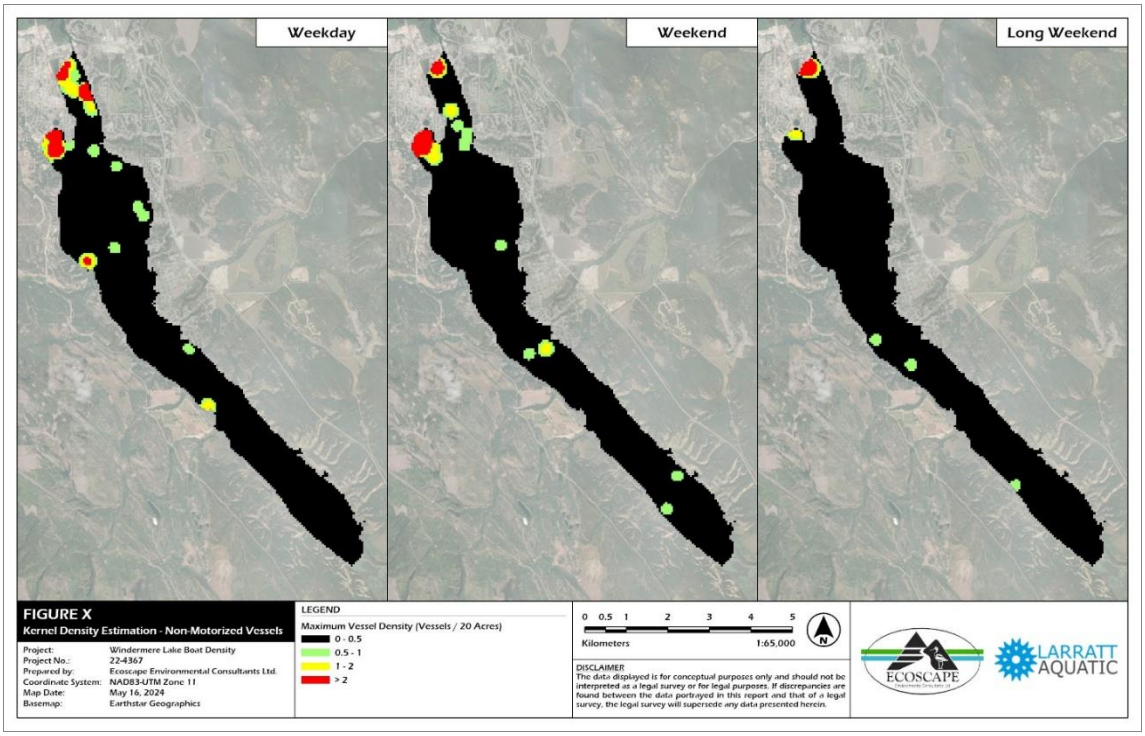


Figure 3: Non-motorized vessel density on summer weekdays, weekends, and long weekends

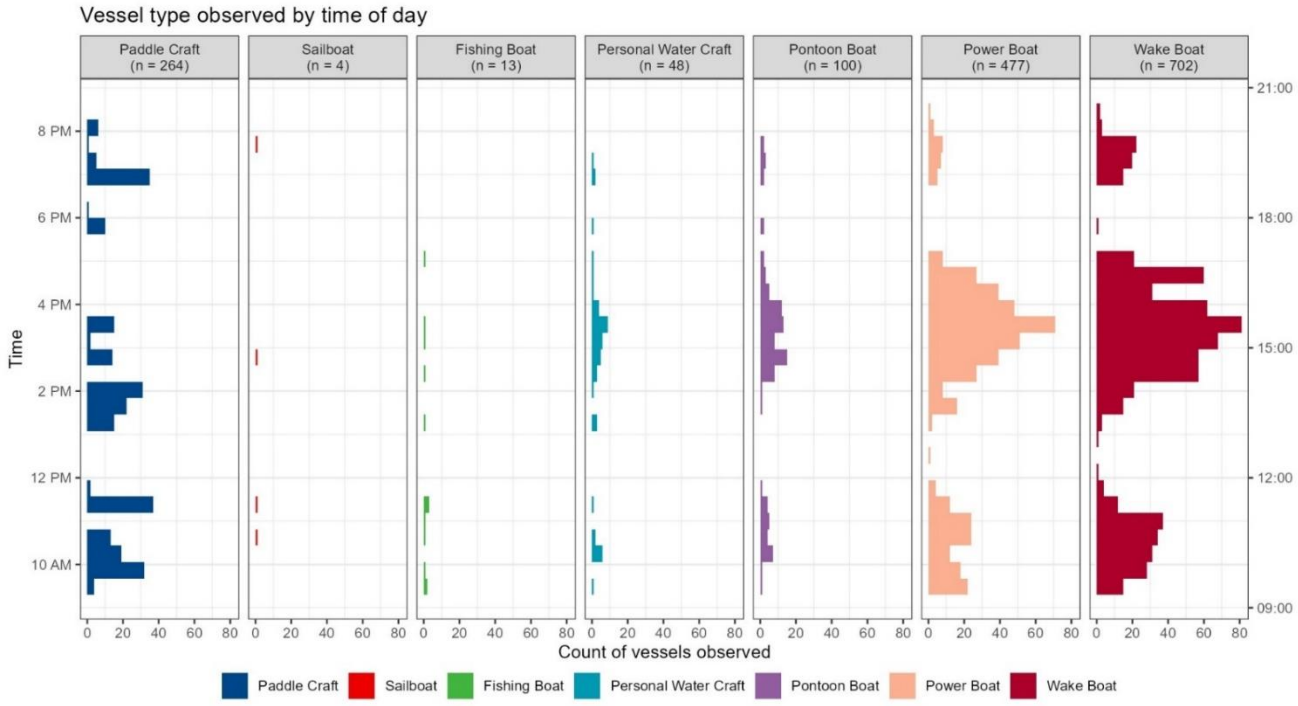


Figure 4: Vessel type observed by daylight hour in summer 2022 and summer 2023 by Lake Windermere Ambassadors.

2.2. Resident survey results

The residential survey comprised of 222 respondents. Of total respondents, 71% identified as full-time residents, 27% as part-time residents, and 2% as visitors. The highest ranked recreation type was swimming (188), followed by paddling/SUP (178), fishing (66), and boating (66). Over 50% of respondents (138) supported implementation of bylaws and regulations to mitigate impacts of boating activities. The full survey results can be found on the LWA website.

The LWA survey summary is reproduced below:

Demographics:

- most respondents are residents local to the Lake Windermere area (98%)
- the largest group identified as full-time residents (71%)

Recreation Activities:

- highest-ranking recreation activities on the lake are non-motorized, including swimming and paddling/SUP (75-83 %), *making non-motorized water sports the most popular activity of part-time residents in the Columbia Valley*
- indicated a preference for swimming and paddling over powerboating among locals

Boat Density and Safety:

- large majority of residents would like to see a maximum number of boats on the lake at any given time (77%)
- safety concerns, particularly from non-motorized users, are prevalent in the comments
- most respondents feel there are too many boats on the lake, exceeding its capacity (56%)
- approximately half of the respondents expressed concerns about their safety on the lake; (25% *often* feel unsafe on Like Windermere while only 10 % of residents *never* felt unsafe)
- more respondents voiced safety concerns than those who did not

Boating Education and Habits:

- about 60% of respondents are open to boating education and learning improved boating habits

Voluntary Codes of Conduct:

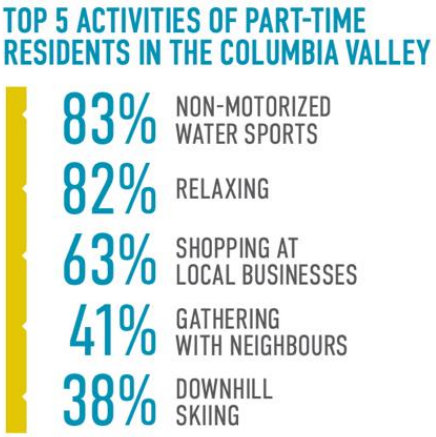
- 87% of respondents would follow all or some voluntary codes of conduct to protect the lake's sensitive areas and water quality
- similar numbers support the installation of slow, no-wake zones, and buoys to protect sensitive habitats and water quality

Regulations and Bylaws:

- respondents expressed interest in regulations but highlighted concerns around enforcement
- comments emphasized the need for increased regulation due to concerns about the negative impact of certain boat types and sizes on the shallow, soft lake bottom
- there is strong support for potential regulations, including a ban on motorized watercraft and/or horsepower limits.
- protecting drinking water through support for by-laws and regulations was not commonly mentioned, but the issue was raised in the question on participant concerns for Lake Windermere

Main Concerns:

- Overwhelmingly, community concerns revolve around water quality, quantity, and preservation of the ecological health of Lake Windermere and the attached wetlands.
- Specific concerns include the impact on fish, birds, aquatic life, and the introduction of invasive species.
- Many express concerns about the size and type of boats operating within the physical parameters of the lake, especially given its small size, shallow, and soft bottom (Figure 5).
- Safety concerns extend to include all types of lake users, with a desire for more boat-free spaces.
- Significant concerns about noise pollution and pollution from boats (gas, oil, fuel spills) and humans (garbage seen in the lake) in both long answer questions.



Source: 2022 Vital Signs - Columbia Valley Community Foundation (www.valleyfoundation.ca)

Tourism in BC is booming and some jurisdictions are now shifting from attracting more visitors to learning how to manage overtourism. Overtourism - where visitation either exceeds a destination's carrying capacity and/or the type of tourism taking place causes significant negative impact - is an increasing issue worldwide. For example, the Lil'wat and the Province developed

the Joffre Lakes Park 2019 Visitor Use Management Action Plan[2] which put a day-pass system in place with closures to protect cultural practises. The Sea-to-Sky Destination Management Council launched the impactful "Don't Love It to Death[3]" program in 2022. Internationally, Fodor's International travel guide put Lake Tahoe on its list of places to avoid due to overtourism in 2023 and that triggered development of the Lake Tahoe Destination Stewardship Plan.[4] The 143-page plan considers measures adopted by other tourist destinations, such as requiring reservations, timed-entry permits and capacity limits. The problems faced by these areas match the ones confronting Lake Windermere. A Lake Windermere Stewardship Plan could be modelled after these and other plans designed to address overtourism.

Figure 5: Power boat in wake-surf mode passing too close to Lake Windermere shoreline
Photo supplied by LWA

[2] https://stewardshiptahoe.org/wp-content/uploads/2023/06/Lake-Tahoe-Stewardship-Plan-6-19-23-FINAL.pdf
[3] https://dontloveittodeath.com/
[4] https://stewardshiptahoe.org/wp-content/uploads/2023/06/Lake-Tahoe-Stewardship-Plan-6-19-23-FINAL.pdf

2.3. Sediment Study of Lake Windermere

Sediment samples, sediment traps and existing habitat data were used to determine potential risks associated with sediment disruption or contamination resulting from recreational power craft use of Lake Windermere.

Sediment Hydrocarbons

Sediment samples collected in 2022 contained detectable hydrocarbons at 6 of 9 sites distributed through the lake (Figure 7). The highest recorded hydrocarbon result was 460 mg/kg of EPH $_{19\text{-}32}$ [5], measured at the Rockier Sediment site. The LAC field crew noticed a hydrocarbon odor when they took sediment cores in marinas – an observation supported by detection of EPH $_{19\text{-}32}$ in marinas.

Sediment quality guidelines are not set for EPHs because it is a broad category including both natural biogenic hydrocarbons from decomposition of algae and human-caused petroleum hydrocarbons. The results from the 2022 sampling trip indicated there would be value in a more thorough investigation of hydrocarbon contamination in Lake Windermere. More detailed analyses panels were collected in 2023 for guideline comparison. These results showed that 91% of the sites contained detectable EPH $_{19\text{-}32}$. In response to the original samples indicating potential wide-spread hydrocarbon contamination in Lake Windermere sediments, silica-gel cleanup was added as an extra QA step to the 2023 testing. Research indicates that silica-gel can remove false positives in cases where high biogenic organics may be affecting results but unfortunately, weathered gasolines will not be detected.

Both silica gel QA samples contained no detectable EPH $_{19\text{-}32s}$. This result, in conjunction with PAH[6] tests that were below detection at all sites, indicates that hydrocarbon contamination is not a significant concern for Lake Windermere as a whole, but marina sediments may be contaminated. Volatile gasoline-range hydrocarbons dissipate and are rarely observed at concentrations of concern in lake sediments. Although more testing using different panels such as BTEX, VOC, and or resins/fatty acids could shed more light on the unusual EPH results, the costs of such testing can be prohibitive for small groups such as LWA.

[5] Extractable petroleum hydrocarbons with 19-32 carbon atoms per molecule
[6] Polycyclic aromatic hydrocarbons from incomplete combustion; persistent in the environment

Sediment Metals

Sediment samples from Lake Windermere were analysed for metals in 2022. When metals enter lakes, most deposit in lake sediment. Metals adsorb onto organic particulates and more readily accumulate in fine sediments than sandy or rocky sediments.

The deep sediment site contained the highest values for most analyzed parameters, a result likely attributed to fine sediment travelling to the deepest point of the lake when resuspended. Fine sediments have greater surface areas than coarse sediment; this increases accumulation and retention of contaminants in fine sediments. Most sediments in Lake Windermere were fine, with the notable exception of sandy sediments in the alluvial fan created by Windermere Creek.

Metals can resuspend into the water column when sediment is disturbed. Reintroduction of metals from the sediment can occur during overturn and from boat wake turbulence in shallow lakes (Shu et al. 2021; Daeger et al. 2022).

Numerous heavy metals correlated strongly with the high moisture content of fine sediments (R=0.88 for lead) while metals in sandy mineral soils correlated very weakly or negatively with moisture (R=0 for calcium). Diffusion occurs between the uppermost sediment layer and water interface, continuously releasing metals into the water column. Metals released from the sediments can cause water quality deterioration and food chain impacts, posing a threat to aquatic ecosystem health (Zhang et al. 2023). Natural diffusion is accelerated by turbulence, particularly wake-surf turbulence that can reach to the sediments throughout Lake Windermere.

The mean sediment concentrations for the southern Rocky Mountain tectonic region for the metals of interest in Lake Windermere are found in Table 2 and mapped in Figure 8. The redox-sensitive metals iron (Fe) and manganese (Mn) were many times the regional averages in Lake Windermere sediments. Sediment manganese concentrations were elevated at 5 of 7 sample sites with 4 sites exceeding the BC ISQG by between 3% and 85%. Sediment enriched with Fe and Mn layers indicate carbon enrichment with oxygen present at the sediment-water interface but reducing conditions within a few cm into the sediment column. Higher erosion, prolonged anoxia, and humic matter input affect Fe and Mn accumulations (Makri et al. 2021).

Of the heavy metals, copper and lead were below both the regional and guideline concentrations, however they exceeded the 80% of maximum allowable concentration warning threshold[7] (Table 2). Exceedances for sediment arsenic and nickel were detected, however, these sediment metal concentrations were within the lower end of the range for this region (Reiberger 1992). Arsenic exceeded the BC sediment quality guideline (<5.9 mg/kg) with 5 of 7 sites exceeding the guideline

[7] Screening samples against a warning value of 80% of the maximum allowable concentration is a common analysis technique used to flag samples that do not currently exceed guidelines but may warrant further investigation because of relatively high concentrations for a given parameter.

by as much as double at the deep and control sites. Sources of arsenic include stormwater, septage, treated lumber in the lake, groundwater, and crop/livestock agriculture (manure, fertilizers, pesticides; US EPA; Barringer et al. 2011). Nickel was also elevated and exceeded the BC ISQG in the control site and deep site sediments by 26% and 21% respectively.

Recent research on heavy metal contamination in Taihu Lake, China indicated that American and Canadian environmental quality standards for freshwater sediments are insufficient to protect against ecological risks of heavy metals (Zhang et al. 2023). The study also found invertebrates and algae from shallow lakes had higher eco-risks from heavy metals than similar sediments protected by deep water columns. Applied to shallow Lake Windermere, adverse impacts on lake health from sediment metals and contaminants should be anticipated. The metals detected at or above concentrations of potential concern in Lake Windermere sediments included copper, lead, arsenic and nickel. These metals are known to adversely impact aquatic food webs and their respective guidelines reflect those impacts (Table 2).

Table 2: Concentrations of metals of interest in Windermere Lake sediments

Metal of Interest		Sediment guidelines	Mean ± SD for region	Mean ± SD for Lake Windermere
Heavy Metals	As arsenic	<5.9 mg/kg	15.48 ± 10.37 ug/g	6.81 ± 2.89 mg/kg
	Cu copper	35.7 mg/kg	178.9 ± 84.46 ug/g	13.85 ± 10.13 mg/kg
	Fe iron	21,200 mg/kg	234.0 ± 159.7 ug/g	17,776 ± 8,767 mg/kg
	Mn manganese	460 mg/kg	141.9 ± 107.5 ug/g	450 ± 180 mg/kg
	Ni nickel	16 mg/kg	27.26 ± 25.68 ug/g	12.51 ± 4.88 mg/kg
	Pb lead	35 mg/kg	37.89 ± 19.69 ug/g	14.51 ± 10.0 mg/kg

NOTE: ug/g = mg/kg | Range for region from Reiberger 1992

Sediment Nutrients

Lake sediments are a repository for nutrients reporting from the watershed. Phosphorus concentrations in Lake Windermere sediments averaged 489 ± 270 mg/kg, within the range of expected values for this region (889 ± 458 mg/kg; Reiberger, 1992). Iron concentrations are high and can help retain phosphorus as iron minerals and Fe sorbed to organic matter (Table 2; Munch et al. 2024). Additional phosphorus retention with sulphates, Al(OH), $Ca_3(PO_4)_2$ and as detrital organic P compounds all work best in undisturbed lake sediments (Hupper and Lewandowski 2008). Because Lake Windermere is so shallow, its water column is fully oxygenated which helps restrict nutrient release from the sediments if the sediments remain undisturbed. However, sediment resuspension from boat turbulence is commonly observed, particularly near marinas

on Lake Windermere (Figure 6). Sediment resuspension releases the stored phosphorus and plays an important role in the nutrient dynamics of shallow lakes because nutrients are returned to the euphotic zone where they can stimulate algae growth (Dillon et al. 1990; Nedohin and Elefsiniotis 1996).

Power Boat Impact on Lake Sediments

Sediment re-suspension keeps sediment contaminants in contact with the water column when they would otherwise become gradually buried in accumulating sediment layers. Sediment resuspension is a very important mechanism for releasing metals into the water column (Kalnejais et al. 2007). Weakly bound and particulate-phase metals and other contaminants are remobilized in sediment plumes induced by the downward propwash thrust of power boats (Pourabadehei and Mulligan 2016), especially wake-surf boats (Daeger et al. 2022).

Outboard engines on typical powerboats create turbulence that can reach as deep as 3 m (10') (Gucinski 1982; Keller 2017), while wake propellers generate water velocities with the capacity to resuspend unconsolidated sand, silt, and smaller organic materials at a depth of 4.5m (15') when the boat was in wake-making modes (Raymond and Galvez-Cloutier 2015). Larratt and Self (2018) measured lakebed wake impact at 8 m depth after passage of a moderate-sized wake boat. Models developed by Ray (2020) calculated that modern wake boats can cause sediment resuspension in water down to 10m (33') deep, or about a three-storey building. We can safely conclude that wake boats can disturb fine sediments throughout the entirety of Lake Windermere with its average depth of 3.4 m and maximum depth of 6.4 m.

Power Boat Infrastructure Impact on Lake Sediments

Marinas concentrate sediment resuspension, particularly when boats power up just past the marina mouth (Figures 6, 15). A mandatory signing of a marina Code of Conduct could mitigate some of these impacts. The Code of Conduct should include statements involving nuisance noise, safety, and respect for property such as the following excerpt from the Shelter Bay Marina, West Kelowna, slip rental agreement[8]:

- Members observed to engage in dangerous operation of a Vessel in the marina basin will result in immediate loss of moorage privileges.
- All Vessels entering or leaving the marina basin must always be dead slow – no wake. The area 100 feet beyond the breakwater at the entry and exit is a no wake zone, boats departing the marina at the south exit should navigate to avoid disturbing the foreshore and residences. Stereos should be off, and engines muffled when under power near the marina
- Guests shall not throw, discharge, or deposit from any boat or float into the water any litter.

[8] Shelter Bay Marina Slip Rental agreement shelterbaykelowna.com/files/2023-Rules-and-Regulations-Schedule-B.pdf

- There is no release of waste permitted into the basin. Vessels bilging oily water into the basin may be deemed a hazard and may be removed from the basin without notice to the member.
- There is no fueling of vessels permitted on SBM premises other than by approved fuel dispensers at the gas dock. If you have just refueled your boat at the fuel dock and topped off your tanks, please burn off a few gallons before you return to your slip. In warm weather fuel will expand and may spill into the basin.
- Members and their guests shall receive, handle, use, store, treat ship and dispose of all environmental contaminants (as established from time to time by applicable legislation or regulation or bylaw) In strict compliance with all applicable environmental, health or safety laws, regulations, order, or approval and will remove prior to the end of the terms of this agreement and off marina premises, all environmental contaminants. Members and their guests agree that they shall not release in the environment or deposit, discharge, place or dispose of at or near SBM premises, any hazardous or toxic materials, substances, pollutants, contaminants, and or waste from any activities carried on by the member or their guests on SBM Property.
- Propane tanks, tires, construction materials, batteries and other hazardous materials are prohibited from the provided garbage bins on marina premises. These items must be removed from the premises by the member or guest. Depositing these items in or around either bin will result in immediate loss of moorage privileges.
- On Land: Discharge of contaminated bilge water, holding tanks, engine cooling system fluid(antifreeze), transmission fluid, hydraulic fluid, engine oil, gear oil, drainage of fresh water supply, including hot and cold and hot water heater after the boat has been hauled, blocked and or stored is prohibited.

Docks and buoys have a widespread but less intensive impact compared to marinas, except in cases where buoys are set out in a tight layout similar to a marina. All on-water storage of power boats can lead to contamination from boat cleaning (chlorine, ammonia, phosphates, plastic fragments), fueling (hydrocarbons, heavy metals), maintenance (heavy metals, grease) and effluents (fecal contamination and personal care products).

The Lake Windermere dock and buoy count document from August 2022 show very high densities (Table 3; Ecoscape 2022). Totals of 936 docks and 431 buoys were counted for a total moorage of 1367 in 2022. The total moorage alone could exceed safe boating capacity and environmental tolerances of Lake Windermere, before marina slips and launched boats are considered.

Table 3: Lake Windermere Dock Buoys and Boat Count August 2022

LAKE WINDERMERE - DOCKS, BUOYS AND BOAT COUNT - AUGUST 16, 2022

	Buoys Without Boat	Buoys With Boat	Total Buoys	Docks without Boat	Docks With Boat	Total Docks	TOTAL BOATS	TOTAL MOORAGE	COMMENTS
WEST SHORE									
Chabot Park to Bayshore	25	50	75	0	0	0	50	75	
Bayshore Dock	0	0	0	13	23	36	23	36	Community Dock
Canterbury to Kinsmen	15	3	18	14	27	41	30	59	
Kinsmen Beach	5	0	5	0	5	5	5	10	
KPOKL	24	9	33	0	0	0	9	33	
Kinsmen Bay West Shore	4	5	9	2	3	5	8	14	
West Shore	0	5	5	6	0	6	5	11	
Larch Point	6	4	10	4	9	13	13	23	Slalom Ski Course
Rushmere	9	8	17	9	1	10	9	27	
SUB-TOTAL	88	84	172	48	68	116	152	288	
EAST SHORE									
Camp Land	9	23	32	0	0	0	23	32	Slalom Ski Course
Indian Beach Estates	24	4	28	8	54	62	58	90	Community Dock
IBE Waterfront	0	0	0	6	10	16	10	16	
Coldstream	0	0	0	20	12	32	12	32	Community Dock
Public Access	4	8	12	0	0	0	8	12	
Windermere South	0	0	0	20	72	92	72	92	Community Docks
Shady Brook	0	0	0	7	53	60	53	60	Community Dock/Gas
Windermere North	3	7	10	9	38	47	45	57	Community Docks
Hidden Bay	0	0	0	21	22	43	22	43	Community Docks
YaKoNaki	2	2	4	2	0	2	2	6	Community Dock
Akiskinook	0	0	0	42	84	126	84	126	Community Dock
Calberly	6	15	21	2	2	4	17	25	
Terra Vista	0	0	0	34	70	104	70	104	Community Dock
Terra Vista to Baltac Bay	13	18	31	17	4	21	22	52	
Baltac Bay	13	27	40	0	0	0	27	40	
Baltac Bay to Timber Ridge	23	13	36	4	6	10	19	46	
Timber Ridge	0	2	2	16	107	123	109	125	Community Dock
Timber Ridge to Athalmer	20	23	43	37	16	53	39	96	
Pete's Marina	0	0	0	1	24	25	24	25	Commercial Dock/Gas
SUB-TOTAL	117	142	259	246	574	820	716	1079	
LAKE TOTAL	**205**	**226**	**431**	**294**	**642**	**936**	**868**	**1367**	

Sediment Sampling

The Deep Site surface sediment sample had among the highest values for most parameters, a result likely attributed to sediment focusing toward the deepest point of the lake every time it becomes resuspended.

Sediment traps were deployed throughout Lake Windermere in September 2022 to measures sediment deposition rates (Figure 6). Because Lake Windermere is very shallow, the traps were visible to boaters and unfortunately, often removed. Eight traps were deployed but only two were retrieved after one year despite frequent checks by LWA volunteers. Deliberate removal of these traps occurred despite clearly labelling them as part of scientific study, "please do not remove and a phone number to contact for questions". Most of the traps (6) were tampered with, making this important part of the study inconclusive. The loss of the sediment traps prevented analysis of power boating impacts on sedimentation rates.

Comparing the two remaining traps showed higher sediment accumulation at the Marina 2 site (500 g/m²/year or 0.05 g/cm^2/yr) than the deep site (213 g/m²/year). Without other influences, sedimentation rates should be greatest at central deep lake areas. The Marina 2 site had two major influences that probably increased its sedimentation rate: power boat sediment resuspension (Figure 7) and Windermere Creek deposition. For comparison, sedimentation rates measured in the North Arm of Kalamalka Lake subjected to powerboating and agricultural/urban affected creek inflow averaged 285 g/m²/year at the deepest site. The Marina 2 site appears to have unusually high sedimentation rates. The Ecoscape FIM team and the LAC field team both witnessed sediment plumes emanating from the marina for hours during peak boating activity. Aerial photography confirms the repeated scouring of the shallow sediments by boats as tracks where the deeper anoxic sediment layer become exposed (Figure 15).

The organic fraction of the accumulated sediment was similar between both sites on Lake Windermere (70.6 g/m²/year) with higher inorganic sediment at the Marina 2 site.

These results indicate a modest estimated sediment accumulation rate of 1 cm every 20-30 years (0.05 cm/yr)[9]. For comparison, shallow Wood Lake in the Okanagan showed a sedimentation rate of 0.2 cm/yr (Okanagan Basin Study, Chpt 4 1973). We expect resuspended sediment is a major component of trap material, congruent with research in other shallow lakes (Dillon et al. 1990; Chung et al 2009; Qi et al. 2019).

[9] An estimate assuming density of water: convert from g/m^2 to cm/m^2 using an estimated sediment density of 1 g/cm^3

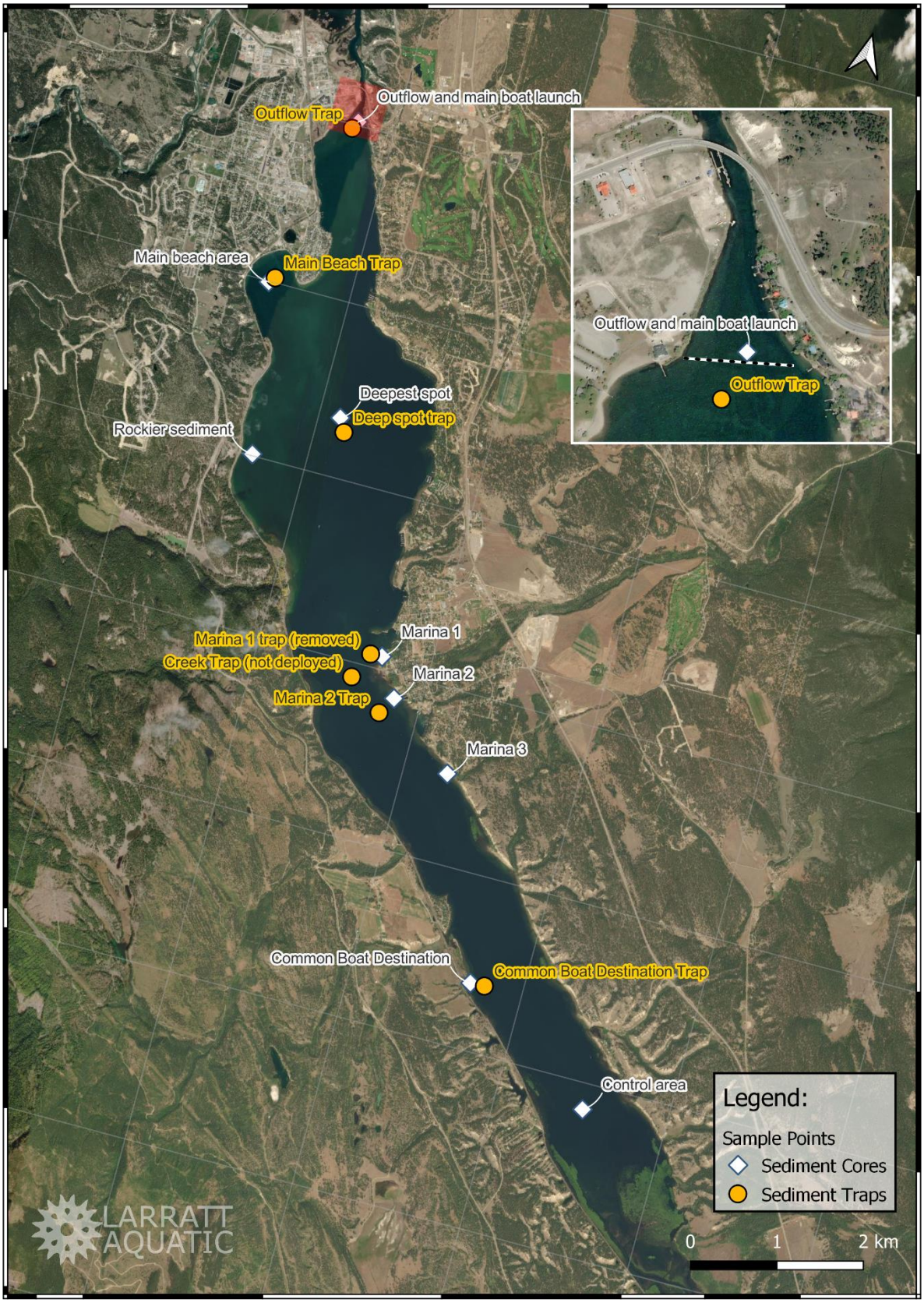


Figure 6: Sediment Sampling Sites

Figure 7: Aerial image of sediment plume from a wake-surf boat operated in shallow water. Note the tracks through the sediments from other boat passage, all emanating from the marina.

(Photo from LWA)

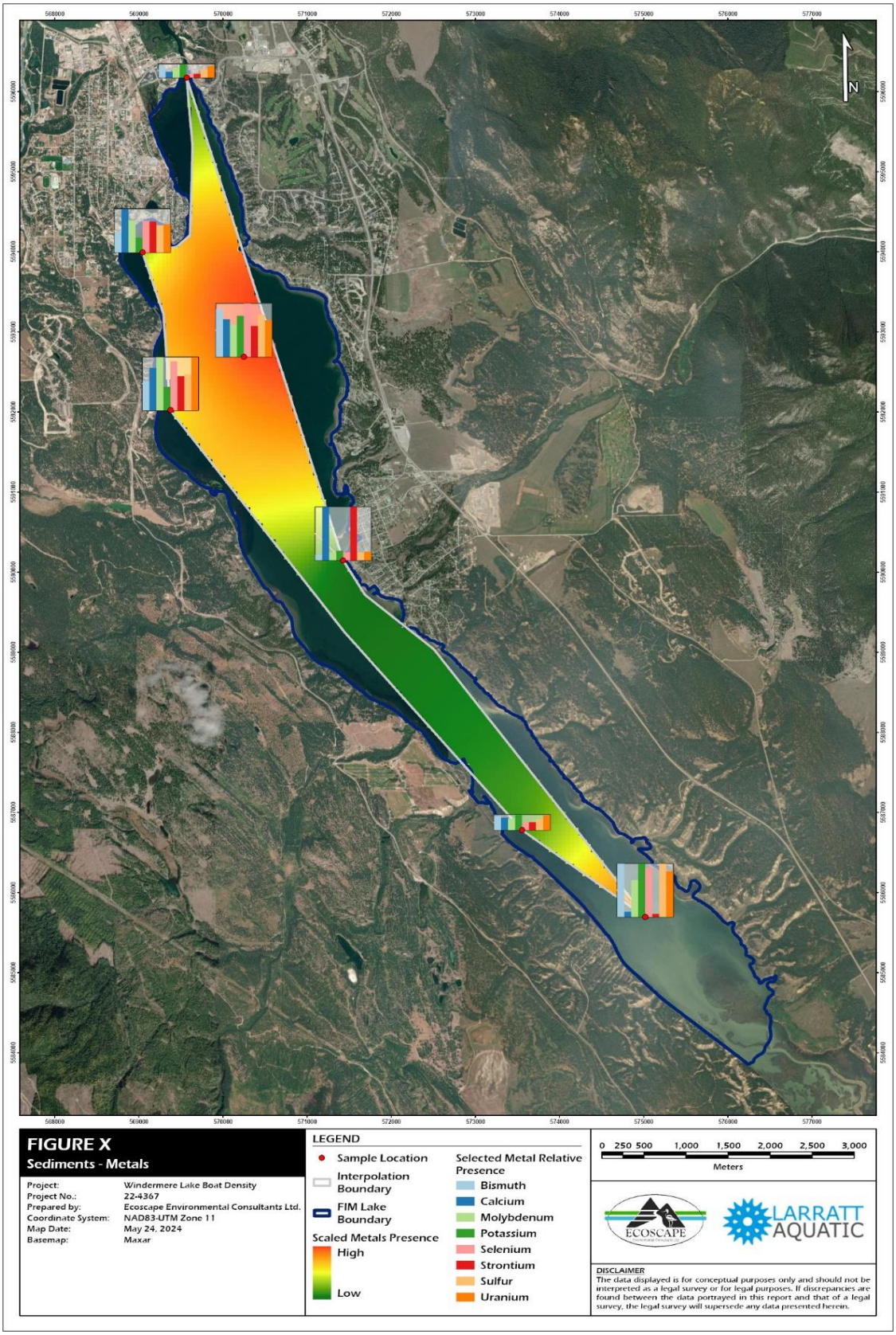


Figure 8: Map of sediment chemistry concentrations for metals and metalloids

2.4. Lake profile data

Lake profiles were collected with a field meter at each WQ site during 2022 and 2023 (Figure 9). The shallow water depth of Lake Windermere precludes thermal stratification. These profiles revealed a distinct south to north increasing temperature gradient. Peak surface water temperatures exceeded 20^{o}C each summer. Lake Windermere water temperatures are very responsive to summer weather. The range of summer water temperatures will support cyanobacteria blooms.

The sediment-water interface is warm in Lake Windermere because it does not stratify. The bottom water temperatures reached 20.4°C during September 2022 during an extended late-summer heatwave and the average was 18.5 ± 2.6°C between both years at 5 m. For reference, the maximum recommended water temperature for domestic intakes is 15°C (IHA).

These bottom water temperatures are unusually warm for a BC lake. Although we did not measure this directly, warm surficial sediments will accelerate sediment bacterial activity including decomposers, methanogens, and sulfate-reducing bacteria.

Increased conductivity occurred at the sites surrounding Windermere Creek compared to those farther away (Figure 10). Conductivity reached 326 µS/cm near the inflow plume, suggesting some combination of resource extraction, stormwater, agricultural and septage influence in the Windermere Creek watershed. Like all lakes, most of the contaminants entering Lake Windermere will eventually become deposited on the sediment surface. Recent deposits can be re-suspended by wakes and waves.

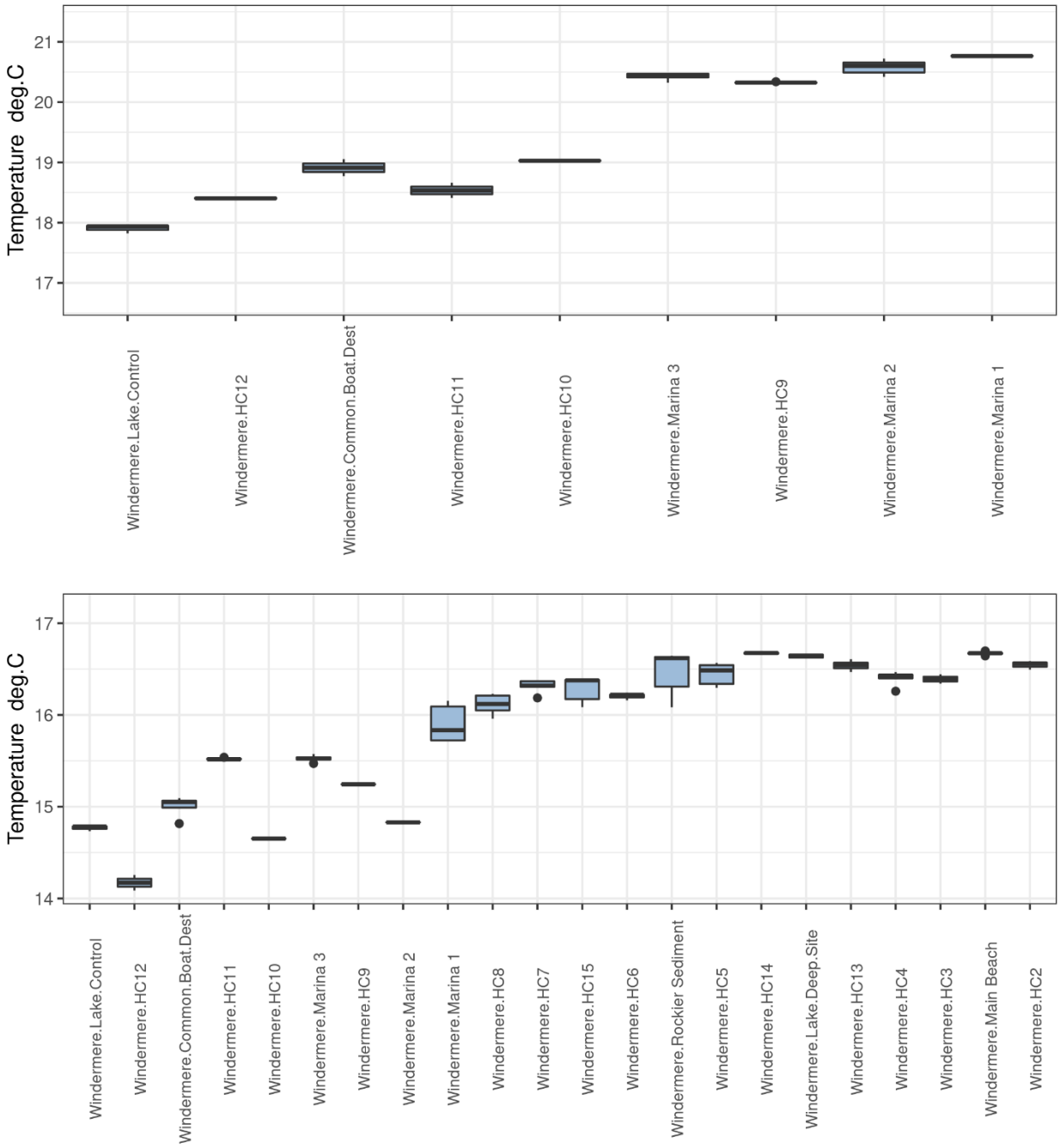


Figure 9: In-situ temperature profile data from Lake Windermere during 2022 (top) and 2023 (bottom) from south (left) to north (right)

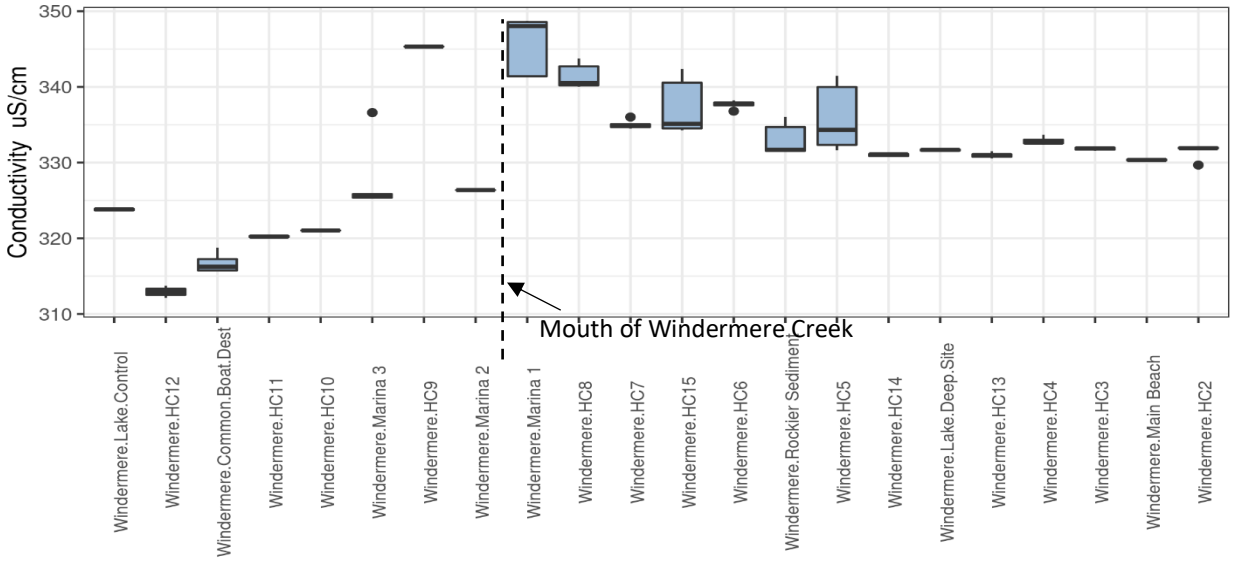


Figure 10: In-situ conductivity profile data from Lake Windermere during 2023

2.5. Nutrient data

Phosphorus (TP) and nitrogen (TN) are the two primary nutrients that affect phytoplankton production in lakes. If either is present in abundance relative to the other, then nutrient limitation occurs. For example, if phosphorus were limiting production, adding more phosphorus would trigger phytoplankton growth while adding additional nitrogen would have no effect because there was already excess nitrogen in the lake. The ratio of nitrogen to phosphorus describes this limiting relationship. A TN:TP ratio of < 5:1 indicates nitrogen limitation or phosphorus overabundance. This condition is common in eutrophic or highly productive lakes. A ratio of >15:1 indicates phosphorus limitation and is common in oligotrophic lakes. The BC Ministry of Health cyanotoxin screening tool uses a ratio of <23: 1 to protect against cyanobacteria blooms that are driven by phosphorus influents.

Since routine sampling by ENV began in 2015, TN averaged 0.169 ± 0.030 mg/L as N while TP averaged 0.0062 ± 0.0051 mg/L as P leading to an average TN:TP of 39:1. This ratio means Lake Windermere is susceptible to phosphorus inputs either from its watershed or from sediment disturbance. TP met the objective (<0.010 mg/L as P) during most years, including 2023 (EMS data). No statistically significant trends emerged in either TP or TN data since 2015 in Lake Windermere (Figure 11). TP as measured by LWA from 2018-2023 averaged 0.0078 ± 0.0037 mg/L as P. Nutrient concentrations are controlled by the high flushing rate of only 47 days and are therefor not as strong an indicator of lake-wide change as phytoplankton algae or sediment coring. A Lake Windermere core representing the past 300 years found a lake health breakpoint in the 1950's concurrent with land development. This study also found a significant amount of evidence that Windermere Lake water quality is slowly deteriorating (McDonald, 2000; Masse and Miller 2005).

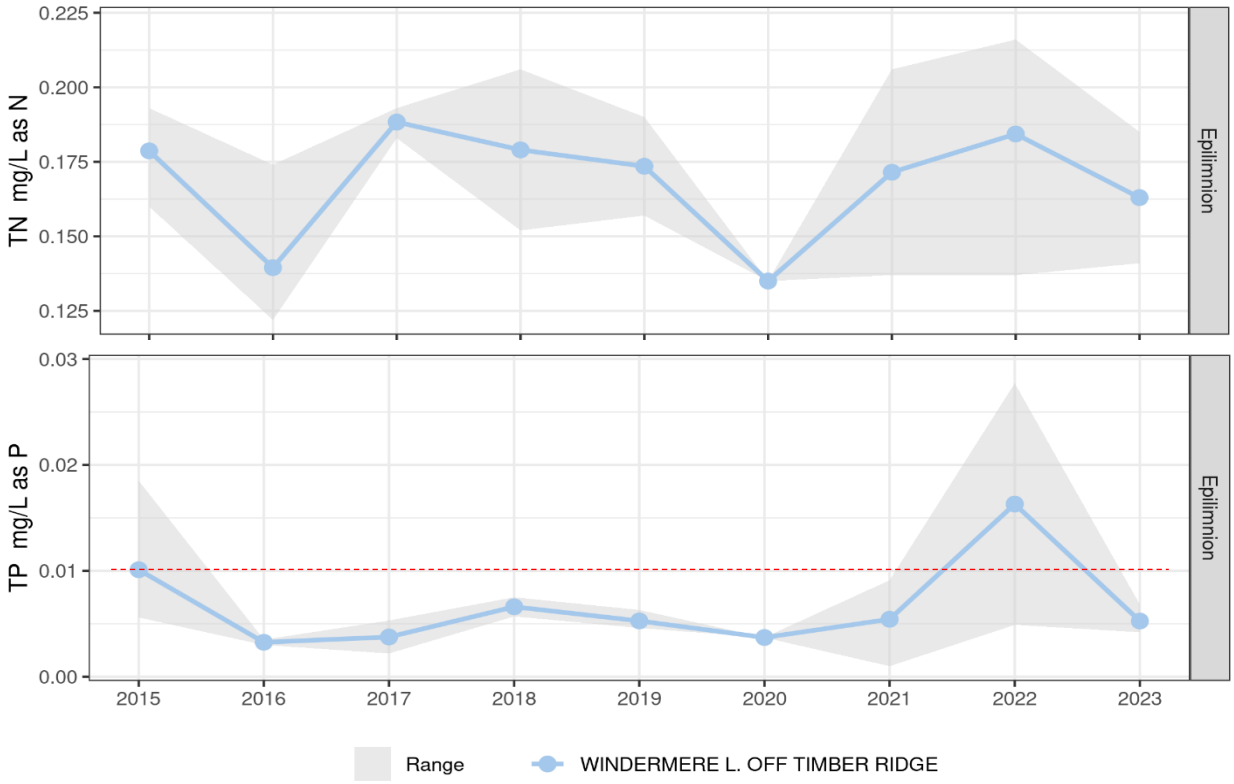


Figure 11: Total nitrogen and total phosphorus in Lake Windermere, 2015-2023

Note: red dashed line marks the Windermere Lake TP objective

2.6. Phytoplankton

Phytoplankton (free-floating algae) densities were measured at four sites on the September 2022 field trip using surface grab samples (Figure 12). Phytoplankton densities were moderate in the southern sample site while the northern sites had very high densities and were dominated by the potentially toxic cyanobacteria *Anacystis sp.* The beach sample contained 21,410 cells/mL of cyanobacteria, a concerning result for a popular swimming area. These algae tend to accumulate along shorelines with on-shore winds, creating increased risk, as shown by the Main Beach sample cyanotoxin risk meter illustration (Figures 13, 14). If nutrient concentrations increase, particularly phosphorus, these summer cyanobacteria blooms could become more problematic for Lake Windermere. Sediment resuspension presents a rapid localized release of nutrients. Researchers found total phosphorus levels increased by an average of 25% with only two passes of a wake boat in surf mode in waters 4.5-7.6 m deep in lakes they studied (Tyre and Luebke 2022).

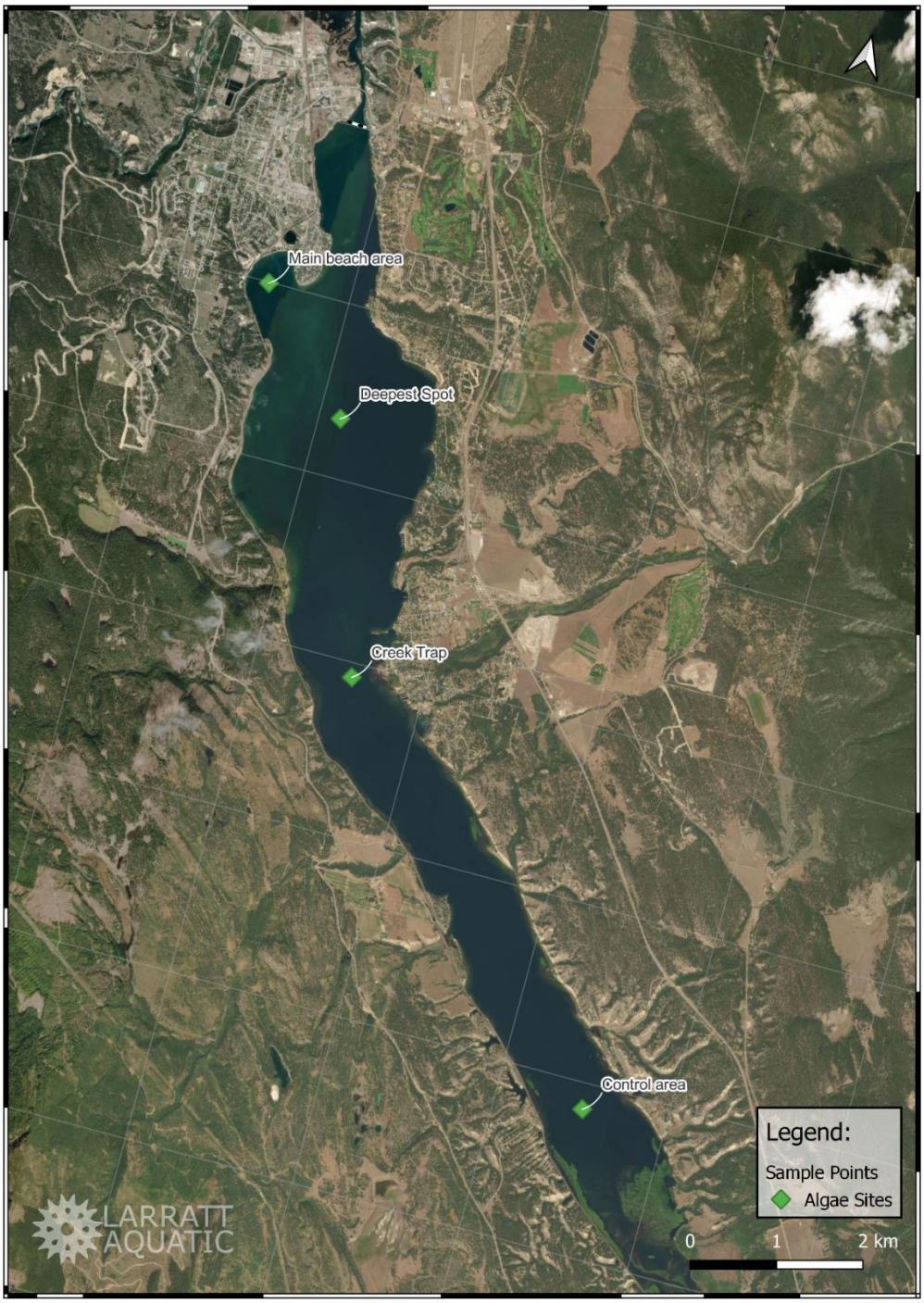


Figure 12: Algae sample sites

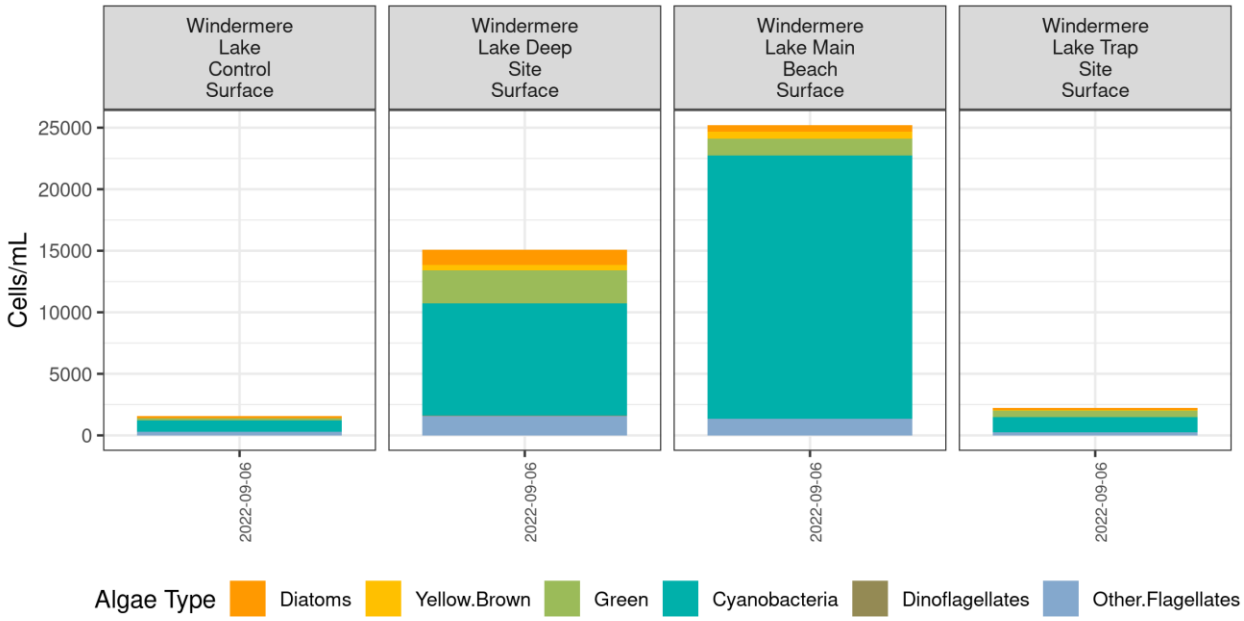


Figure 13: Phytoplankton densities in Lake Windermere sample sites, Sep 6 2022

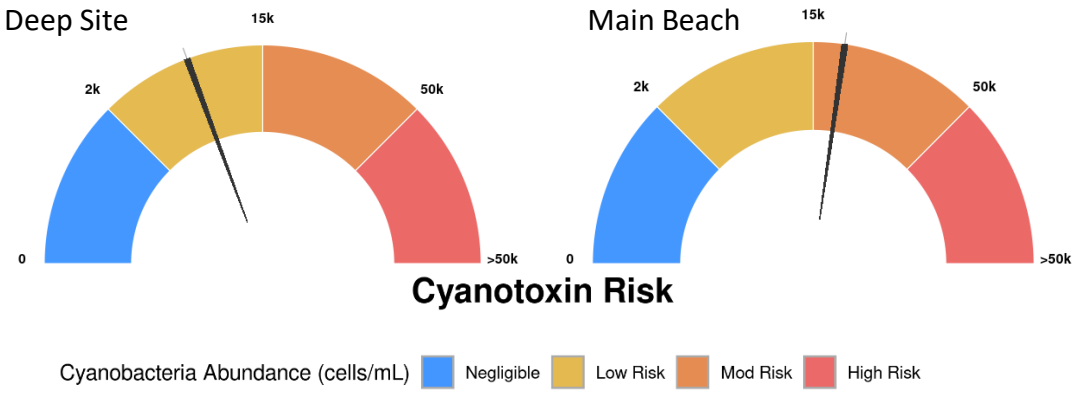


Figure 14: Cyanotoxin production risk estimate for September 2022 Lake Windermere algae samples

2.7. Invasive mussels

Lake Windermere is very susceptible to invasive dreissenid mussels. Total calcium averaged 41.9 mg/L in 2023 which is more than adequate for shell development. All other habitat criteria were met as well, meaning Lake Windermere is one infested boat away from the serious ecological and economic harm these invaders cause. Boats and especially those equipped with ballast tanks or engine cooling reservoirs are the most common transporters of live invasive mussels. Please refer to the OBWB mussel guide on the OBWB website at: https://tinyurl.com/Z-Q-Mussel-vulnerability-guide.

2.8. Sensitive environmental values

Fisheries

Lake Windermere fishery and salmonid restoration efforts are affected by excessive powerboating in numerous, well documented ways (Asplund, 2000; Beacher and Hill 2003; Whitefield and Becker 2014), not all of which could be assessed in this study:

- Sediment resuspension returning contaminants to the water column (see Section 2.3)
- Alterations in the wave climate and water turbidity can affect fish and their habitats, including submerged and emergent plant beds (see Section 3.8 FIM).
- Shoreline erosion and impacts on shore-nesting birds, shore spawning fish (see Section 3.8 FIM report).
- Sound generated by boat motors and boat music can influence behaviour and distribution of some fish species (not assessed in this study; comments made in LWA survey on noise).
- Pollution arising from fuel spillages, exhaust emissions including carbon monoxide and antifouling paints all have detrimental effects on fish.
- Recreational boats are a critical vector for aquatic invasive species transport (Not assessed in this study; see OBWB Preparing For Invasive Mussels – vulnerability assessment guide).
- Boat infrastructure such as marinas and moorings displace natural habitat, causing a loss of usable habitat by fish (see Section 3.8 FIM).

Shoreline Fisheries

LWA's 2021 shoreline fisheries assessment of Lake Windermere pointed to a potential increased ratio of Northern Pikeminnow in Lake Windermere from the previous survey conducted in 2007 (Hildebrandt, 2022). Pikeminnow are known to be voracious predators often out competing more sensitive native species, especially in highly disturbed aquatic environments. In 2007 the most common fish in Lake Windermere (according to the survey) were Redside shiner making up 84.1% of fish identified, while they made up only 6.5% of fish identified in our 2021 survey. What has changed to encourage these differences? During the survey Lotic Environmental pointed out Northern Pikeminnow were common in all disturbance levels, however Northern Pikeminnow were about three times as common in highly disturbed sites than in sites with moderate or low disturbance (Hildebrand, 2022). In contrast Redside Shiner and other more vulnerable native fish appeared to prefer low disturbance sites.

2.9. Foreshore Inventory Mapping FIM/FIMP

Foreshore Inventory Mapping (FIM) identified the ecological importance of different shore zones segments for Lake Windermere. The Foreshore Habitat Sensitivity Index or FHSI considered numerous criteria to determine the relative shoreline habitat value. This data was used in conjunction with biological zones of sensitivity to understand the environmental sensitivity of the lake spatially (Figure 16). This preliminary analysis was designed to assess boating impact on lake

values. We acknowledge that consideration of independent values may be more appropriate when more data is available to expand this spatial analysis. The following criteria were considered and weighted in a simple index (see Appendix C for weightings):

1. Depth was considered, with areas less than 4 m in depth considered the most valuable in the index;
2. FHSI Score was broken down into three groups, High, Moderate, and Low which considered of the FHSI groups from the FIMP report. The effect of the FHSI was limited to areas within 150 m of the high-water mark, to acknowledge the focus on the foreshore areas of the lake versus that of deep water habitat;
3. Mussel Presence, High Value Kokanee, Aquatic Vegetation, Burbot Spawning, and Waterfowl Migrations habitat zones were also considered.

Considering individual Zones of Sensitivity (ZOS) is important because impacts from boating recreation will affect lake values by different mechanisms. The most important ZOS's are those where a direct causal mechanism can be identified. The following summarizes the ZOSs from the FIMP report that most likely to be impacted through intensive power boat recreation:

- High Value Kokanee areas occur near the river mouths adjacent to known spawning areas for these fish. Spawning sites are considered critical habitat and occur around the boat launch area in the north end of the lake. Once spawned, eggs reside in the gravels until emergence many months later. Any vibration or significant sediment disruption can directly impact eggs in gravels, causing mortality of eggs or juveniles.
- Mussels were identified in numerous areas of the lake. Mussels can be harmed by sediment disruption and crushing impacts from props running in shallow water. While no specific analysis was done, it is possible mussels could be locally extirpated in some high traffic areas as observed on the air photos. A detailed inventory of mussels and the most important beds has not occurred. However, these areas are considered critical habitat and power boating in these areas should be avoided.
- Aquatic vegetation is abundant in the south end of the lake. Numerous waterfowl use this vegetation for nesting. Species that use this type of vegetation to make floating nests are very susceptible to boat wakes that can topple and submerge nests. During the breeding and nesting season, power boats with large wakes should not recreate in areas with vegetation or within a large buffer determined by wake energy. The breeding and nesting season overlap with most of the boating season.

2.10. Available tools in BC Legislations

BC legislation has provision for designating Ecological Reserves such as the Mahoney Lake Ecological Reserve (Prov BC 2006). The main purpose of a Lake Windermere Ecological Reserve would be to protect the unique history and fragile limnological features of the lake from recreational impacts. The potential for unnatural disturbance of lake sediments and water chemistry is a management concern. Lake Windermere values and significance include:

1. Ktunaxa traditional uses including fishing salmonids and native mussel collection
2. Unique and fragile limnology and aquatic ecology
3. Species at Risk around Lake Windermere include the American Badger (*Taxidea taxus*), Painted Turtle (*Chrysemys picta*), Lewis's Woodpecker (*Melanerpes lewis*), Stiff Pondweed (*Potamogeton strictifolius*), Saltwater Cress (*Eutrema salsugineum*), and Bull Trout (*Salvelinus confluentus*).
4. Education opportunities for matching power craft with lake suitability using an index developed in this project.

Other alternatives include using provisions of the Water Sustainability Act to guide development of a Water Sustainability Plan. A plan can consider a broad range of important watershed factors in addition to conserving lake values.

Figure 15: Sediment scouring along boat travel routes from marinas, Lake Windermere 2024
(Photo from LWA)

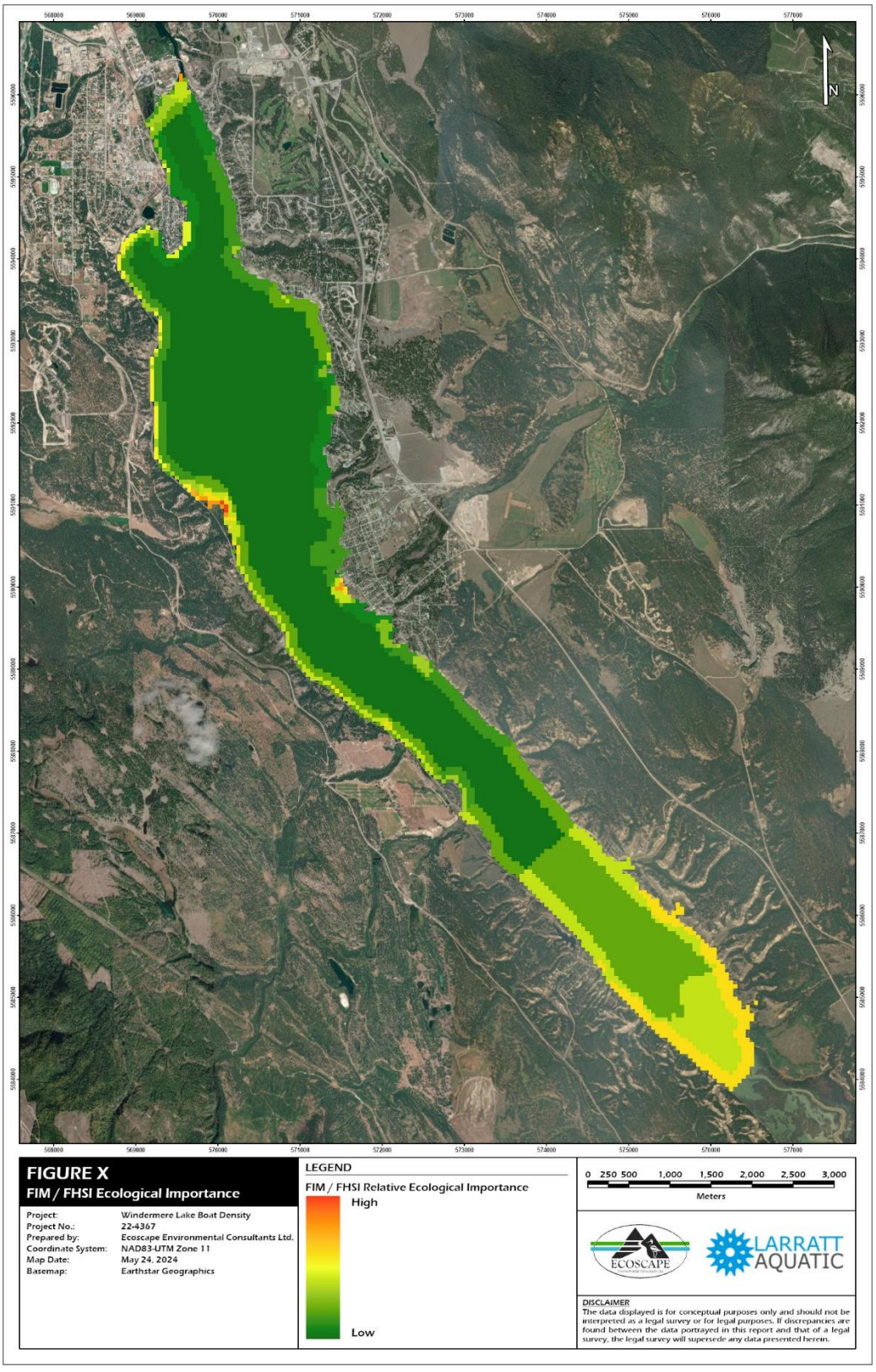


Figure 16: Foreshore Inventory Mapping (FIM)/FHSI Ecological importance Zones for Lake Windermere BC

3.0 LAKE SUITABILITY INDEX

LAC developed the Lake Suitability Index for power boating alongside this project in collaboration with Lake Windermere Ambassadors and Ecoscape Environmental Consultants Ltd. It is intended to identify lakes that can withstand power boating, particularly wake-surf boating, and those that will be adversely impacted. The intent of the Lake Suitability Index is to direct boaters to lakes that can support responsible wake-surfing in sustainable numbers. We used all available peer-reviewed lake wake research to 2024 (see metrics and references tab in Excel spreadsheet). The risk rating uses recent and well supported limnological research.

The Lake Suitability Index returned a rating of 53/60 for Lake Windermere which corresponds to Extreme Risk (50 – 60) - unsuitable for large power boats and wake-surf boats (Tables below).

3.1. Changes To Transport Canada - Canada Shipping Act (2001) Wake-surfing restriction

Recognition of the unique potential for lake damage from wake-surfing prompted the Federal Department of Transport to make wake-surfing a separate category by amending the Canada Shipping Act 2001 in July 2023 Part 1 Vol. 157 No 24: Regulations Amending the Vessel Operation Restriction Regulations. Transport Canada created this separate category for wake-surf boats in recognition of the large number of Canadian jurisdictions experiencing harm to lakes as explained in the following except:

> The proposed amendments would remove wake-surfing from the existing Schedule 7 (restrictions on all towing activities) and introduce a new Schedule that specifically provides for restrictions on wake-surfing. This would allow a local authority to apply for a prohibition on wake-surfing without prohibiting all other towing activities, except during permitted periods. The restriction would not prohibit the use of wake-surfing boats but would restrict the activity of wake-surfing as described in each restriction. These proposed amendments would necessitate amendments to the *Contraventions Regulations* to establish a fine for the contravention of the new restriction as is currently the practice for all other restrictions under the Regulations. The amendments to the *Contraventions Regulations* would be introduced as part of a separate regulatory proposal following the publication of these proposed amendments in the *Canada Gazette*, Part II. Until amendments are made to the *Contraventions Regulations*, specific wake-surfing prohibitions would not be enforceable via tickets.
>
> **Waters in Which Allowing a Person to Wake-surf Is Prohibited Except During the Permitted Hours**
>
> The waters of the Columbia River and its tributaries lying within the flood plain of the Columbia River north of a point at 50°21’13.4” 115°52’51.9” (approximately 1.6 km northwest of Fairmont Hot Springs) and south and east of a point at 51º28’48” 117º09’33”, on the northernmost tip of a small island (approximately 1.8 km south of Trans-Canada Highway bridge at Donald) but excluding the waters of Windermere Lake (Columbia River main channel 50°55’04.3” 116°22’47.9”) (https://canadagazette.gc.ca/rp-pr/p1/2023/2023-06-17/html/reg4-eng.html).

LAC Ranking of Lake Suitability to Power Boating

	Boating Impact	very highly vulnerable lakes (5)	high vulnerability lakes (4)	moderate vulnerability lakes (3)	low vulnerability lakes (2)	lakes at very low risk (1)	Risk	Data sources
LIMNOLOGY	mean depth	<10m	10-25 m	>25m	>60 m	> 80m	1-5	bathymetry
	trophic condition	eutrophic/ hyper eutrophic	eutrophic-mesotrophic	mesotrophic	oligotrophic	ultra oligotrophic	1-5	lake studies
	percent of littoral shallows (<8 m deep)	>15%	10-15%	5-10%	2-5%	<2%	1-5	bathymetry
	littoral fine sediments (clay silt sand)	common throughout lake	common in bays and fans	only in isolated shallow areas	rare	do not occur	1-5	lake surveys
	shoreline erosion /riparian condition	>20% of shorelines eroding	20-10% of shoreline eroding	>10% -small eroding patches	erosion isolated and rare	no measurable erosion	1-5	FIM
SAFETY	swimmer/paddlecraft safety	often unsafe in majority of lake	often unsafe in high traffic areas	Peak use unsafe in high traffic areas	generally safe	safe throughout lake	1-5	resident surveys
	power boat safety (summer, key areas)	boat density >1/ha	boat density >0.75/ha	boat density >0.375/ha	boat density >0.125/ha	boat density <1 boat/10 ha	1-5	lake studies
HABITAT	vulnerable riparian-littoral habitats	>10% of littoral/shoreline	7-10% of littoral/shoreline	5-7% of littoral/shoreline	2-5% of littoral/shoreline	<2% of littoral/shoreline	1-5	FIM + AHI
	aquatic/riparian species at risk	reproduction threatened	seasonal use threatened	occasional use threatened	SARA sp. seldom encountered	SARA sp. not evident	1-5	FIM SARA
	vulnerability to invasive mussels	suitable & connected to infestation	all suitability parameters met	most suitability parameters met (Ca>32 mg/l	Ca suitability met (Ca > 15 mg/L)	Ca <12 mg/L or salinity >10	1-5	OBWB
WATER QUALITY	degraded water quality potential	exceedances throughout lake	localized exceedances/impacts	episodic local exceedances	impacts detected, no exceedances	impacts not detected	1-5	SWP plan
	harmful algae bloom potential	significant and frequent	significant and occasional	moderate and occasional	low potential and rare	not detected at any time	1-5	lake studies
						SUM	0	/60

Description of risk rating scale for power boating impacts

Risk Level	Numeric rating	Description
Very Low Risk	1	Power boating should not have a detectable effect on lake values.
Low Risk	2	Power boating could impact lake values but both the likelihood and scale of impact are expected to be low.
Moderate Risk	3	Power boating could impair lake values with either a high likelihood of occurring or high impact potential.
High Risk	4	Power boating is highly likely to have rapid and significant negative consequences on lake values.
Very High Risk	5	Power boating has the potential to cause rapid and catastrophic impacts to lake values.

LAC Ranking of Lake Suitability for Power Boating		Duck	Wood	Kalamalka	Okanagan	Skaha	Osoyoos	Windermere	Nicola	Head of Lake	
LIMNOLOGY	mean depth	5	4	2	2	3	4	5	3	3	
	trophic condition	5	4	2	2	3	4	3	4	4	
	percent of littoral shallows (<8 m deep)	4	4	2	2	3	5	5	5	4	
	littoral fine sediments (clay silt sand)	5	4	4	4	4	5	5	5	4	
	shoreline erosion /riparian condition	4	3	2	3	3	3	3	3	3	
SAFETY	swimmer/paddlecraft safety	3	4	4	3	4	4	5	3	2	
	power boat safety (summer, key areas)	3	4	4	4	4	4	5	3	3	
HABITAT	vulnerable riparian-littoral habitats	4	4	3	3	4	4	4	5	3	
	aquatic/riparian species at risk	4	4	4	4	4	4	5	4	3	
	vulnerability to invasive mussels	5	5	5	4	4	4	5	4	4	
WATER QUALITY	degraded water quality potential	4	4	3	3	3	3	4	4	4	
	harmful algae bloom potential	5	5	4	3	4	4	4	5	5	
		51 Extreme	49 High	39 Moderate	37 Moderate	43 High	48 High	53 Extreme	48 High	42 High	TOTALS/60

LAC Ranking of Lake Suitability for Power Boating

Lake score

Lake score /60	Suitability to power boating	Suggested Actions (cumulative)
Negligible Risk (0-15)	suitable	preserve ecological values/services
Very Low Risk (16-23)	suitable	assess ecological resilience
Low Risk (24-32)	suitable - education advised	active >150m from shore >8 m water depth
Moderate Risk (33-39)	suitable - restrictions advised	code of boating behavior in place
High Risk (40-49)	unsuitable - permit system advised	pre-registration for daily permit to operate
Extreme (50-60)	unsuitable - prohibitions advised	power craft should be excluded

4.0 CONCLUSIONS

The boat tally component of this study demonstrated that powerboating and particularly wake-surfing exceeds the safe boating capacity of Lake Windermere on summer weekends. About a third of the lake surface exceeded the local safe boating capacity of Lake Windermere on summer weekends and especially on long weekends. Navigation of popular boating areas were made dangerous to power craft and especially to paddle craft.

The community questionnaire component showed community concerns revolved around water quality, quantity, and preservation of the ecological health of Lake Windermere. Many expressed concerns about the size and type of boats operating in such a small, shallow lake. Restrictions on boat numbers and more boat-free spaces were advanced by respondents as possible solutions.

This study confirmed that intensive boating simultaneously threatens Lake Windermere values including:

- sediment resuspension releasing nutrients and contaminants,
- increased ongoing threat of invasive mussel introduction,
- accelerated algae growth and algae blooms
- wake shoreline erosion
- impact on fish, birds, and aquatic life

As the watershed and lake pressures mount on Lake Windermere these symptoms of overall lake health are likely to worsen. That change is needed to address the escalating power boat pressure on Lake Windermere is evident from all components of this study. Lake Windermere is unlikely to withstand increasing power boat and especially wake-surf pressure without harm to its ecology, water quality and aesthetic value.

If Lake Windermere were a deep lake, the theoretical boat carrying capacity would be 200 vessels (surface area of 4000 acres or 1610 ha at 20 acres per vessel). However, Lake Windermere is extremely shallow, reducing its suitability to motorized recreation. Figure 17 provides the bathymetry used in the following calculations.

- Using water deeper than 4 m for powerboats, the approximate area available is 705 ha or 43% of the lake area or 97 power boats if they were evenly distributed.
- If paddle craft/swimming is confined to <4 m water depth and the shoreline to 150 m from shore, the approximate area available is 926 ha or 57% of the lake area (see Appendix B for map of proposed play areas).
- Using water at or deeper than 6.5 m for wake-surfing *and 150 m (500 feet)* from shore the approximate area available is 75 ha or 4.6% of the lake area or 9 wake-surf boats.
- Using water deeper than 8 m for active wake-surfing (recommended minimum depth to prevent fine sediment disturbance), none of Lake Windermere's surface area is suitable for this sport, because the lake is not that deep.

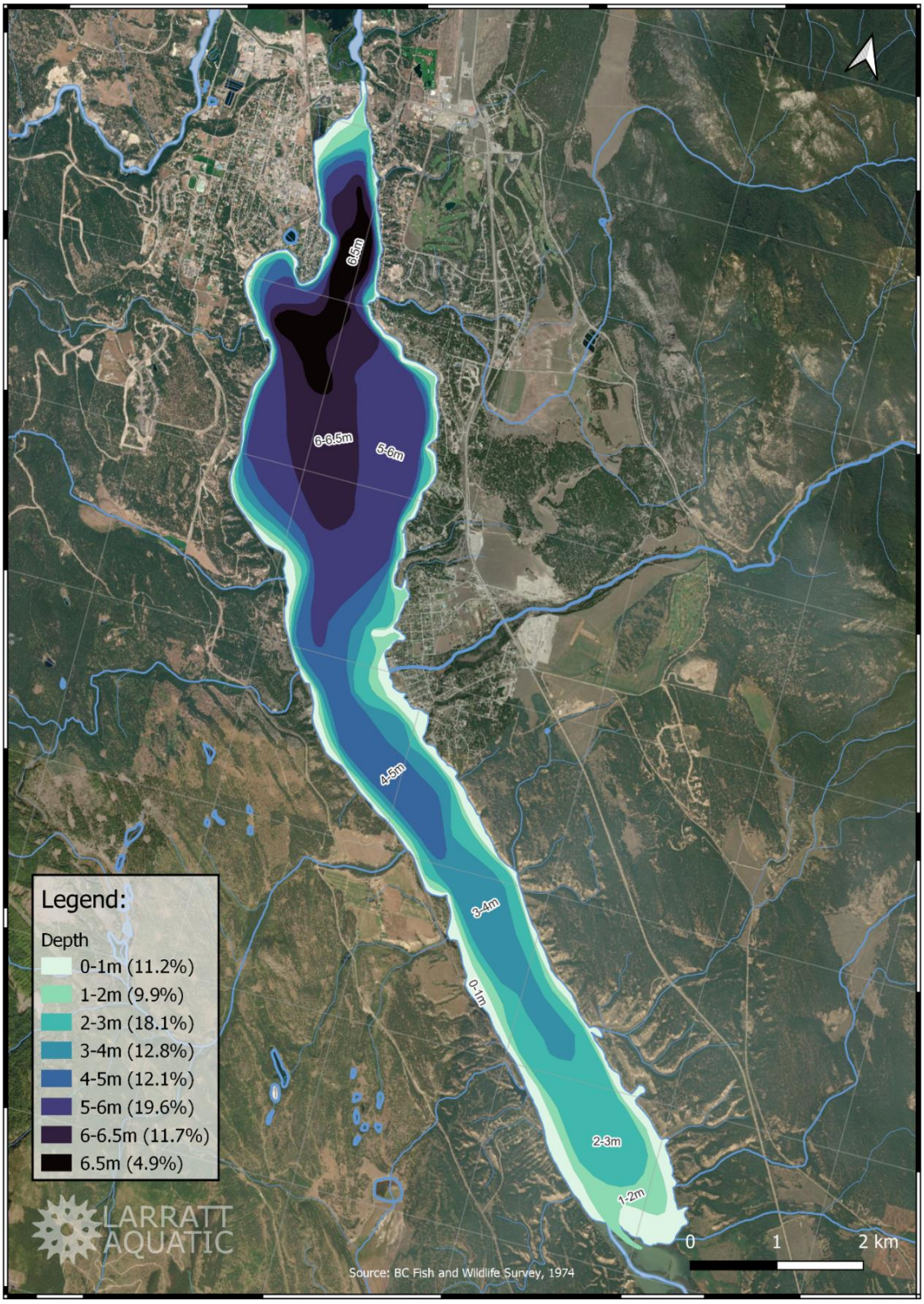


Figure 17: Bathymetric map of Lake Windermere

These water depths (or deeper) by boat type align with the latest research (Francis et al. 2023; Self and Larratt 2020) and with legislation elsewhere (Vermont 2024[10]). An example of Play Zone mapping is presented in Figure B-8 using the 4 m criteria presented above. Keeping the paddle craft Play Zone in waters shallower than 4 m ensures minimal wake disruption of nesting birds and littoral habitats. If paddle craft move into deeper waters, they should recognize that they are in the powerboat Play Zone and return to the shallows. Keeping the powerboats in waters deeper than 4 m and further from shore helps protect littoral values and prevent shoreline damage. When powerboats need to transit though shallow waters to reach their Play Zone, they should be travelling dead slow-no wake to ensure environmental protection and recreator safety. More stringent criteria could be adopted to further protect Lake Windermere as presented in Next Steps (Powerboat Play Zone > 4.5 m *and* 150 m from shore). Creating Play Zone maps is easy after the criteria are finalized. An App. could be built to show folks where their Play Zone is.

We conclude that Lake Windermere is not suited to wake-surfing and power boating requires a boating capacity number assigned with a mechanism to limit the number of power boats operating on Lake Windermere through the summer.

[10] Vermont's New Wakeboat Rule
https://www.bing.com/search?q=dec.vermon&cvid=e78d3b220dbf4c86ba55ad550c729e94&gs_lcrp=EgZjaHJvbWUyBggAEEUYOTIGCAEQRRg8qAIAsAIA&FORM=ANAB01&PC=ACTS

5.0 NEXT STEPS

We applaud the monitoring efforts of Lake Windermere Ambassadors. Long-term lake data sets are invaluable.

- Continue to collect nutrient, including calculating N:P ratios.
- Continue to monitor cyanobacteria blooms because they can accelerate using nutrients released during sediment disturbance.

The following recommendations were developed from the findings of this project and endorsed by the LWA survey results. These folks know their lake:

Planning	**Create a Lake Windermere Stewardship Plan that can house the lake management and restoration initiatives presented below from least to most enforcement-heavy and a Lake Windermere Restoration Steering Group to include governance, First Nations, stakeholders and LWA**
Re-educate	Mount an education campaign to help local and guest boaters enjoy Lake Windermere safely and responsibly. This could involve voluntary codes of conduct to protect the lake, drinking water quality, ecology and cultural use
	Install slow, no-wake zones and marker buoys to protect sensitive habitats and water quality.
Reserve	Apply to Province for an Aquatic Ecological Reserve to protect cultural native mussel beds, spawning areas and wetlands and/or pursue a Water Sustainability Plan under the Water Sustainability Act
	Keep shallow areas (<4m depth) for self-propelled/paddle craft activities and swimming. Non-motorized lake users can be disregarded by some power boats, they need safe, wake-free space. Paddle craft should not stray into the deeper water powerboat play zone.
	Use the project maps to delimit the powerboat play zone >4.5 m water depth and 150 m from shore
Regulations	Ensure that boating regulations protect cultural use and the work of Indigenous stewards on the reintroduction of salmon.
	Implement bylaws and regulations to mitigate impacts of boating activities and boating infrastructure (buoys, moorage, marinas and docks) on Lake Windermere values. Remove illegal moorage and dock material.
Restrictions	Consider a ban on motorized watercraft on the lake for all or part of the year, such as critical salmon spawning and shorebird nesting periods and summer periods since most residents prefer non-motorized boating.
	Consider joining the Okanagan Basin Water Board's call for a ban on out- of- province boats to limit the risk of introducing aquatic invasive mussels
	Institute noise and horsepower/boat type limits.
	Lobby for power boat restrictions to limit the number of power craft at any given time – in alignment with the Lake Windermere safe boating capacity. Many residents experienced safety concerns during recent summers. A launch fee could be considered to cover management costs.
	Consider requesting Transport Canada ban on wake-surfing on the Columbia River to extend to both Windermere and Columbia lakes since they are essentially widenings in that river system. – Seek to collaborate such a ban with First Nations
	Ensure that SARA-listed species and habitats are protected
Enforcement	Enforce existing laws; DUI is unlawful, noise bylaws, holding boat operators responsible for wake damage, and all boat drivers should be licensed. Boaters are *legally responsible for navigating in such a way that their wake doesn't harm anyone or cause any damage*. Boat operators need to be aware of situations and conditions that can endanger them and others and know which steps to take to mitigate the risk. Boaters are required *by law* to take a safety course and pass an online boating exam.

6.0 LIMITATIONS

This report has been prepared by Ecoscape and LAC. This report is intended for the sole and exclusive use of Lake Windermere Ambassadors, for the purposes set out in this report. The Consulting team relied upon personal communications with Lake Windermere Ambassadors and other information sources to corroborate the documents and other records available for the subject property. Lake Windermere Ambassadors acknowledges that Ecoscape is relying upon full disclosure and accuracy of this information to enable Ecoscape to properly provide a professional service. Any use of this report by a third party, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Ecoscape, LAC and LWA accepts no responsibility for damages, if any, suffered by any third party because of actions or decisions made based on this report.

7.0 CLOSURE

We trust that this report satisfies the present requirements. Should you have any questions or comments, please contact the undersigned at your convenience.

Respectfully Submitted

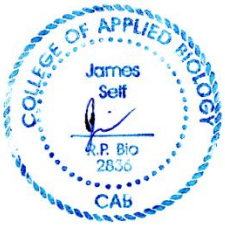
Written By:

Jason Schleppe, M.Sc., R.P.Bio
Senior Natural Resource Biologist
Direct Line: (778) 940-3479

Written By:

Heather Larratt, 1st H. B.Sc., R.P.Bio
LAC Lead Aquatic Biologist
Direct Line: (250) 769-5444

Written By:



Jamie Self H. B.Sc. R.P. Bio
LAC Senior Aquatic Biologist

Statistical Analysis By:

Luke C

Luke Crevier, M.Sc.
Ecoscape Senior Data Analyst

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APPENDICES

Appendix A: General Terms and Conditions

General Conditions

This report applies and is subject to these "General Conditions".

Use of Report

This report concerns a specific site and a specific scope of work and is therefore not applicable to any other sites or any other developments not referred to in the report. Any deviation from the specific site or scope of work would require a supplementary investigation and assessment.

Conclusions and recommendations contained in this report are solely intended for the use of Ecoscape's client. Ecoscape bears no responsibility for the accuracy of information, the analysis of data or recommendations contained or referenced in this report when the report is utilized by or relied upon by any party other than Ecoscape's client unless otherwise authorized in writing by Ecoscape. Any unauthorized application of this report is at the discretion and sole risk of its user.

This report is subject to copyright, and therefore shall not be reproduced in part or in whole without prior written consent by Ecoscape. Additional copies of this report may be available upon request, if required, and will be supplied after receipt of payment for expenses associated with report production.

Limitations of Report

This report was derived solely from the conditions that were present on site during Ecoscape's investigation. The client, and any other parties making use of this report with the express written consent of Ecoscape and the client, are aware that conditions affecting the environmental condition of the site can vary both temporally and spatially, and that the conclusions and recommendations included in this report are temporally sensitive.

The client, and any other parties making use of this report with the express written consent of Ecoscape and the client, are also aware that conclusions and recommendations included within this report emanate from limited observations and information, and that both on-site and off-site conditions may vary, which in turn could affect the conclusions and recommendations that were made.

The client is aware that Ecoscape is not qualified to, nor is it making any recommendations in terms of purchase, sale, investment, or development of the subject property, as such decisions are the sole responsibility of the client.

Information Provided to Ecoscape by Others

During the extent of the preparation and work carried out in this report, Ecoscape may have relied upon information provided by parties other than the client. While Ecoscape strives to validate the accuracy of such information when instructed to do so by the client, Ecoscape accepts no responsibility for the validity of such information which may affect the report.

Limitation of Liability

The client acknowledges that property containing hazardous wastes and contaminants poses a high risk of claims brought by third parties stemming from the presence of those materials. Accounting for these risks, and in consideration of Ecoscape providing the requested services, the client agrees that Ecoscape's liability to the client, with respect to any issues relating to hazardous wastes or contaminants located on the subject property, shall be limited to the following:

With respect to any claims brought against Ecoscape by the client arising out of the provision or failure to provide services hereunder shall be limited to the amount of fees paid by the client to Ecoscape under this Agreement, whether the action is based on breach of contract or tort;

With respect to claims brought by third parties arising out of the presence of contaminants or hazardous wastes on the subject property, the client agrees to indemnify, defend and hold harmless Ecoscape from and against any and all claim or claims, action or actions, demands, damages, penalties, fines, losses, costs and expenses of every nature and kind whatsoever, including solicitor-client costs, arising or alleged to arise either in whole or part out of services provided by Ecoscape, whether the claim be brought against Ecoscape for breach of contract or tort.

Disclosure of Information by Client

The client agrees to fully cooperate with Ecoscape with respect to the provision of all available information on the past, current, or proposed conditions on the site, including historical information respecting the use of the site. The client acknowledges that in order for Ecoscape to properly provide the service, Ecoscape is relying on full disclosure and accuracy of any such information. Ecoscape does not accept any responsibility for conclusions drawn from erroneous, invalid, or inaccurate data provided to us by another party and used in the preparation of this report.

Standard of Care

Services performed by Ecoscape for this report have been completed in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Professional judgement has been applied in developing the conclusions and/or recommendations made in this report.

No warranty or guarantee, express or implied, is made concerning the results, comments, recommendations, or any other portion of this report.

Notification of Authorities

The client acknowledges that in certain instances the discovery of hazardous materials, contaminants or conditions and materials may require that regulatory agencies and other parties be informed and the client agrees that notification to such parties or persons as required may be done by Ecoscape in its reasonably exercised discretion. Further, Ecoscape reserves the right to notify Provincial agencies when rare or endangered flora or fauna are observed, whether the species classifications are identified as such at the local, Provincial, or Federal levels of government.

Ownership of Instruments of Professional Service

The client acknowledges that all reports, plans, and data generated by Ecoscape during the performance of the work and other documents prepared by Ecoscape are considered its professional work product and shall remain the copyright property of Ecoscape.

Alternate Report Format

Where Ecoscape submits both an electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed Ecoscape's instruments of professional service), the client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by Ecoscape shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the client agrees and waives all future right to dispute that the original hard copy signed version archived by Ecoscape shall be deemed to be the overall original for the Project.

The client agrees that both electronic file and hard copy versions of Ecoscape's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party other than Ecoscape. The client warrants that Ecoscape's instruments of professional service will be used only and exactly as submitted by Ecoscape.

The client recognizes and agrees that electronic files submitted by Ecoscape have been prepared and submitted using specific software and hardware systems. Ecoscape makes no representation about the compatibility of these files with the client's current or future software and hardware systems.

Appendix B: Supporting Maps and Figures

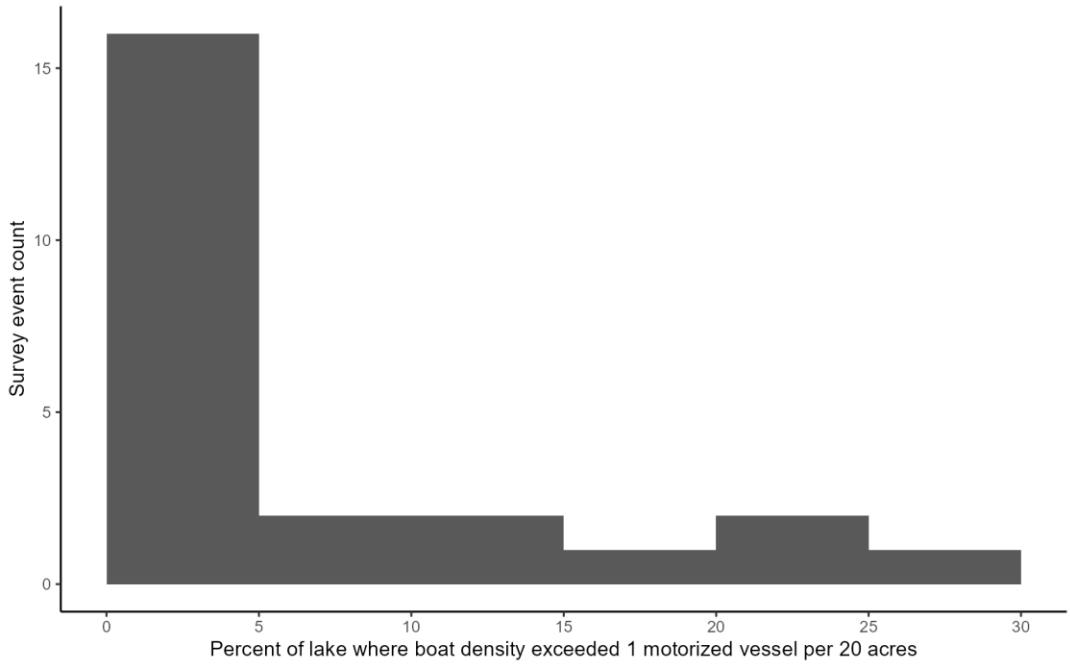


Figure B-1: Histogram showing percent of lake area where motorized vessel density locally exceeded safe boating density during individual survey events.

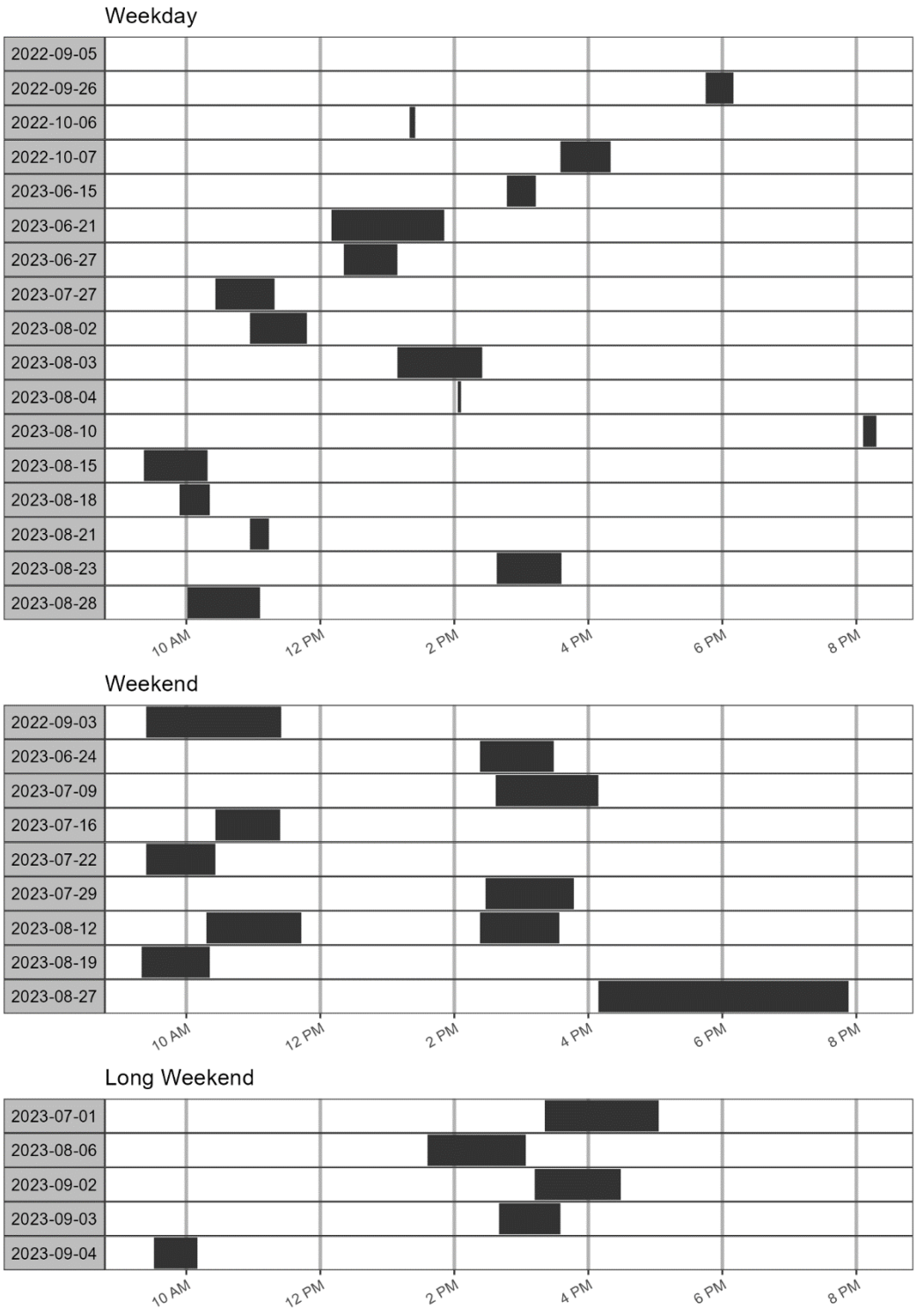


Figure B-2 Boat survey timespans by day and day type.

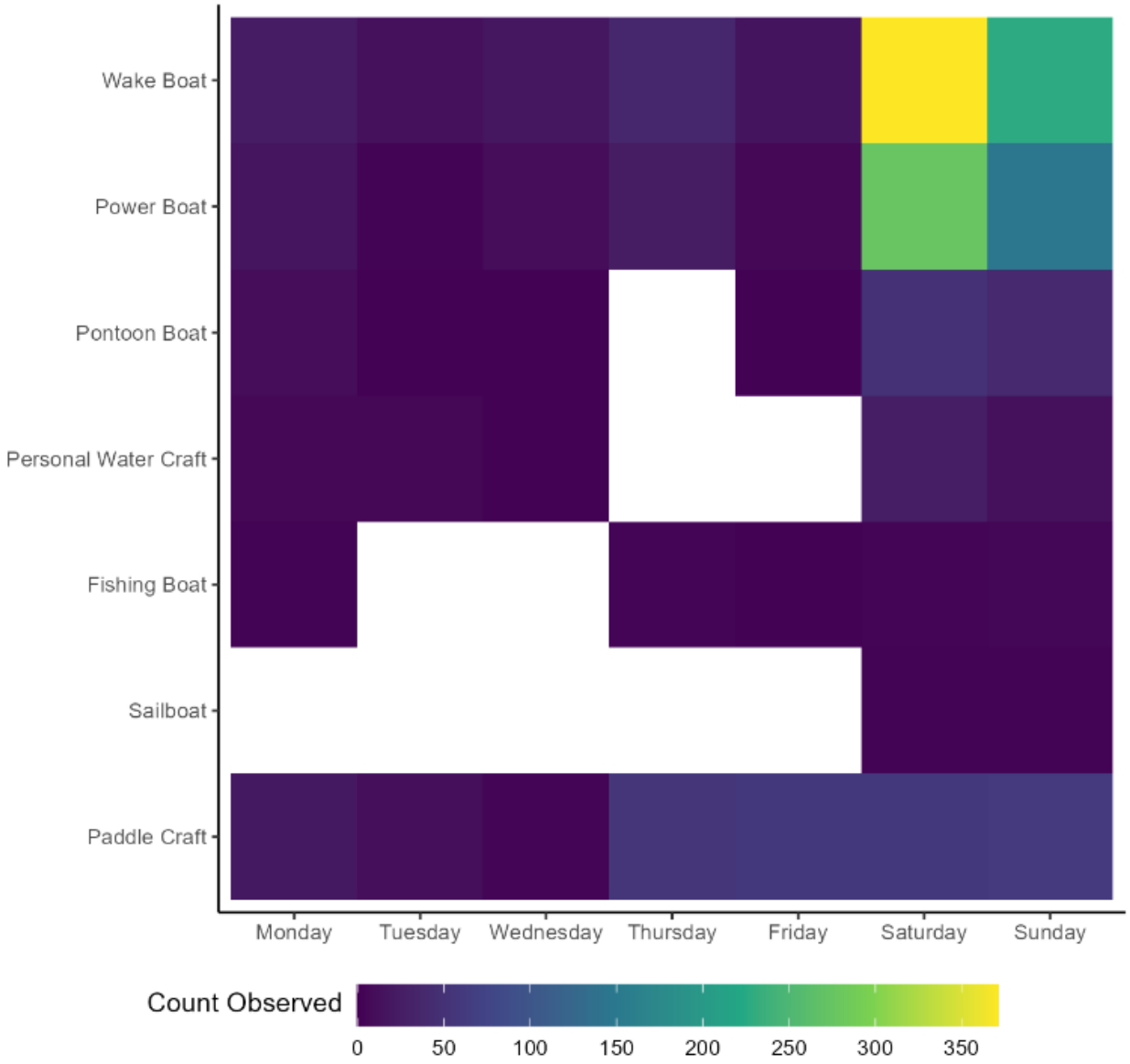


Figure B-3: Heatmap showing total counts of vessels observed by Windermere Lake Ambassadors in summer 2022 and summer 2023, broken up by vessel type and day-of-week.

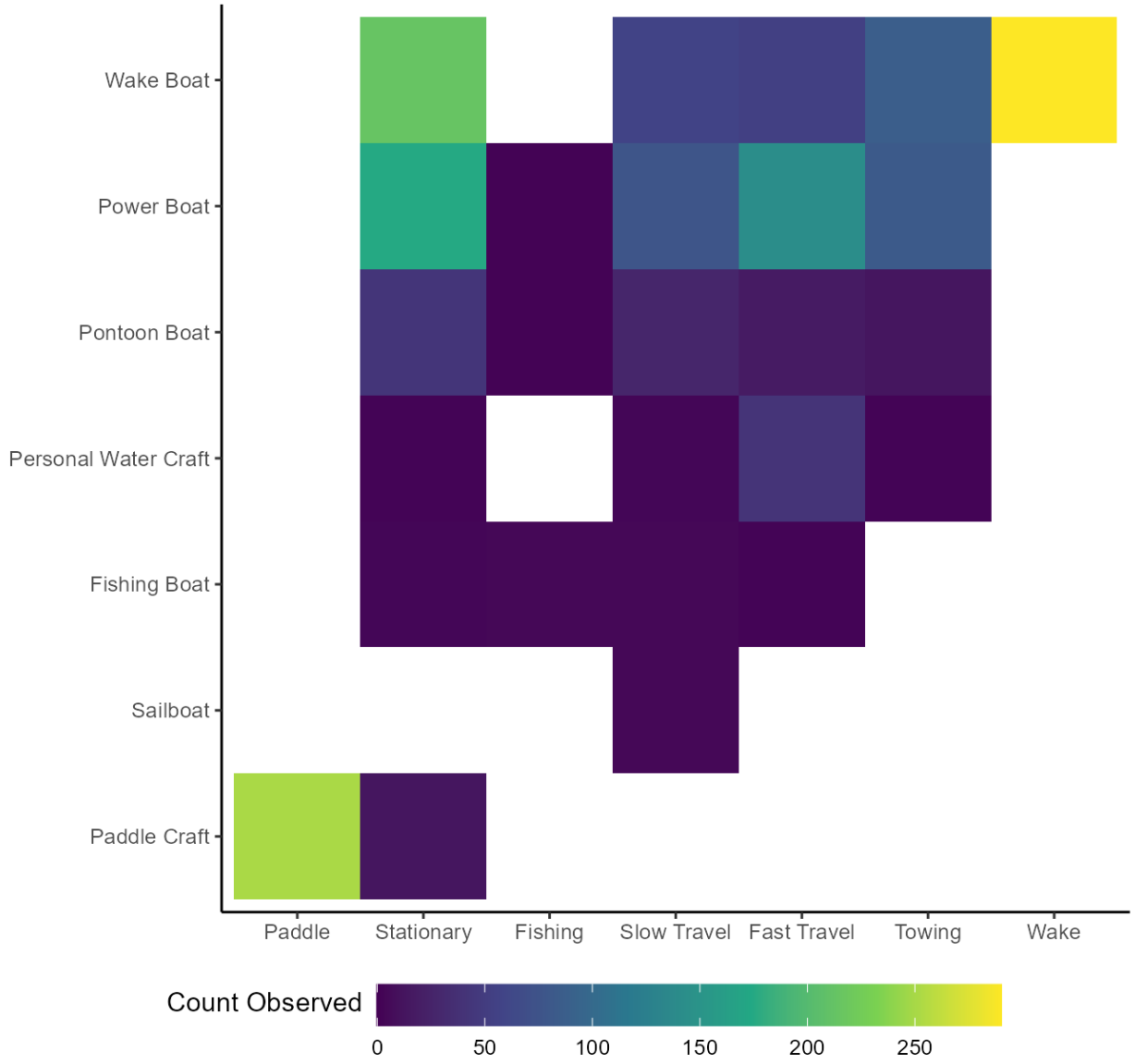


Figure B-4: Heatmap showing total counts of vessels observed by Windermere Lake Ambassadors in summer 2022 and summer 2023 broken up by vessel type and activity type.

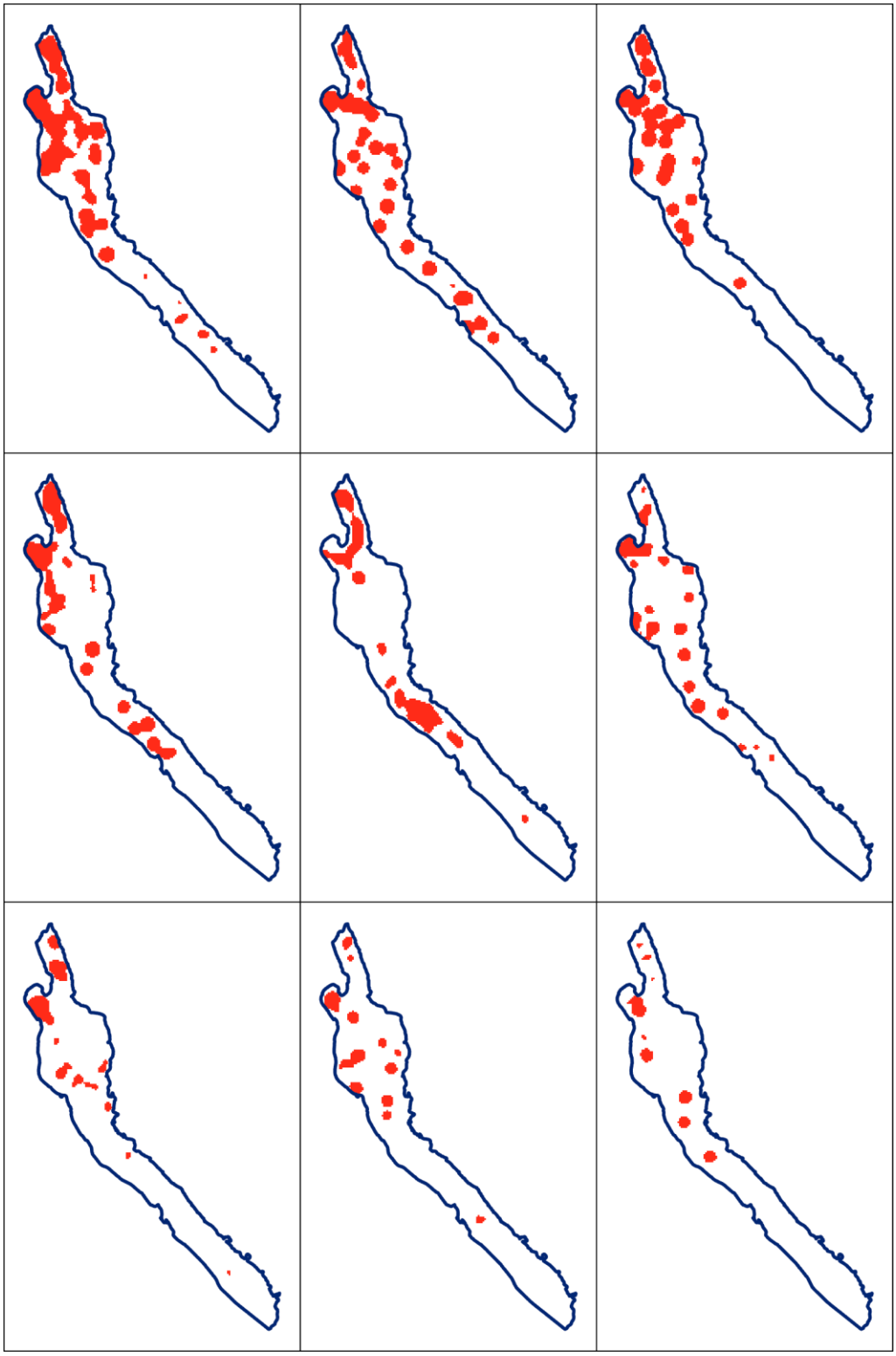


Figure B-5: Maps of local safe boat density exceedance for motorized vessels for the nine highest-density individual survey events. Red indicates a density greater than 1 motorized vessel per 20 acres.

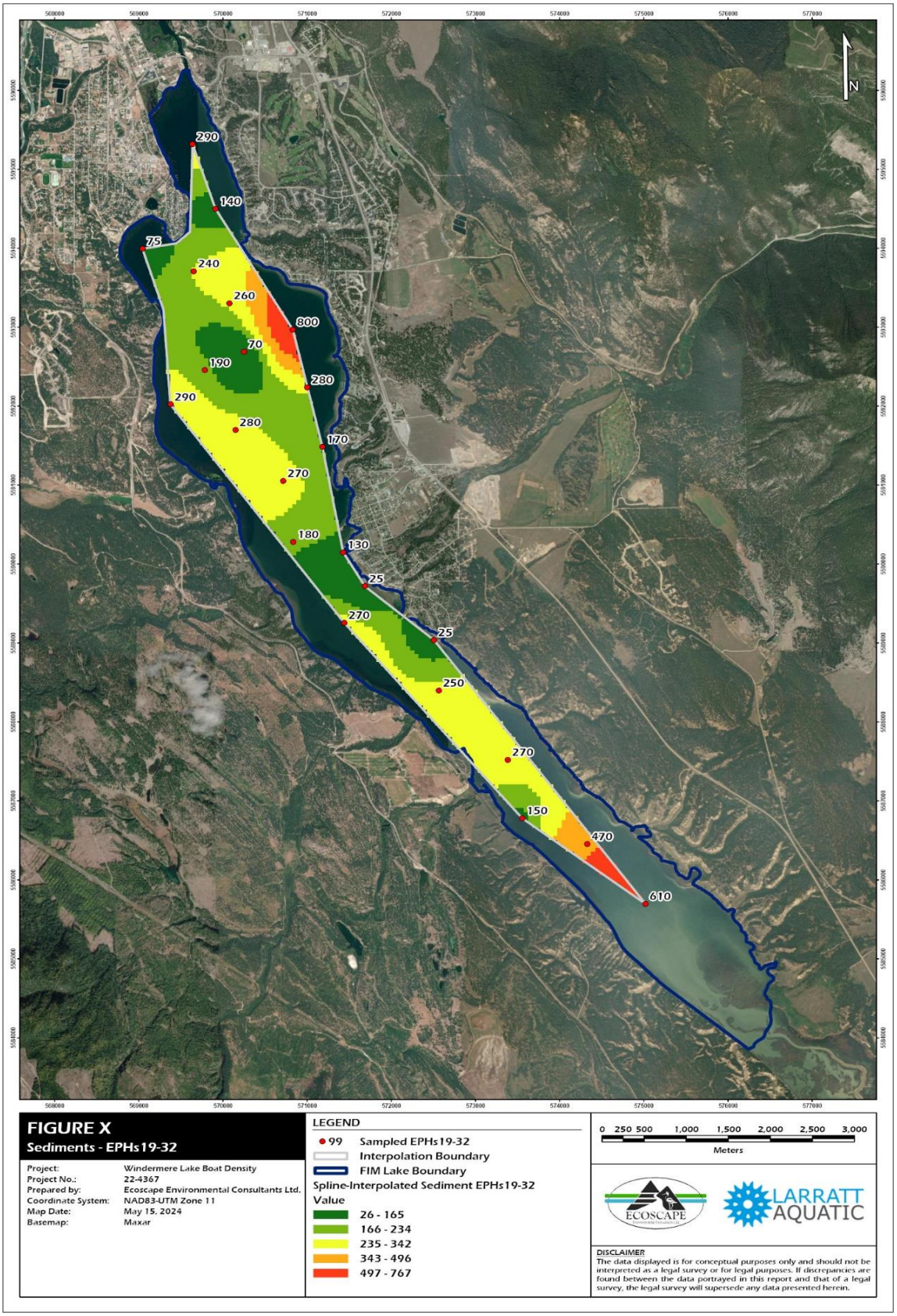


Figure B-6: Sediment hydrocarbons EPH19-32 detected in 2022 sediment samples

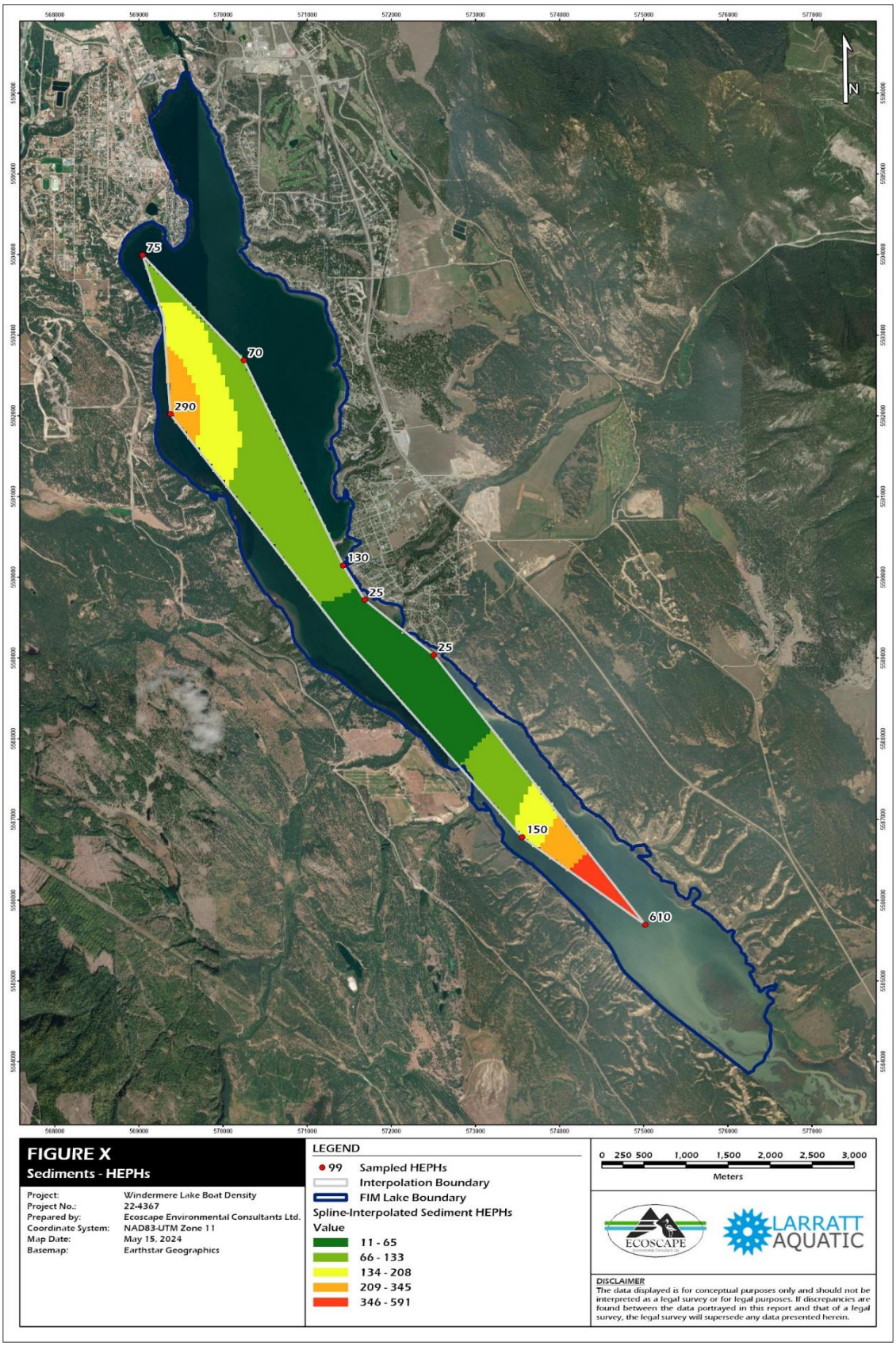


Figure B-7: Sediment hydrocarbons HEPH detected in 2022 sediment samples

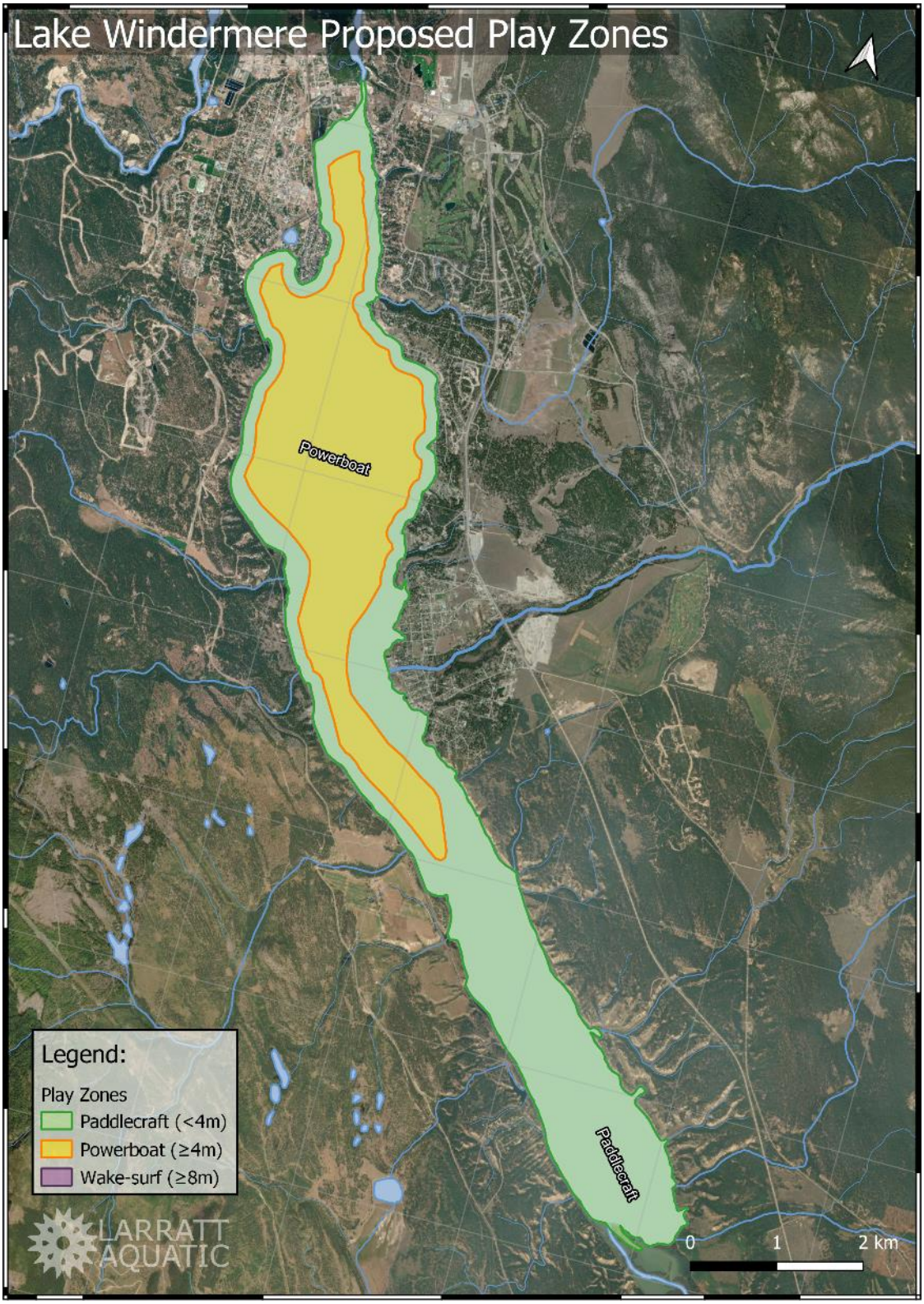


Figure B-8: Proposed boating Play Areas map for Windermere Lake

Appendix C: Study Methods

Boat Data Collection Summary

Boat data requires the data collected as a "snapshot" in time. Each data collection event identified the following information for the boat density modelling from a safe view point with binoculars:

- Date and time of the sampling event
- Location on the lake
- Boat types and modes of operation
- Activity occurring (sitting still, pulling a water skier, creating wake for a wake boarder, paddling, etc.)
- Mark boats on maps as accurately as possible. This data will be digitized to support the study as will the recorded details
- To record boat location, use a laptop or a printed copy of the GIS map sets, several coloured permanent markers, small stickers to label the Sample ID on maps. Ensure that the Sample ID for each boat is clearly labelled on the maps. *A new printed map should be used for each sample day.*
- Ideally, sampling events should occur throughout the day, with numerous sampling events during the morning, midday, afternoon, and evening. Sampling peak and low density use periods over the summer period is essential.
- Review and correct all data collected the day of collection.
- Back up each day of data to a computer system

Boat Field Data Details

The database setup used during 2022 included the following data fields:

- Sample ID: Sample ID is the unique identifier for each boat counted. This field is extremely important because it is used to relate the boat counted in the survey to the real world spatially. For each sample day, use labels 1-1, 1-2 for sample day 1, and 2-1,2-2, for sample day three. *Stickers may be useful to stick to the map grid, with pre labelled Sample IDs for efficiency.*
- Date – Sample date
- Time – 24 hour clock time the boat was counted. Try to sample the entire lake in a short period (1 to 2 hours) to reduce the potential for counting a vessel more than once.
- Sample Crew – The initial of each field assessor should be logged
- Boat Type – A boat type is used to describe the vessel type
    - Power Boat - This is a vessel that does not produce a large wake but is capable of high speeds. These vessels often have larger outboard motors on them. *All larger vessels capable of high speeds will default to a Power Boat if the boat type is not known*.
    - Wake Boat – A wake boat or a wake-surf boat is a vessel that contains a ballast used to produce a large wake. There are many brands of this vessel type. *A wake boat should only be counted if the assessor is confident of the boat type*.

  - Fishing Boat – A fishing boat is a smaller vessel, typically under 18 feet. They may have motors that range from 10 to 15 horsepower and generally do not produce a large wake. These boats are usually steered using the motor and a tiller.
  - Paddle Craft – A paddle craft is any boat that is powered manually. These can be canoes or kayaks.
  - Other – Other craft that may be counted could be stand up paddle boards (SUP), belly boat / float tubes, or unique floating vessels (e.g., a foot peddle powered toy). *It is not necessary to count these. These data may or may not be used but have been added to address things that don't fit any of the categories above, but may be considered "a boat".*
- Boat Activity – A boat activity is what the boat is doing at the time of sampling
  - Wake / Surf – A boat that is actively towing or facilitating wake boarding or wake-surfing (or any wake-based activity behind a Wake Boat)
  - Fishing - A vessel that is actively fishing, with rods deployed. *A stationary vessel that is casting is considered fishing.*
  - Slow Travel – A vessel that is under power, fully off-plane and settled in the water. These boats would not be generating much, if any wake. These speeds would be similar to what you would view in a marina for example.
  - Towing (Tube/Skier) – Boats that are towing a tube(s), or skier(s) or other similar activities.
  - Paddle – A boat that is being actively paddled around the lake
  - Stationary Single – A boat that is not under power, is stationary, and is not moored or tethered to another vessel.
  - Stationary Multiple – A group of vessels that are stationary, not under power, and tethered together. If desired, the number of tethered boats could also be counted.

- Under Power – This will document whether the boat is moving or stationary (Yes /No)
- Lake Area – If sampling from a vessel, it may not be possible to sample the entire lake from one location. The maps have broken the lake down into three manageable sectors, where the sampler can view the entire sector. The total sample area (North, South, Middle, South Middle, etc.) should be documented. If the area sampled is different than what is shown on the maps, a sharpie should be used to identify the area sampled. *It is ok to move around a bit to fully sample. For instance, you may stop, count one area, quickly move to another vantage to count another area, and this would be considered one sampling event. As noted above, one sampling event should be kept as short as possible to get a snapshot in time, and care should be taken to avoid duplicating or counting a vessel twice.*
- Observed Wake – Identify whether a wake was observed or not
- Within 30 m of Shore – If possible, identify whether the vessel is within 30 m from shore. 30 m from shore is a specific distance referenced in legislation. *If you cannot decide, do not indicate yes in this field.*

- Observed Sediment –If an observable sediment plume is noticed, it should be tracked on the data sheet. However, if it is hard to see, please indicate No.
- Comments – The comments field can be used to put in any comments about the sample point. For instance, if the number of tethered boats is counted, it could be added here.

Boat Data Entry Details

An Excel sheet was prepared in advance of boat surveys. Each sample day was entered onto a new tab and labelled with the date (suitable for QA/QC).

- The Database tab contained the data fields to be collected. The data fields were cut and pasted into each day on the first entry. From that point, the data fields self populated.
- Samplers were cautioned to not change the database into a different short form. These data must all be entered the exact same between days because the software used for analysis is case and character sensitive (i.e., one or two spaces with the space bar are different to the software).

Comparison of Digital to Paper Records

Throughout the 2022 work season, discussion with LWA staff and the project team identified opportunities to use a digital mapping versus the paper method established above. The following summarizes the differences between the two methods.

- Paper Method (presented above) – Using this method, data is entered into an Excel spreadsheet, and the unique SampleID is placed onto a printed paper map. This data is then digitized in GIS (digital mapping) for use in models. This method had the advantage of being quick to setup but was slow during field entry. Entering data as a snapshot is important because it will help avoid duplication of datapoints accidentally.
- Digital Method: An IPad (or equivalent) would replace paper-based data collection described above. This data would be entered in real time to the GIS database and would reduce the need to have both Excel and a paper map copy. Further, this method reduces the number of times data must be transcribed, reducing the potential for error. This method is also more time efficient for data entry and saves time for digitization of boat count data from the paper maps. However, this method requires at least 1, preferably 2 IPads, with appropriate software and licensing.

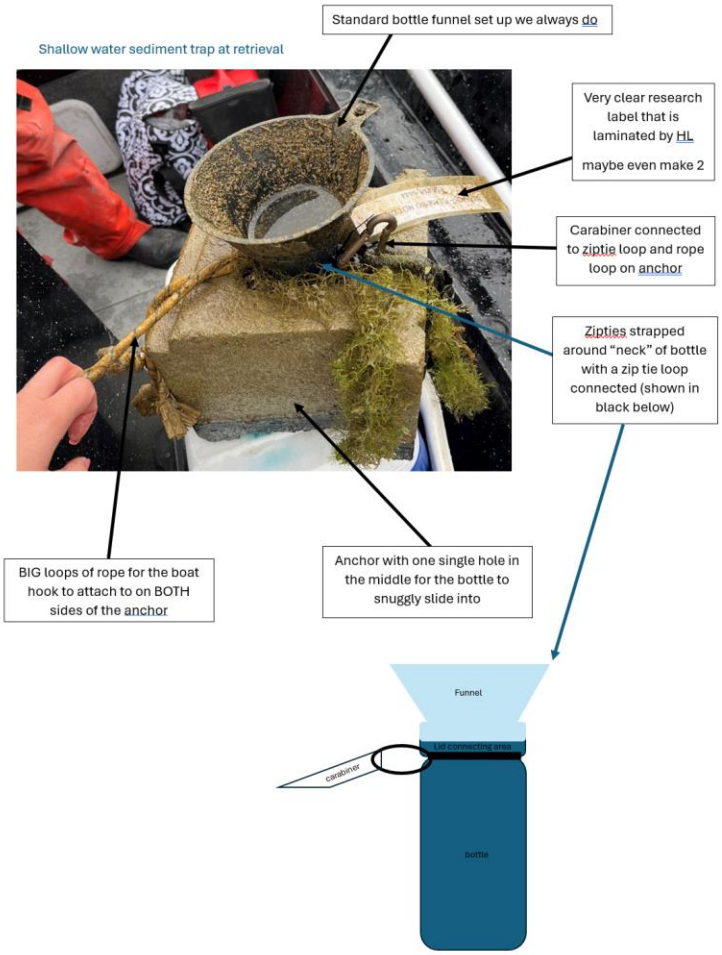
Ecoscape attempted to compare these two methods by benchmarking data entry times to compare the expenses associated with software to collect data entirely digitally. Currently, the costs are likely similar between the two methods, depending on the number of sampling events. Data entry time from the paper maps required 3 hours for about 130 data points between the 6 sampling events. The time for paper data entry likely exceeds the costs associated with digital entry.

Sediment Samples and Traps

As part of the broader boat capacity study, LAC collected sediment cores from nine sites throughout Lake Windermere (Figure 1). LAC used an Eckman sediment sampler. These

samples were analyzed for extractable hydrocarbons (EPHs) as well as total metals. Given the number and size of hydrocarbon detections in the Lake Windermere sediments in 2022, the sediment sampling program expanded in 2023 to more sites. An additional QA step was performed on two duplicate samples during 2023 to verify if the widespread EPH detections were biogenic or human caused using the silica-gel cleanup method (BC ENV 2019)

At the same time, sediment traps for measuring sediment accumulation rates in shallow water were deployed at six sites. The sediment traps consisted of a plastic sample bottle set in a concrete retaining wall block, topped with a funnel of known diameter (illustration below). Shortly after it was deployed, the trap at Marina 1 was removed and returned to LWA. Plans were made to deploy traps at a seventh site but the aquatic macrophyte beds at the creek trap site were too dense.



Field Data Collection

At Lake Windermere during 2023 LAC collected multimeter profiles (temp, DO, cond, pH) and Secchi depth at each sediment core site.

Resident Survey Methods

The LWA survey, "Two Minutes for Lake Health", was designed to get feedback from the community about recreation on Lake Windermere, BC. It is well known that a large population of lake users come from other provinces. This survey was advertised locally, so visitors and second homeowners who were not in the area during the survey period may not be represented in this survey.

Participants were asked to answer 13 questions about their own recreation practices on Lake Windermere and how they feel about the overarching state of recreation on the lake.

- The survey ran from August 31, 2023 to October 1, 2023
- The invite to complete the survey was advertised in the local newspaper "The Columbia
- Valley Pioneer" posted to the Lake Windermere Ambassadors website and LWA social media accounts.
- Posters advertising the survey were also place in the local Canada Post building, a government building entrance way, and displayed at a weekend outreach booth at the Athalmer boat launch.
- The survey was conducted online through Google Forms and included open ended and closed, long answer, multiple choice, checkbox, and linear scale questions.
- To ensure that the survey was filled out only once per person, respondents we asked to input their first and last name, as well as their email address. The names and emails will not be shared in this summary report.
- Respondents were not offered any incentives for completing the survey.

Ecological Sensitivity Index

The following provides a summary of the criteria considered in the ecological sensitivity analysis and the weighting that was applied to each criterion.

Class	Subclass	Score
Depth	Low	1.00
	Moderate	3.00
	High	4.00
FHSI Score	Low	0.25
	Moderate	1.00
	High	2.00
Zone of Sensitivity	Mussel Presence	1.00
	High Value Kokanee Area	1.00
	Aquatic Vegetation Nesting	1.00
	Burbot Spawning or Rearing	1.00
	Migration Corridor	1.00

Appendix D: Sediment Chemistry Data

CARO Analytical Services	**Client**	Larratt Aquatic Consulting																														
FINAL Analytical Testing Report	**Attention**	Heather Larratt																														
Work Order: 23I3238	**Project**	Windermere Boat Study																														
Report Date: 2023-10-10 16:31:54	**Project Info**	[none]																														
Note: This is not the original data. Please refer to PDF / Hardcopy report.																																
LAB ID				23I3238-01	23I3238-02	23I3238-03	23I3238-04	23I3238-05	23I3238-06	23I3238-07	23I3238-08	23I3238-09	23I3238-10	23I3238-11	23I3238-12	23I3238-13	23I3238-14	23I3238-15	23I3238-16	23I3238-17	23I3238-18	23I3238-19	23I3238-20	23I3238-21	23I3238-22	23I3238-23	23I3238-24	23I3238-25	23I3238-26
CLIENT ID				HC1	HC2	HC3	HC4	HC5	HC6	HC7	HC8	HC9	HC10	HC11	HC12	HC13	HC14	HC15	Deepest site	Main Beach	Rockier Sedi	Common Bc	Control Area	Marina 1	Marina 2	Marina 3	Marina 2 tra	Deep trap a	Deep trap b
DATE SAMPLED				2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23	2023-09-23
DATE RECEIVED				2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26	2023-09-26
MATRIX				Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
General Method	**Analyte**	**Units**	**MRL**																													
BCMOE Aggregate Hydrocarbons	EPHs10-19	mg/kg	50	<120	<110	<100	<140	<120	<130	<120	<100	<130	<130	<160	<210	180	<94	<130	<140	<72	<200	<82	<250	<60	<50	<50			
BCMOE Aggregate Hydrocarbons	EPHs19-32	mg/kg	50	290	140	240	260	280	280	270	180	270	250	270	470	800	190	170	<140	75	290	150	610	130	<50	<50			
BCMOE Aggregate Hydrocarbons	EPHs10-19(sg)	mg/kg	50			<100												<130											
BCMOE Aggregate Hydrocarbons	EPHs19-32(sg)	mg/kg	50			<100												<130											
BCMOE Aggregate Hydrocarbons	VHs (6-10)	mg/kg	20																<20	<20	<100	<20	<100	<20	<20	<20			
BCMOE Aggregate Hydrocarbons	VPHs	mg/kg dry	100																<20	<20	<100	<20	<100	<20	<20	<20			
BCMOE Aggregate Hydrocarbons	LEPHs	mg/kg dry	140																<140	<72	<200	<82	<250	<60	<50	<50			
BCMOE Aggregate Hydrocarbons	HEPHs	mg/kg dry	140																<140	75	290	150	610	130	<50	<50			
General Parameters	Moisture	% wet	1	80	77.6	75	82.4	78.9	81.3	79.6	75.5	80.9	81.4	84.8	88.2	85.2	73.5	80.2	82.5	65.1	87.6	69.5	89.9	58.5	41.7	38.1			
General Parameters	Dry Weight (grams)	g dry	0.001																								9	4.07	3.6
General Parameters	Solids, Volatile	g dry	0.001																								1.32	1.37	1.13
Polycyclic Aromatic Hydrocarbons (PAH)	Acenaphthene	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Polycyclic Aromatic Hydrocarbons (PAH)	Acenaphthylene	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Polycyclic Aromatic Hydrocarbons (PAH)	Anthracene	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Polycyclic Aromatic Hydrocarbons (PAH)	Benz(a)anthracene	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Polycyclic Aromatic Hydrocarbons (PAH)	Benzo(a)pyrene	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Polycyclic Aromatic Hydrocarbons (PAH)	Benzo(b)fluoranthene	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Polycyclic Aromatic Hydrocarbons (PAH)	Benzo(b+j)fluoranthene	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Polycyclic Aromatic Hydrocarbons (PAH)	Benzo(g,h,i)perylene	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Polycyclic Aromatic Hydrocarbons (PAH)	Benzo(k)fluoranthene	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Polycyclic Aromatic Hydrocarbons (PAH)	2-Chloronaphthalene	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Polycyclic Aromatic Hydrocarbons (PAH)	Chrysene	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Polycyclic Aromatic Hydrocarbons (PAH)	Dibenz(a,h)anthracene	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Polycyclic Aromatic Hydrocarbons (PAH)	Fluoranthene	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Polycyclic Aromatic Hydrocarbons (PAH)	Fluorene	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Polycyclic Aromatic Hydrocarbons (PAH)	Indeno(1,2,3-cd)pyrene	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Polycyclic Aromatic Hydrocarbons (PAH)	1-Methylnaphthalene	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Polycyclic Aromatic Hydrocarbons (PAH)	2-Methylnaphthalene	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Polycyclic Aromatic Hydrocarbons (PAH)	Naphthalene	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Polycyclic Aromatic Hydrocarbons (PAH)	Phenanthrene	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Polycyclic Aromatic Hydrocarbons (PAH)	Pyrene	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Polycyclic Aromatic Hydrocarbons (PAH)	Quinoline	mg/kg	0.05																<0.143	<0.072	<0.202	<0.082	<0.247	<0.060	<0.050	<0.050			
Volatile Organic Compounds (VOC)	Benzene	mg/kg	0.03																<0.171	<0.086	<0.242	<0.098	<0.297	<0.072	<0.030	<0.048			
Volatile Organic Compounds (VOC)	Ethylbenzene	mg/kg	0.05																<0.286	<0.143	<0.404	<0.164	<0.495	<0.121	<0.050	<0.081			
Volatile Organic Compounds (VOC)	Methyl tert-butyl ether	mg/kg	0.04																<0.229	<0.115	<0.323	<0.131	<0.396	<0.096	<0.040	<0.065			
Volatile Organic Compounds (VOC)	Styrene	mg/kg	0.05																<0.286	<0.143	<0.404	<0.164	<0.495	<0.121	<0.050	<0.081			
Volatile Organic Compounds (VOC)	Toluene	mg/kg	0.2																<1.14	<0.574	<1.61	<0.657	<1.98	<0.482	<0.200	<0.323			
Volatile Organic Compounds (VOC)	Xylenes (total)	mg/kg	0.1																<0.572	<0.287	<0.807	<0.328	<0.990	<0.241	<0.100	<0.162			

CARO Analytical Services		**Client**	Larratt Aquatic Consulting									
FINAL Analytical Testing Report		**Attention**	Heather Larratt									
Work Order: 22I2507		**Project**	Windermere Boat Study									
Report Date: 2022-09-27 12:09:58		**Project Info**	[none]									
Note: This is not the original data. Please refer to PDF / Hardcopy report.												
LAB ID					22I2507-01	22I2507-02	22I2507-03	22I2507-04	22I2507-05	22I2507-06	22I2507-07	22I2507-08	22I2507-09
CLIENT ID					Rockier Sedi	Marina 1 2	Marina 1	Marina 1 3	Party Boat S	Main Beach	Control Site	Deep Site	Main Boat L
DATE SAMPLED					2022-09-07	2022-09-07	2022-09-07	2022-09-07	2022-09-07	2022-09-07	2022-09-07	2022-09-07	2022-09-07
DATE RECEIVED					2022-09-19	2022-09-19	2022-09-19	2022-09-19	2022-09-19	2022-09-19	2022-09-19	2022-09-19	2022-09-19
MATRIX					Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
General Method	**Analyte**	**Units**	**RL**									
BCMOE Aggregate Hydrocarbons	EPHs10-19	mg/kg	140		<200	<59	<50	<50	<70	<140	<170	<180	<50
BCMOE Aggregate Hydrocarbons	EPHs19-32	mg/kg	140		460	89	<50	<50	99	310	410	310	<50
General Parameters	Moisture	% wet	1		87.7	57.7	38.8	26.5	64.2	81.8	85.7	86	44.1
Microbiological Parameters	E. coli	MPN/g	16		<24	22	<4.9	<4.1	<8.4	<16	<21	<21	<5.4
Strong Acid Leachable Metals	Aluminum	mg/kg dry	40		5820	4680	2270	4430	6350	4930	13800	10400	5780
Strong Acid Leachable Metals	Antimony	mg/kg dry	0.1		0.26	0.1	<0.10	0.15	0.18	0.18	0.39	0.34	0.23
Strong Acid Leachable Metals	Arsenic	mg/kg dry	0.3		5.91	6.3	4.5	5.24	6.98	5.25	11.9	11.4	3.88
Strong Acid Leachable Metals	Barium	mg/kg dry	1		228	183	98.7	25.7	63.8	173	135	276	47
Strong Acid Leachable Metals	Beryllium	mg/kg dry	0.1		0.39	0.27	0.12	0.16	0.27	0.3	0.71	0.62	0.18
Strong Acid Leachable Metals	Bismuth	mg/kg dry	0.1		0.27	<0.10	<0.10	<0.10	0.13	0.19	0.49	0.44	0.11
Strong Acid Leachable Metals	Boron	mg/kg dry	2		5.2	4.7	<2.0	<2.0	2.6	4.5	4.6	6.4	<2.0
Strong Acid Leachable Metals	Cadmium	mg/kg dry	0.04		0.191	0.092	0.059	<0.040	0.056	0.139	0.205	0.268	0.056
Strong Acid Leachable Metals	Calcium	mg/kg dry	100		121000	195000	205000	55100	35600	124000	14500	107000	17100
Strong Acid Leachable Metals	Chromium	mg/kg dry	1		8.1	9	4	8.6	11.1	7.9	14.6	13.1	9.1
Strong Acid Leachable Metals	Cobalt	mg/kg dry	0.1		7.4	4.15	2.11	3.72	6.22	6.2	12.7	11.1	5.15
Strong Acid Leachable Metals	Copper	mg/kg dry	0.4		21.3	10.1	2.79	4.7	7.34	14.9	29.4	28	6.15
Strong Acid Leachable Metals	Iron	mg/kg dry	20		20200	11000	5280	12300	18800	16700	33900	27800	14000
Strong Acid Leachable Metals	Lead	mg/kg dry	0.2		23.3	10.5	3.92	4.34	7.48	18.9	20.7	33.1	8.35
Strong Acid Leachable Metals	Lithium	mg/kg dry	0.1		10.5	9.22	5.04	9.96	12.7	9.96	22.9	16.8	14.1
Strong Acid Leachable Metals	Magnesium	mg/kg dry	10		10200	18200	17700	12400	13800	13100	14200	11300	11400
Strong Acid Leachable Metals	Manganese	mg/kg dry	0.4		474	316	283	279	491	569	363	849	427
Strong Acid Leachable Metals	Mercury	mg/kg dry	0.04		0.058	<0.040	<0.040	<0.040	<0.040	0.048	0.052	0.097	<0.040
Strong Acid Leachable Metals	Molybdenum	mg/kg dry	0.1		1.59	0.45	0.14	0.14	0.34	0.95	1.1	0.95	0.3
Strong Acid Leachable Metals	Nickel	mg/kg dry	0.6		14.8	11	4.91	9.89	12.1	11.3	20.1	19.4	9.11
Strong Acid Leachable Metals	Phosphorus	mg/kg dry	10		905	301	194	215	346	583	768	767	318
Strong Acid Leachable Metals	Potassium	mg/kg dry	40		1080	722	325	266	704	678	2440	1880	628
Strong Acid Leachable Metals	Selenium	mg/kg dry	0.2		1.35	0.45	<0.20	<0.20	0.22	0.87	1.35	1.47	<0.20
Strong Acid Leachable Metals	Silver	mg/kg dry	0.1		<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.11	0.11	<0.10
Strong Acid Leachable Metals	Sodium	mg/kg dry	50		102	78	55	<50	64	85	90	107	<50
Strong Acid Leachable Metals	Strontium	mg/kg dry	0.2		240	539	475	112	56.9	220	21.7	218	27.9
Strong Acid Leachable Metals	Sulfur	mg/kg dry	1000		15200	7280	2070	<1000	4700	11500	22500	17800	3500
Strong Acid Leachable Metals	Tellurium	mg/kg dry	0.1		<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Strong Acid Leachable Metals	Thallium	mg/kg dry	0.1		<0.10	0.13	<0.10	<0.10	<0.10	<0.10	0.17	0.13	<0.10
Strong Acid Leachable Metals	Thorium	mg/kg dry	0.5		2.28	1.73	0.99	2.32	3.18	2.28	6.08	3.97	4.12
Strong Acid Leachable Metals	Tin	mg/kg dry	0.2		<0.20	<0.20	<0.20	<0.20	<0.20	0.26	0.33	0.36	<0.20
Strong Acid Leachable Metals	Titanium	mg/kg dry	1		33.8	40.2	15.5	19.6	36.3	39.2	54.6	56.6	73.8
Strong Acid Leachable Metals	Tungsten	mg/kg dry	0.2		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Strong Acid Leachable Metals	Uranium	mg/kg dry	0.05		2.57	0.631	0.402	0.227	0.71	1.36	2.2	1.77	0.58
Strong Acid Leachable Metals	Vanadium	mg/kg dry	1		6.4	9.1	4.1	6	8	5.4	11.9	9.7	7.1
Strong Acid Leachable Metals	Zinc	mg/kg dry	2		46.2	38.2	26.7	19.8	31	47	63.1	62.1	30.1
Strong Acid Leachable Metals	Zirconium	mg/kg dry	2		2.7	<2.0	<2.0	<2.0	<2.0	2.2	5.3	3.2	2.2