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Bear Lake's Alkaline Water Chemistry Fuels Eurasian Watermilfoil Vigor and Complicates Herbicide Control in Utah-Idaho Basin

Ecology & Evolution * Invasive Species * Limnology

Straddling the Utah-Idaho border in a fault-bounded graben basin, Bear Lake is one of the oldest continuously existing lakes in North America and an ecological jewel of the Intermountain West [1, 2] . Renowned for its striking turquoise color -- generated by suspended calcium carbonate (CaCO 3) marl particles scattering blue-green wavelengths -- Bear Lake supports four endemic fish species found nowhere else on Earth, including the Bonneville cisco (Prosopium gemmifer) and Bear Lake whitefish (Prosopium abyssicola) [1, 2] . Since late 2019, however, this oligotrophic, alkaline ecosystem has faced a rapidly expanding biological invasion: Eurasian watermilfoil (Myriophyllum spicatum), an aggressive submerged macrophyte capable of forming dense, light-blocking surface canopies [1, 2] .

In a collaborative research and management initiative, scientists from Utah State University (USU) and the Janet Quinney Lawson Institute for Land, Water and Air are partnering with the Utah Division of Forestry, Fire and State Lands (FFSL) to unravel how Bear Lake's unusual water chemistry alters both the growth physiology of M. spicatum and the effectiveness of standard aquatic herbicides [1, 2] . Alongside systematic lake-wide genetic sampling to detect potential crossbreeding with native milfoil species, the partnership aims to replace broad assumptions with empirical, basin-specific control strategies [1] .

1. Bicarbonate Assimilation: Why Bear Lake's Alkaline Chemistry Accelerates Milfoil Growth

Laboratory and mesocosm evaluations conducted by USU researchers revealed a critical limnological surprise: Eurasian watermilfoil grows substantially faster and produces greater shoot density, stem height, and total biomass in Bear Lake water than in standard neutral tap-water controls [1] . Understanding this physiological boost requires examining the dissolved inorganic carbon (DIC) equilibrium of alkaline lakes:

* Carbonate Alkalinity and pH Regime: Bear Lake exhibits elevated pH values (typically 8.4 to 8.8) and high carbonate/ bicarbonate alkalinity sustained by limestone and dolomite dissolution in the surrounding Bear River Range [1, 2] . At pH levels above 8.3, free aqueous carbon dioxide (CO 2) makes up less than 1% of the total dissolved inorganic carbon pool, with over 95% existing as bicarbonate ions (HCO 3 −) and carbonate ions (CO 3 2−).

* High-Affinity Bicarbonate Utilization: While many native aquatic plants struggle with carbon limitation in high-pH waters because they rely primarily on passive diffusion of dissolved CO 2 , Myriophyllum spicatum possesses an efficient carbon-concentrating mechanism. Using membrane-bound proton pumps and extracellular

carbonic anhydrase , Eurasian watermilfoil actively converts abundant HCO 3 − ions into intracellular CO 2 to fuel RuBisCO carbon fixation [1, 3] .

* Competitive Canopy Dominance: Fueled by abundant bicarbonate and ample littoral sunlight penetration in Bear Lake's clear waters, M. spicatum rapidly elongates toward the surface, branching profusely to form dense mats near marinas, boat ramps, and shallow cobble shorelines [1, 2] . Once established, these canopies shade out native submerged macrophytes, alter dissolved oxygen profiles through nocturnal respiration, and foul boat propellers, accelerating vegetative fragmentation and lake-wide dispersal [1, 2] .

2. The Herbicide Efficacy Bottleneck: 2,4-D Attenuation vs. Targeted Auxin Mimics

The accelerated growth kinetics observed in Bear Lake water directly complicate chemical suppression efforts [1] . Standard aquatic weed management programs frequently rely on systemic synthetic auxin herbicides such as 2,4-D (2,4-dichlorophenoxyacetic acid) to selectively control dicotyledonous watermilfoils while sparing native monocots [1, 3] .

However, USU experimental trials demonstrated that 2,4-D performs significantly worse in Bear Lake water than in control tap water [1] . Several interacting mechanisms drive this attenuation:

* pH-Dependent Ionization and Uptake Kinetics: 2,4-D is a weak organic acid (p K a ~ 2.73). In highly alkaline lake water (pH > 8.4), the molecule exists almost exclusively in its dissociated, negatively charged anionic form rather than its neutral lipophilic acid form, slowing passive diffusion across the waxy plant cuticle and cell membranes.

* Biomass Dilution and Rapid Regrowth: Because Bear Lake water stimulates accelerated meristematic shoot production and tissue expansion, standard short-exposure herbicide concentrations are rapidly diluted across proliferating biomass, allowing surviving root crowns and stem fragments to recover before lethal auxin-induced cell-wall loosening and vascular collapse occur [1] .

To overcome these chemical hurdles in high-traffic marinas and launch basins, management agencies -- including FFSL and the Idaho State Department of Agriculture -- have shifted toward next-generation arylpicolinate auxin mimics such as florpyrauxifen-benzyl (formulated as ProcellaCOR EC) [2] . Florpyrauxifen-benzyl binds with high affinity to distinct TIR1/AFB auxin receptor complexes, achieving systemic control at parts-per-billion concentrations with substantially shorter required contact times in dynamic, wind-mixed littoral zones [2] .

3. Genetic Surveillance for Hybrid Watermilfoil (M. spicatum x M. sibiricum)

Beyond water chemistry, USU scientists are conducting systematic shoreline rake surveys to collect plant tissue across Bear Lake for molecular genotyping [1] . Their primary genetic concern is interspecific hybridization between invasive Eurasian watermilfoil (Myriophyllum spicatum) and native northern watermilfoil (Myriophyllum sibiricum), which historically inhabits cold-water lakes across North

America [1, 4] .

| Taxon / Lineage | | Ecological Origin | | Growth & Canopy Vigor | | 2,4-D Herbicide Sensitivity | | Bear Lake Management Risk |

| Northern Watermilfoil (M. sibiricum) | | Native North American macrophyte | | Moderate; grows below surface without choking canopies | | High sensitivity to standard auxin treatments | | Provides beneficial benthic cover for native juvenile fishes [1, 4] . |

| Eurasian Watermilfoil (M. spicatum) | | Introduced Eurasian invasive | | High; vigorous surface matting in alkaline water | | Moderate to reduced in high-pH Bear Lake water | | Confirmed in marinas and littoral zones since 2019 [1, 2] . |

| Hybrid Watermilfoil (M. spicatum x M. sibiricum) | | Interspecific F 1 and backcross lineages | | Superior (heterosis) ; outgrows both parent species | | Significantly reduced (heritable resistance) | | Primary genetic surveillance target via USU ITS/SSR genotyping [1, 3, 4] . |

As first documented genetically by Moody and Les (2002) and demonstrated experimentally by LaRue et al. (2013), hybrid watermilfoil lineages frequently exhibit hybrid vigor (heterosis), growing significantly faster than pure parental M. spicatum while displaying markedly reduced sensitivity to 2,4-D [3, 4] . Furthermore, repeated chemical applications in infested lakes can inadvertently select for tolerant hybrid genotypes, turning localized nuisance patches into herbicide-resistant populations [3] . Early molecular detection across Bear Lake's marinas allows FFSL managers to identify emergent hybrid genotypes before they dominate the shoreline seed and fragment bank [1] .

4. Ecosystem Protection and Containment Across the Bear River Watershed

Because complete lake-wide eradication of an established submerged macrophyte in a 280-square-kilometer alpine basin is logistically impossible without damaging native flora, the USU-FFSL partnership focuses on adaptive containment and ecological triage [1, 2] .

Protecting shallow rocky shoals from dense milfoil encroachment is vital for Bear Lake's four endemic fishes, particularly the Bear Lake sculpin (Cottus extensus) and Bonneville cisco, which depend on clean, oxygenated cobble substrates for spawning [1, 2] . Simultaneously, suppressing milfoil density around boat ramps and outlet channels prevents motorized watercraft from carrying viable stem fragments downstream into the Bear River watershed or overland to neighboring western reservoirs [1, 2] . By pairing limnological chemistry, molecular phylogenetics , and precision herbicide timing, resource managers are building a science-driven defense for one of North America's most distinctive ancient lakes [1, 2] .

References & Primary Sources

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