Great Salt Lake: A model of sustainable resource management

Thomas Bosteels, Timothy Hawkes, Phil Brown, Great Salt Lake Artemia

The Great Salt Lake (GSL) offers a model of sustainable resource management across three dimensions: (1) proactive management of the brine shrimp (Artemia) harvest that enhances year-to-year stability and the overall productivity of the population; (2) active management of salinity to protect the critically important ecology of Gilbert Bay; and (3) significant state-level policy changes and public investments designed to protect the Lake's water supply and the health of its ecosystem. When viewed individually, each effort has shown measurable, and often dramatic, improvement in the resource directly or its future. Combined, these efforts put the lake on a more sound and sustainable footing moving forward. They also offer lessons that could be applied to other terminal lakes and ecosystems under threat.

Background

The largest terminal lake in the Western Hemisphere, GSL, is a hypersaline endorheic lake currently measuring approximately 2,500 km^2. The lake is a remnant of Lake Bonneville, a late Pleistocene Lake that, at its largest extent, covered most of western Utah. In recent decades, the lake's surface area has varied widely from 2,285 to 8,500 km^2 as a result of wet and dry cycles, increasing atmospheric heat, and increased water demands upstream (Great Salt Lake Policy Assessment, 2023). GSL supports roughly $1.6 billion in direct economic activity each year as well as other values like dust suppression, temperature moderation, and more (ECONorthwest *et al.*, 2019). Artemia cysts provide an essential live feed used primarily in marine fish and

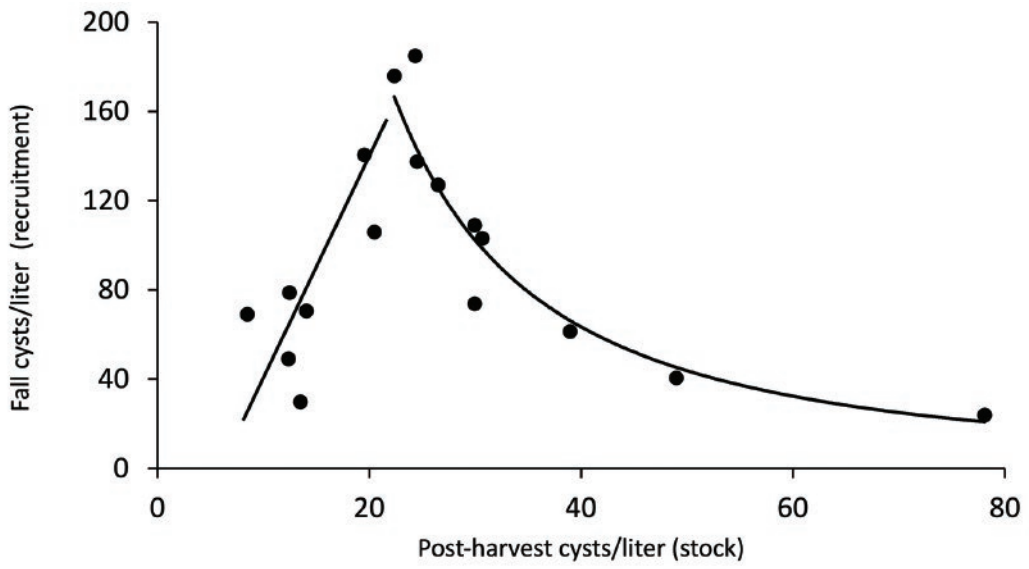

Figure 1. Modified stock-recruitment curve showing the relationship between the post-harvest escapement stock in cyst per liter and the subsequent fall cysts count. The relationship indicates an optimal escapement stock of around 21 cysts per liter.

shrimp hatcheries globally (Lavens & Sorgeloos, 1996) and support more than 10 million metric tons of marine shrimp and fish aquaculture worldwide (Naylor *et al.*, 2021). Artemia cyst production from GSL, estimated at up to 49% of worldwide Artemia production (Litvinenko *et al.*, 2015), is therefore key to supporting sustainable global marine aquaculture. The Artemia population also provides essential food for millions of migratory birds that fly through Utah on their way to far-flung destinations from Siberia to Patagonia.

Sustainable harvest management

Sustainable harvest management began in the mid-1990s as a result of a partnership between the Utah Division of Wildlife Resources (UDWR) and the Artemia industry (Marden, Brown & Bosteels, 2020). Artemia harvesters, familiar with the overfishing of marine fish stocks, became concerned about the over-exploitation of the Artemia resource and approached UDWR to request action. Subsequently, with financial support from the industry, UDWR formed the Great Salt Lake Ecosystem Program (GSLEP), tasked with managing the avian and aquatic resources of GSL. The UDWR also created a Technical Advisory Group (TAG) to advise and provide direction on related ecosystem research. Today, the TAG is made up of experts and researchers from state and federal agencies, academia, and the Artemia industry.

Initially, GSLEP focused on sustainable management of the Artemia resource as well as studying how the resident and migratory avian populations of GSL rely on that resource. In 1997, GSLEP first introduced an adaptable harvest model based on leaving an optimal escapement stock of 21 cysts per liter to overwinter and repopulate the lake each spring. This model, which has now been in place for more than two decades, is described in detail in published studies (Belovsky *et al.*, 2011; Belovsky & Perschon, 2019), and is based on a modified stock-recruitment curve (Fig. 1). Over time, the use of this model has resulted in a more stable harvest, evidenced by the five-year trailing standard deviation (Fig. 2) and a larger average Artemia harvest.

GSLEP subsequently expanded its ecosystem research to focus on phytoplankton studies, nutrient inputs, and nutrient cycling research as well as, more recently, the ecology of the lake's benthic environment. The benthic ecosystem of GSL contains vast microbialite fields (unique biologically-mediated sedimentary structures with highly productive biofilms) which provide a habitat for brine flies, and which play an important role in the health of the Artemia population and the GSL ecosystem as a whole.

Active salinity management

Over the past few years, the state of Utah, through the Division of Forestry Fire and State Lands (FFSL) and

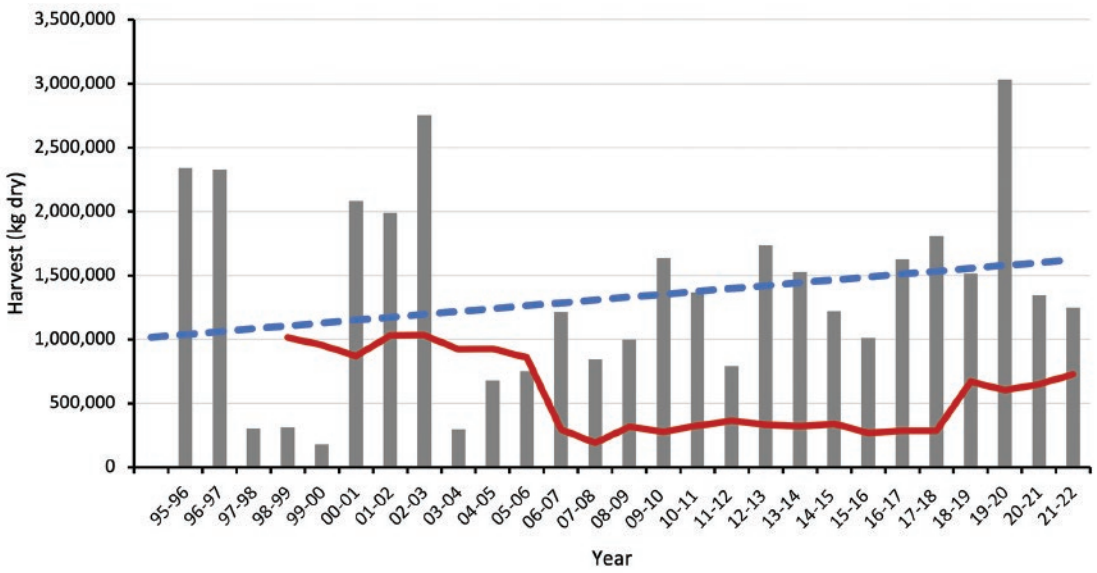

Figure 2. Great Salt Lake Artemia cyst harvest in kilograms dry since 1995 with the five-year trailing standard deviation (red line) and regression of harvest with time (dotted line).

the Division of Water Quality (DWQ), focused efforts on salinity management in support of the resident Artemia, microbialite, and brine fly population of Gilbert Bay. In 2017, FFSL supervised the construction of a breach with an adaptive management berm connecting the more saline North Arm of GSL to the highly productive South Arm (Gilbert Bay) of GSL (Fig. 3, 4). Less saline South Arm brine flows to the North because of a head difference created by freshwater riverine inflows into the South. Conversely, density-dependent flow in the deeper portion of the breach brings back saturated brine from the North Arm. The adaptive management berm situated in the breach allows for active salinity management by controlling this bi-directional flow (Fig. 5).

FFSL and DWQ created the Salinity Advisory Committee (SAC) to advise the divisions on how best to manage the berm. The SAC is made up of experts from state and federal agencies, academia, and industries that rely on the lake. The breach and adaptive management berm allows for the export of salt to the North during drought conditions and import of salt to the South during wet cycles, thus maintaining a suitable salinity range in the South Arm (90-160 ppt) for Artemia, brine flies, and microbialites even as lake levels fluctuate.

Analysis of a decade of salinity and salt mass presented at the SAC (Brown, Bosteels & Marden, 2023), CFM

Figure 3. The breach in the causeway connecting Gilbert Bay (South Arm) to Gunnison Bay (North Arm) of Great Salt Lake

modeling of the bi-directional flow (Rasmussen *et al.*, 2021), and more recent unpublished studies have informed the state of Utah on how best to manage the berm. During the past nine months, the berm was raised twice: first, in July of 2022, to block the return of saturated brine from the North Arm; and second, in February of 2023, to capture spring run-off in the southern portion of the lake to better dilute the South Arm and, potentially, set conditions for future modifications, including export of salt to the North Arm. These modifications in conjunction with high run-off from unusually heavy winter precipitation have already brought the salinity of the South Arm back to levels that better support the health of the Artemia resource,

Figure 4. The breach showing the raised adaptive management berm blocking the return flow of saturated brine from the North Arm (pink color)

the microbialites and brine flies, and the millions of migratory birds that rely on them.

Legislation and funding

Since 2020, unprecedented legislative action, including dozens of bills encouraging water conservation generally and benefiting GSL in particular, have driven structural changes to a system of water law historically stacked against conservation in general and particularly GSL. With these changes, Utah's State Engineer and water managers are better able to move blocks of conserved water downstream to GSL. Additional changes earmark future mineral royalties derived from the lake to protect and enhance water flows to the lake. Lastly, the legislature over the past two years has allocated more than $60 million to help secure water supplies for the lake as well as more than $560 million to promote water conservation in homes, businesses, and farms within the GSL watershed.

These measures will take time to come to fruition, nevertheless, the combination of structural legal changes, long-term funding, and water conservation have laid the foundation to significantly improve the amount of water that flows annually into GSL.

Conclusion

The trifecta of adaptive and sustainable harvest management, active salinity management, and unprecedented policy innovations and new funding all reflect a robust model of sustainable management for GSL. Reflecting this, the Marine Stewardship Council (MSC) recently gave the Great Salt Lake Brine Shrimp Cooperative, Inc. (DBA Great Salt Lake Artemia) its sustainable wild fishery certification, making it the first inland fishery in the United States to earn this prestigious recognition. MSC certification is a testament to the unprecedented cooperation between the brine shrimp industry, state agencies, academia, and NGOs for their dedicated efforts to maintain a healthy and sustainable Great Salt Lake.

References available on request.

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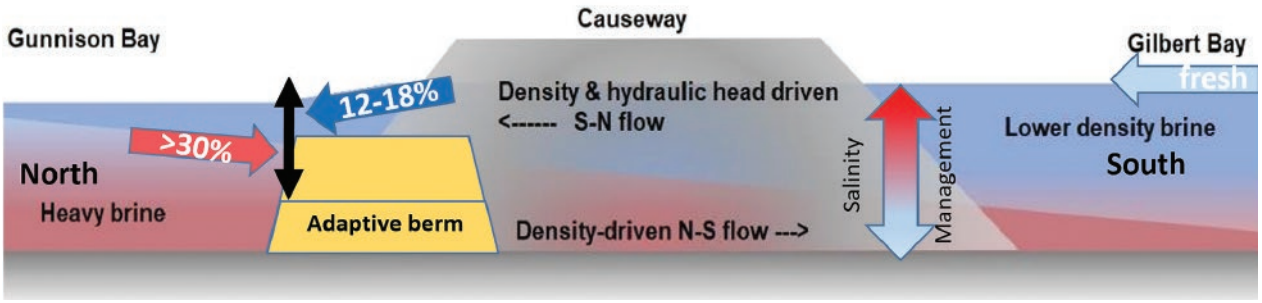

Figure 5. Schematic diagram of a cross-section of the breach with the adaptive management berm. Raising the berm prevents the return flow of saturated brine from the North Arm, thus allowing a reduction of South Arm Salinity through dilution from freshwater inflow and salt export to the North. Conversely, lowering the adaptive berm allows for saturated brine to enter the South Arm and thereby increase salinity in times of excess precipitation.