Restoring Lake Urmia to a Range of Lake Levels

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More than 5 million people live near Lake Urmia in northwestern Iran. Urmia is one of the world's largest hypersaline lakes, yet over the past two decades, the lake has lost 95% of its volume and the lake level has dropped more than 7 m. We synthesized 40 years of available data, defined 10 management objectives for human health, water quality, ecology, recreation, and agro-economy (Box 1), and described trade-offs between these objectives and lake level. Results show that a single "ecological level" such as that set recently by the Iranian government may not achieve the objectives. Managers should identify a range of lake levels to maintain priority ecosystem benefits.

In response to falling Lake Urmia lake levels, the Iranian government set a target lake restoration level of 1274 m above sea level (corresponding water volume of 14.5 km^3). This "ecological level" is thought to be the lake level at which salinity will fall below 263 g L^{-1} and increase survival of brine shrimp (*Artemia* spp.), a primary food source for millions of birds that once inhabited Lake Urmia, including 40,000–80,000 pairs of breeding greater flamingos (*Phoenicopterus roseus*).

New Contributions

Many of the 40 years of available experimental, field, satellite, and model data we used to define the 10 management objectives are noisy and have many variations (Box 2). We found:

1. A lake level of 1274 m may result in lake salinity between 240 to 290 g L^{-1} (Fig. 1). The ecological lake level may not recover brine shrimp and flamingo populations.

2. Lake ecosystem services do not converge neatly to a single lake level as the ecological target of 1274 m implies (Figs. 2–3).

3. Lake managers should identify which objectives they care about and restore the lake to a range of levels that maintain those ecosystem benefits.

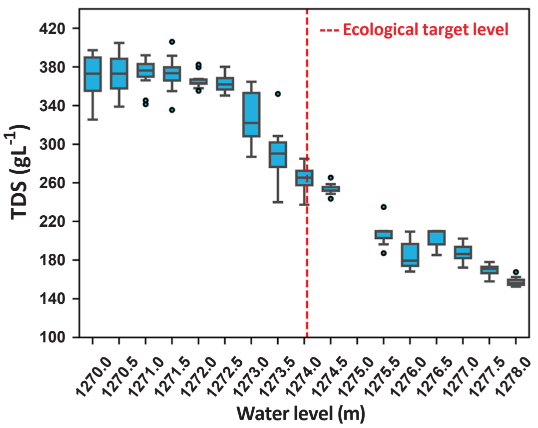

Figure 1: Total dissolved solids (TDS) vs. Lake Urmia Level from 1977–2017. Note: Error bars show the range of TDS data at each lake elevation. For comparison, the TDS of seawater is near 35 g L^{-1}.

Box 1
The 10 management objectives

Human Health	1. Reduce dust produced from dried lake bed.
Water Quality	2. Keep salinity below the brine shrimp survival level. 3. Keep suitable ionic composition.
Ecology	4. Increase number of brine shrimp. 5. Conserve indicator bird species. 6. Prevent islands from connecting to each other. 7. Prevent islands from connecting to lake shore. 8. Keep north and south arms connected.
Recreation	9. Promote boating and recreation.
Agro-Economy	10. Increase agricultural benefits.

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Benefits of Considering a Range of Lake Levels

- Gain Flexibility to Adapt—Lake managers will have the flexibility to adapt water allocation, agricultural development, and restoration strategies over time. They can adapt as they learn more about salinity, salts forming and collecting on the lake bottom, inflows to reservoirs, illegal water withdrawals, agricultural runoff and returns to rivers, flooding, evapotranspiration, and other important lake system processes.
- Achieve Many Restoration Objectives—Some objectives, such as reducing dust, protecting threatened and endangered sheep and deer on islands, and promoting recreation can be achieved below the ecological level.

Limitations

- Because the data are noisy and bounds will change over time, we do not provide lower or upper bounds for the range of suggested lake levels.
- We assume historical observations of water quality, brine shrimp, flamingos, and other objectives will again hold when the lake rises to the medium and high levels.
- We lack data to include climate and wetland objectives.

Box 2
Sources of Noisy and Uncertain Data

- ±0.27 m discrepancy between measured lake levels and levels estimated from satellite derived depth-area-volume data.
- Min and max lake levels each year that differ by at least 0.5 m (Fig 3, green error bars).
- Lake inflow volume different than evaporation volume and lake volume change.
- Uncertainty in measuring salinity at saturation state.
- Salts that form and collect on lake bottom and decrease lake depth.
- Uncertain invertebrate densities needed to support birds.
- Changing dust areas.
- Iranian currency devalued and crop prices changed after 2012.

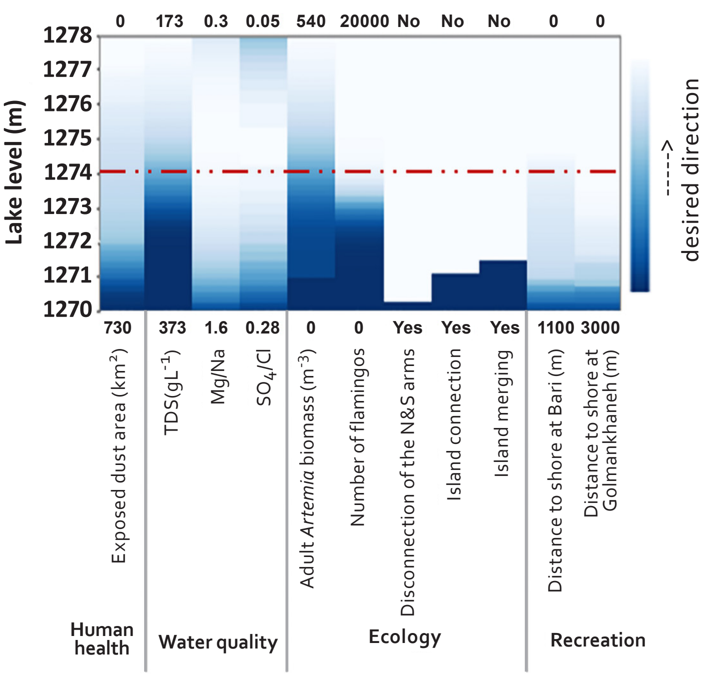

Figure 2. Tradeoffs between management objectives and lake level for the first 9 objectives in human health, water quality, ecology, and recreation.

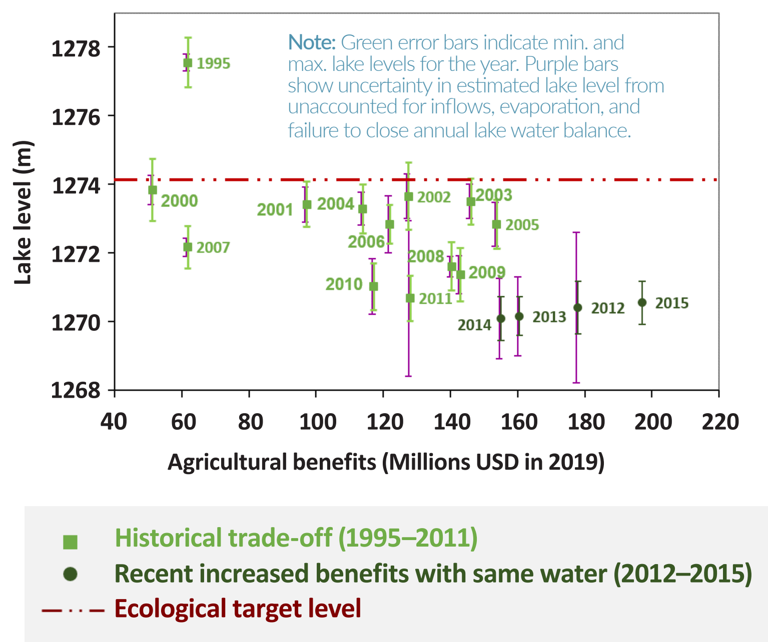

Figure 3. Tradeoff between lake level and 10th objective for agricultural benefits. After 2012, agricultural benefits increase from inflation and rising crop yields, while reservoir releases for agriculture are relatively steady.

READ further about data, restoration objectives, and results at Sima et al. (2020)

"Restoring a Saline Lake to a Range of Water Levels with Noisy Data and Diverse Objectives"

http://digitalcommons.usu.edu/cee_facpub/3757/

WHAT ELSE CAN I DO?

- **ENCOURAGE** researchers and managers to identify a range of lake level scenarios in their new experiments, modeling studies, and lake restoration efforts, rather than a single ecological level of 1274 m.
- **CONTACT** us to join this ongoing collaboration between U.S. and Iranian researchers with joint interests to tackle large, complex, and long-lasting natural resource management problems.

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