PROJECT INFORMATION

Title:	Stop the Squeeze: utilizing hypolimnetic oxygenation to improve sport fish habitat, water quality, climate adaptation, and economic opportunity for Island Park Reservoir and the Henry's Fork of the Snake River, Idaho
Location	Island Park Reservoir and its largest tributary, the Henry's Fork of the Snake River network. Fremont County, Idaho, USA
GPS Coordinates	All waters upstream of the dam at: 44.418996° N, 111.396496° W exclusive of Henry's Lake and the tributaries that feed Henry's Lake
U.S. Congressional District	Idaho 2nd district
Target Species	1. Kokanee salmon (*Oncorhynchus nerka*) 2. Rainbow trout (*O. mykiss*) 3. Yellowstone cutthroat trout (*O. clarkii bouvieri*) 4. Brook trout (*Salvelinus fontinalis*) 5. Mountain whitefish (*Prosopium williamsoni*)
Region	Western Mountains
Project Objectives:	**Oxygenate Island Park Reservoir's hypolimnion** to restore pelagic migratory salmonid sportfish habitat and improve downstream water quality in the face of habitat loss due to climate change and reservoir draw-down. 1. **Develop** a hypolimnetic oxygenation design plan, including outreach and education to the local community 2. **Evaluate** plan efficacy through the development of a limnological model for Island Park Reservoir 3. **Monitor** oxythermal habitat and fisheries indicators in Island Park Reservoir 4. **Implement** the hypolimnetic oxygenation plan by leveraging funds available from project partners
Estimated start date:	April 2024
Estimated end date:	December 2026
Estimated total cost	Hypolimnetic oxygenation project design: $50,000
Partner list	• Idaho Department of Fish and Game—Upper Snake Region (IDFG) • United States Bureau of Reclamation (USBR) • Idaho Department of Environmental Quality (IDEQ) • Fall River Rural Electric Cooperative (FRREC)

PROJECT DESCRIPTION

Project overview

Introduction

Excessive annual drawdowns negatively affect water quality and fish habitat in Island Park Reservoir and its tailwater, the Henry's Fork of the Snake River ("Henry's Fork", 44.418996° N, 111.396496 W°, Fremont County, Idaho, in the Western Mountain ecoregion, Figure 1) which is managed by the United States Bureau of Reclamation (USBR) to meet downstream irrigation water needs. In 2021, the Henry's Fork Foundation (HFF) received a grant from Friends of Reservoirs and the Reservoir Fish Habitat Partnership (RFHP) in part to study how fish habitat in Island Park Reservoir reacts to high drawdowns. Drawdowns are becoming more frequent as water supply declines (Van Kirk et al. 2019, Williams et al. 2020). We found Island Park Reservoir drawdown reduced water depth, increased turbidity, increased water temperatures in the epilimnion, and reduced dissolved oxygen in the hypolimnion (Figure 2; McLaren et al. 2023). Called an "oxythermal habitat squeeze", this loss of cool, oxygenated deep water refugia restricted habitat for pelagic salmonid sportfish (Figure 3), and damaged salmonid sportfish populations (Figure 4; McLaren et al. 2023). The oxythermal habitat squeeze also negatively affected water quality and ecology of the Henry's Fork downstream. Fall River Rural Electric Cooperative (FRREC) generates hydropower at Island Park dam through a hypolimnetic outflow ~3 meters above the bottom of the reservoir. Dissolved oxygen in FRREC's outflow is required to be greater than than 6 mg/L to protect salmonid life. Low dissolved oxygen concentrations in the hypolimnion outstrips FRREC's original aeration infrastructure, forcing unplanned cessation of power generation. Outflow then switches to the original USBR outflow structure located at the deepest point in the reservoir. The USBR outflow structure entrains nutrient-rich sediment on the bottom of the reservoir, negatively affecting important aquatic macroinvertebrate populations that support trout growth and survival (Figure 5).

The oxythermal squeeze in Island Park Reservoir negatively impacts watershed-scale ecological and economic benefits. Island Park Reservoir's fishery has declined since the 1980s, when it was once a "fishery of significant state interest" (High et al. 2015, Flinders et al. 2016). The loss of aquatic macroinvertebrates in the Henry's Fork downstream damages a world-famous dry-fly fishing experience that drives a local fishing-based economy worth around $30 million (Grunder et al. 2008, Loomis 2006, Van Kirk et al. 1999, Van Kirk et al. 2019a). Reduced kokanee populations could decouple nutrient cycling between Island Park Reservoir and its tributaries—i.e., reducing food availability for threatened Grizzly bears (Figure 5). Finally, FRREC is not able to generate hydropower to their original design specifications, resulting in revenue loss. Local management priorities are restoring the Island Park and Henry's Fork fisheries to their former status (High et al. 2015, Flinders et al. 2016).

The Henry's Fork Foundation (HFF) is a 501(c)(3) nonprofit organization whose mission, ability to leverage additional funding, expertise, and skills make it uniquely positioned to effectively address the issues at Island Park Reservoir. Our mission is to conserve, restore, and protect the unique fishery, wildlife, and aesthetic qualities of the Henry's Fork of the Snake River watershed. HFF is supported by donations from its 2,500 members and grants from private foundations and public agencies. Since HFF first hired full-time staff in 1992, science-based collaboration has been the HFF's primary mode of mission accomplishment. With Fremont-Madison Irrigation District (FMID), HFF co-facilitates the Henry's Fork Watershed Council, which has become a nationally recognized model of collaborative watershed management and community outreach. The HFF's science-based work is supported by a science and technology program that includes an in-house water quality/aquatic ecology laboratory and is staffed by five full-time equivalent employees, one graduate students, and as many as six undergraduate interns. The program is directed by Dr. Rob Van Kirk, who has a 25-year record of conducting a wide

range of research in the Upper Snake River Watershed to inform conservation and management of fisheries and water resources. Dr. John McLaren is the project manager. He has seven years of experience specifically researching the limnology and ecology of Island Park Reservoir. He is the Aquatic Ecology Program Manager for the Henry's Fork Foundation; the Aquatic Ecology program uses cutting-edge aquatic ecology concepts to identify permanent infrastructure- and policy-based solutions to anthropogenic pressures on the Henry's Fork watershed.

Our project goal is to permanently eliminate the drawdown-driven oxythermal habitat squeeze by designing, evaluating, and installing a hypolimnetic oxygenation system. Hypolimnetic oxygenation is a proven technique for improving fish habitat (McQueen & Lean 1986, Horne 2019) and downstream water quality (Horne 2019). In 2021, a hypolimnetic oxygenation system would have increased total habitat for kokanee salmon in Island Park Reservoir from ~1,000 acre feet to ~3,500 acre-feet, an increase of 350%. Absolute habitat savings will be even larger in years where Island Park Reservoir drawdown is lower—preliminary data from Henry's Fork Foundation monitoring indicates up to 20,000 acre-feet in habitat improvement is possible in years with lower drawdown. Hypolimnetic oxygenation will permanently increase deep, cold-water refugia despite Island Park Reservoir's shallowness (mean depth = 5 m) and climate-driven uncertainty in water regime. Funds provided by the RFHP will be used to develop a shovel-ready design plan. A shovel-ready plan includes necessary engineering design, stakeholder outreach, plan evaluation, and monitoring. A shovel-ready plan allows us to leverage up to $3 million in USBR WaterSmart grants available through the Infrastructure and Jobs Act and Inflation Reduction Act.

Objectives

With the help of Reservoir Fish Habitat Partnership (RFHP) funding, HFF will oxygenate Island Park Reservoir's hypolimnion to restore pelagic migratory salmonid sportfish habitat and improve downstream water quality in the face of habitat loss due to climate change and reservoir draw-down.

1. **Develop** a hypolimnetic oxygenation design plan to oxygenate the Island Park Reservoir hypolimnion to 6 mg/L, including outreach and education to the local community and project stakeholders including Fall River Rural Electric Cooperative through the Henry's Fork Watershed Council.
2. **Evaluate** plan efficacy through the development of a limnological model for Island Park Reservoir in conjunction with the Idaho Department of Environmental Quality and the Idaho Department of Fish and Game
3. **Monitor** oxythermal habitat and fisheries indicators in Island Park Reservoir through the implementation of continuous temperature and dissolved oxygen monitoring of Island Park Reservoir
4. **Implement** the hypolimnetic oxygenation plan by leveraging funds available from project partners, including U.S. Bureau of Reclamation WaterSmart grants

Completion of these objectives will allow us to continue creating measurable improvements in water quality and fish habitat in a valuable fishery resource, reduce management uncertainty, and potentially restore Island Park Reservoir's fishery to a quality not seen since the 1980s.

Project details

Methodology

Objective 1 conducts the critical preliminary scoping, design, and siting work to create a shovel-ready plan for a hypolimnetic oxygenation facility. Multiple potential hypolimnetic oxygenation designs have individual benefits and drawbacks in effectiveness, space and siting requirements, initial cost, and ongoing operating and maintenance costs (Miranda 2017). Project scoping is initially determined by the

amount of oxygen required for the project, which is controlled by oxygenation goals, the volume of water to be oxygenated, and the induced oxygen demand resulting from oxygenation. Induced demand can affect project scope by affecting both infrastructure design as well as the amount of oxygen required to reach project goals (Beutel 2003, Miranda 2017). RFHP funding will identify Island Park Reservoir's stable and induced oxygen demand to accurately identify project scope. Next, RFHP funding will be used to contract an engineering firm with expertise in hypolimnetic oxygenation to design and site a hypolimnetic oxygenation system that will be capable of oxygenating Island Park Reservoir's hypolimnion to 6 mg/L of dissolved oxygen. We chose this standard because it exceeds minimum survival requirements for salmonid sportfish (Davis 1975, Berge 2009), and because it would allow FRREC to operate their hydroelectric facility without pause. This would maximize in-reservoir fish habitat, upstream salmonid runs, and downstream water quality. A shovel-ready design plan will next be evaluated with objectives 2 and 3, which will be aimed at building outreach and support for the project with stakeholders and the local community. Finally, a shovel-ready design plan can be used to accomplish objective 4: implementation.

Objective 2 aims to develop mechanistic and predictive models of water quality and fish habitat, thereby assisting in improving precision management and water conservation. Tools like Delft3D and CE-QUAL W2 by the US Geological Survey can produce 3D models of water temperature and dissolved oxygen in reservoir systems given known inputs like depth, local weather, and the quantity and quality of inflows and outflows. Once calibrated, these models can predict future water quality conditions in Island Park Reservoir given a wide range of scenarios, such as with a hypolimnetic oxygenation plan. This transition from reactive monitoring to proactive prediction represents a major step forward for smart management of Island Park Reservoir and its fisheries resources. It also represents a major step forward in outreach and stakeholder engagement. Showing the efficacy of hypolimnetic oxygenation will lead to additional non-federal match as more stakeholders—in particular IDFG, FRREC, and other partners through the HFF's proven collaborative management, outreach, and education.

Objective 3 continues the HFF's comprehensive monitoring of water quality in Island Park Reservoir to assess the efficacy of management actions on Island Park Reservoir. Findings from 2021 revealed significant spatial variability in water quality in Island Park Reservoir. An undergraduate intern presented the findings of our 2021 RFHP-funded work to the public through the HFF's popular "Summer Seminar Series", and we intend to continue to engage with community members in reporting our scientific findings (https://www.henrysfork.org/post/4th-annual-hff-summer-seminar-series). Monitoring will assist in pre-project monitoring of a hypolimnetic oxygenation project.

Objective 4 is the implementation of the plan developed through objective 1. USBR WaterSmart infrastructure grants such as the Environmental Water Resources Program require projects with clear, quantifiable benefits to aquatic habitats and water quality, a clear strategy or plan with significant stakeholder support, a shovel-ready design plan, and a pre- and post-project monitoring plan. Objective 1 produces a shovel-ready design plan, and objectives 2 and 3 will allow for further quantification of specific benefits, a path for developing a clear plan with significant stakeholder support through the Henry's Fork Foundation's science-based collaboration model, and infrastructure for pre- project monitoring. Objectives 1-3 will produce a very strong proposal to develop a permanent infrastructure solution to Island Park Reservoir's declining water quality, thereby increasing fish habitat quantity by an order of magnitude, improving downstream water quality, and benefitting a $30 million angling-based economy.

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BUDGET

Categories	Partner Contribution Amount	Cash or In-Kind	Timeline (anticipated date of expenditures)
Reservoir Fisheries Habitat Partnership	**$55,000.00**	Cash	
SOD/HOD study	$25,000.00	Cash	April 2024 - September 2024
Engineering design/siting	$25,000.00	Cash	April 2024 – December 2025
Administration/overhead	$5,000.00	Cash	April 2024 – December 2025
Henry's Fork Foundation	**$32,440.00**		
Administrative/Technical Services	$13,440.00	In-kind	April 2024 – December 2025
Island Park Reservoir sampling	$6,000.00	In-kind	May 2024 - October 2025
Undergraduate internship	$13,000.00	In-kind	June 2024 - August 2025
IDFG	**$44,518.52**		
Construction Costs/Materials	$400.00	In-kind	April 2024 - June 2025
Construction Costs/Materials	$8,301.04	In-kind	April 2024 - June 2025
Labor (paid)	$31,865.4	In-kind	April 2024 - June 2025
Administrative/Technical Services	$3,952.08	In-kind	April 2024 - June 2025
IDEQ	**$4,500.00**		
Construction Costs/Materials	$4,500.00	In-kind	April 2024 - October 2025
Total Non-federal Match	**$81,458.52**		
TOTAL	**$131,458.52**		

Budget narrative

RFHP

Objective	Amount	Timeline	Explanation
1,4	$25,000	April 2024 - September 2024	Sediment Oxygen Demand & Hypolimnetic oxygen demand + limnological study to properly scope the size of the hypolimnetic oxygenation system required
1,4	$25,000	April 2024 – December 2025	Production of an engineering design of a hypolimnetic oxygenation facility plus siting
1,4	$5,000	April 2024 – December	Grant administration: administering the grant & conducting the RFP process to identify the consultant.

		2025	

The RFHP will fund a Sediment Oxygen Demand (SOD) and Hypolimnetic Oxygen Demand (HOD) study to determine the scope of the project. Then, RFHP money will be used to contract an engineering and design firm with expertise in hypolimnetic oxygenation to develop a shovel-ready engineering design and siting plan.

All other materials and administrative costs are covered by the HFF. IDFG is also matching our effort with fisheries netting and electrofishing in Island Park Reservoir and the Upper Henry's Fork across two years; their effort is outlined below. For each of the following contributors, I outline which objective the match is directed towards, as well as a brief explanation for what each line item will be used for. Field and Lab equipment necessary for collecting data required for creation and calibration of mechanistic models will be provided by the HFF. This equipment includes the maintenance of two in-stiu EXO-II waterproof sondes in the Henry's Fork River upstream and downstream of Island Park Reservoir, a flowmeter for measuring river stage and discharge, vehicle use, boat use, and time and labor of an undergraduate intern.

Henry's Fork Foundation

John will lead sampling of multiple locations around Island Park Reservoir with an EXO-II waterproof sonde (provided in-kind by Idaho Department of Environmental Quality, below), as well as collecting data necessary to create and calibrate predictive, mechanistic models of temperature and dissolved oxygen in Island Park Reservoir, thereby obtaining a clear picture of temperature/oxygen conditions with drawdown.

Objective	Amount	Timeline	Explanation
1,2,3,4	$13,440.00	April 2024 – December 2025	HFF staff time: intern supervision, analyzing the reservoir data, and providing the consultant with the appropriate background information and data
3	$6,000.00	May 2024 - October 2025	2024 & 2025 Island Park Reservoir monitoring: vehicle mileage, boat fuel, technician time
2,3	$13,000.00	April 2023-April 2025	2024 & 2025 HFF internship to process monitoring data, evaluate dissolved oxygen dynamics.

Idaho Department of Fish and Game

Objective	Amount	Timeline	Explanation
2,3	$400.00	April 2024 - June 2025	IDFG Field Consumables
2,3	$8,301.04	April 2024 - June 2025	IDFG Field Equipment
2,3	$31,865.4	April 2024 - June 2025	IDFG Staff Salary
2,3	$3,952.08	April 2024 - June 2025	IDFG Vehicle Usage

Idaho Department of Environmental Quality

Objective	Amount	Timeline	Explanation
3	$4,500.00	April 2024 - October 2025	Field equipment (temperature/oxygen sensing multiparameter sonde). For monitoring

			reservoir water quality.

United States Bureau of Reclamation

Objective	Amount	Timeline	Explanation
4	~$2,000,000	September 2025-December 2027	USBR WaterSmart grant to implement shovel-ready design

OPTIONAL SUPPORTING MATERIALS

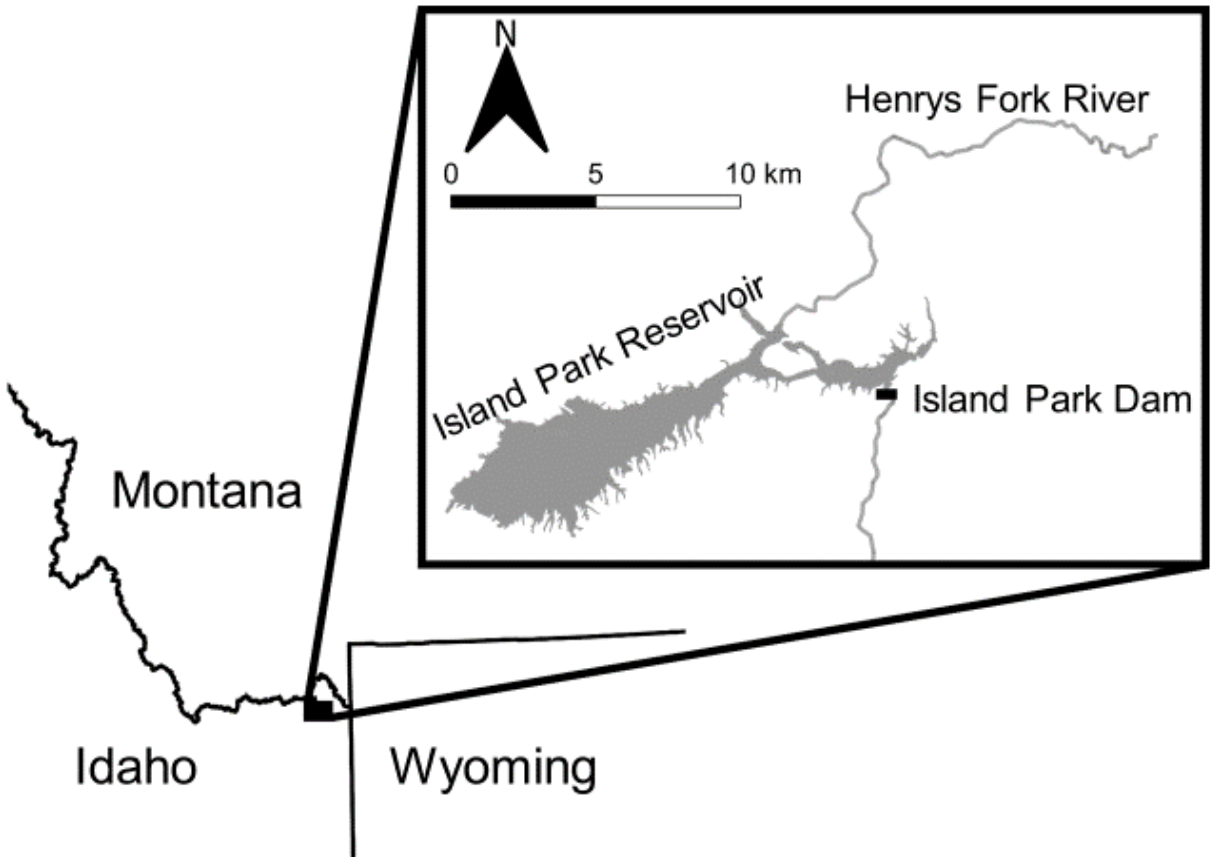

Figure 1: Proposed project area: Island Park Reservoir and the Henry's Fork of the Snake River watershed from Big Springs to Mesa Falls, Fremont County, Idaho, USA.

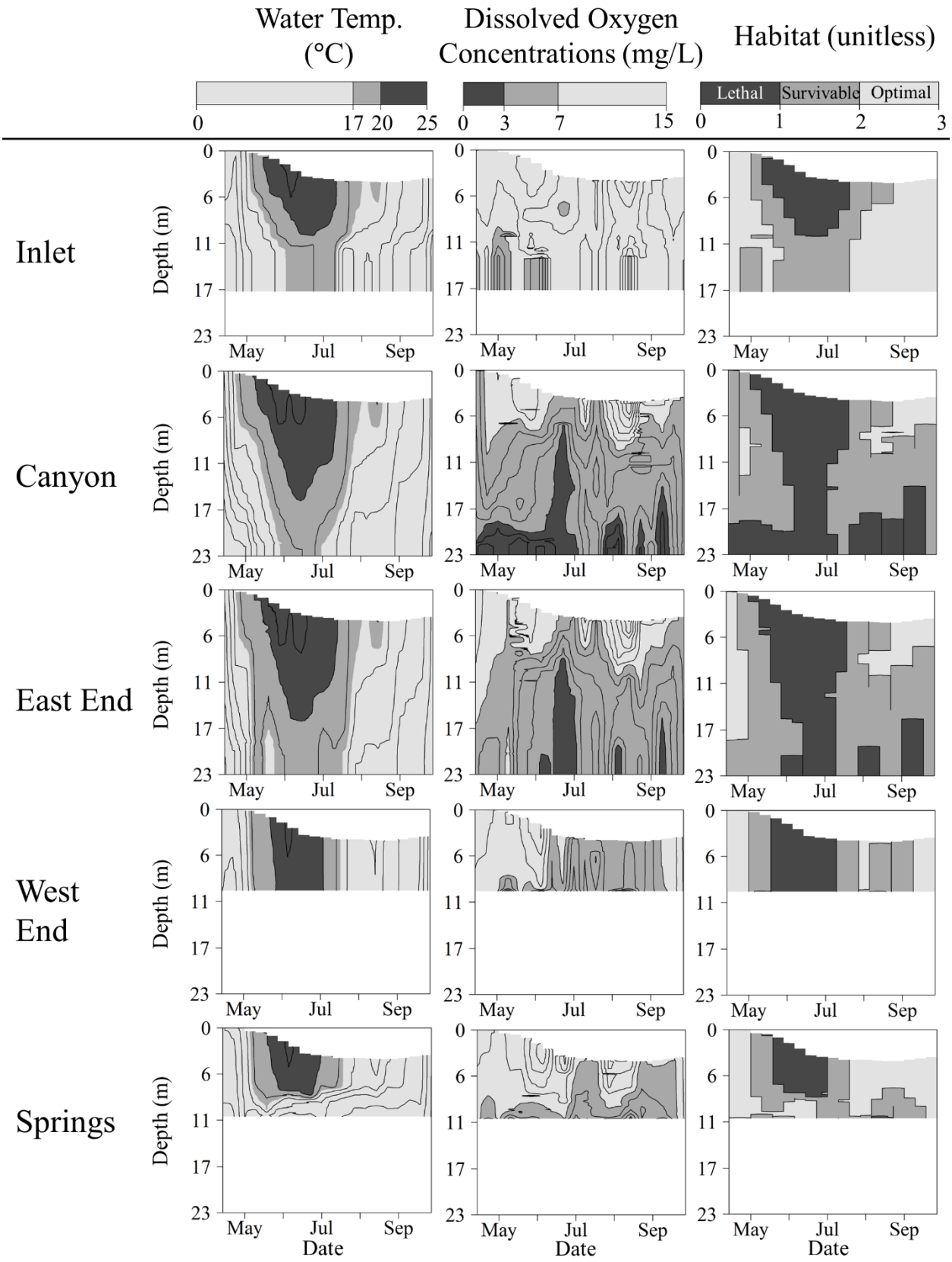
Water Temp. (°C)
Dissolved Oxygen Concentrations (mg/L)
Habitat (unitless)
0
17
20
25
0
3
7
15
Lethal
Survivable
Optimal
0
1
2
3
Inlet
Canyon
East End
West End
Springs
Depth (m)
0
6
11
17
23
May
Jul
Sep
Date

Figure 2: Interpolated water temperature (°C, left column), dissolved oxygen concentration (mg/L, middle column) and total habitat availability (unitless, right column) from May to October 2021 in Island Park Reservoir. Rows represent each of the five habitat units in Island Park Reservoir. Isopleth lines for the left column represent water temperatures at 2 °C intervals. Isopleth lines for the middle column represent dissolved oxygen concentrations at 1 mg/L intervals. Shading highlights kokanee habitat criteria in all graphs, with dark gray indicating lethal conditions (>20°C, <3 mg/L O_2), medium gray indicating survivable conditions (<20°C, >3 mg/L O_2), and light gray indicating optimal conditions (<17°C, >7 mg/L O_2). The top of the shaded area represents the surface of the water, whitespace at the top of each panel shows water level loss due to drawdown at each location. Habitat availability is a derived variable acquired by overlaying plots of water temperature and dissolved oxygen concentration.

Henry's Fork of the Snake River from its headwaters at Big Springs to Mesa Falls, Fremont County, Idaho, USA.

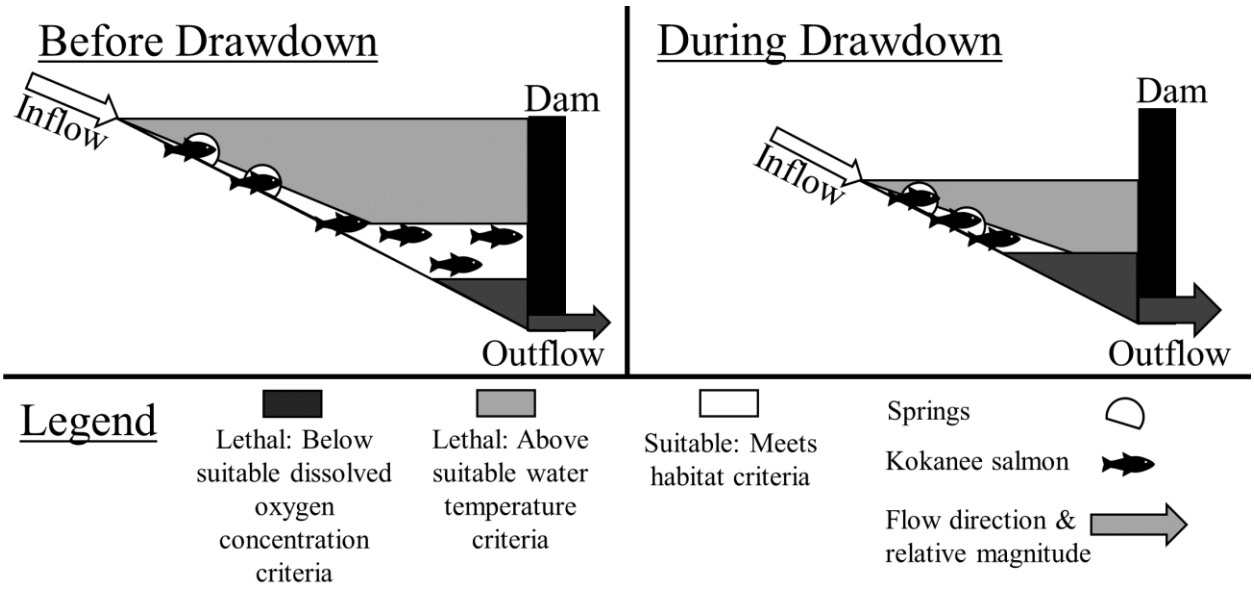

Figure 3: Cross-sectional conceptual model of Island Park Reservoir illustrating how drawdown in Island Park Reservoir is hypothesized to alter salmonid habitat and populations. During drawdown, outflows are greater than inflows. Thus, hypolimnetic outflows will evacuate hypolimnetic water downstream faster than replacement from cool, oxygenated inflows. The hypolimnion will be replaced by the warm, organic matter-rich epilimnion, resulting in temperature increases and dissolved oxygen decreases, reducing oxythermal habitat. Oxythermal habitat loss concentrates salmonids in spring-fed thermal refugia, where they may be susceptible to density-dependent processes such as predation, competition, or escapement.

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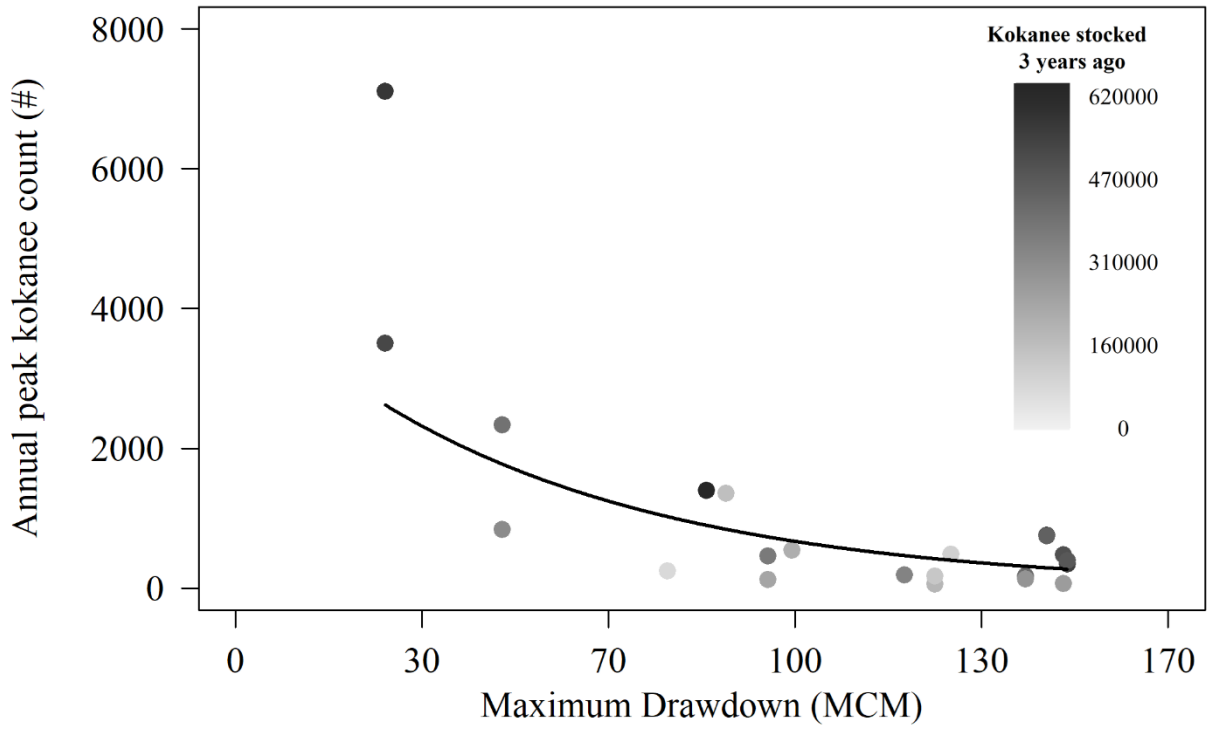

Figure 4: Annual peak kokanee spawner counts in Henrys Lake Outlet (#) and stocking (#) across maximum drawdown volumes (million m^3 or MCM) in Island Park Reservoir in the two years previous to each kokanee observation. The curve depicts the AICc averaged model vs. drawdown at mean stocking, mean air temperature, and mean observations per year.

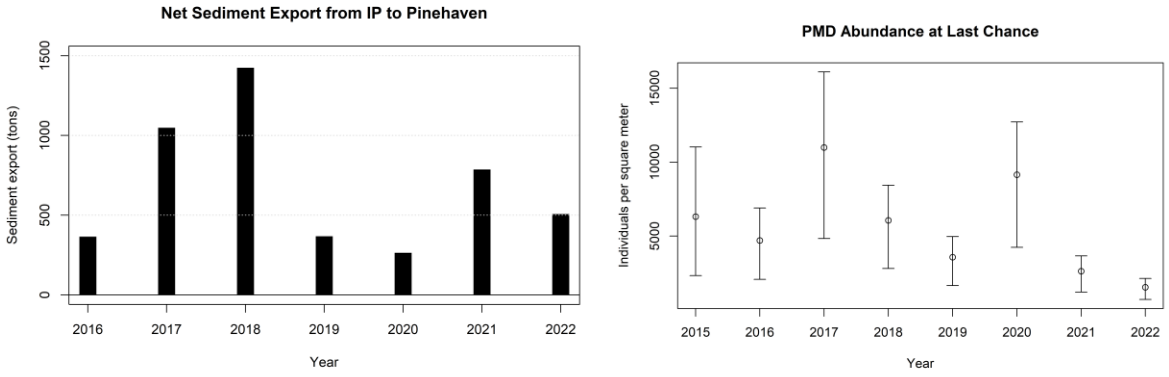

Figure 5: Left-hand panel depicts total annual net sediment export from the Henry's Fork downstream of Island Park Reservoir across years. The right-hand panel depicts the annual abundance of Pale Morning Duns (PMDs) a sediment-intolerant mayfly species important to fish and anglers in the Henry's Fork downstream of Island Park Reservoir across the same time period. Sediment export is high when clean flows from Island Park Reservoir move sediment out of the Henry's Fork and flush it downstream. Sediment export from the Henry's Fork is low

when sediment from Island Park Reservoir's USBR gates is released and deposits in the river. There is a clear correlation between low PMD abundance and low net sediment export.