
# Restoring Lake Urmia: Moving beyond a Uniform Lake Level

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## INTRODUCTION

*More than 5 million people live near Lake Urmia in northwestern Iran, one of the world's largest hypersaline lakes. Over the past two decades, the lake has lost 95% of its volume, lake level has dropped more than 7 m, and lake restoration has gained widespread interest. The government seeks a uniform "ecological" target lake level of 1274.1 m above sea level to lower salinity below 240 $gL^{-1}$ and recover brine shrimp (Artemia spp.) and flamingos (Phoenicopterus roseus).*

*We have synthesized 40 years of available data, defined 8 ecosystem services for human health, water quality, ecology, recreation, and economy (Box 1), and related each service to lake level with uncertainties (Box 2).*

## KEY FINDINGS

1. *Lake variations prevent setting a precise target restoration level.*
2. *The current ecological target will not sufficiently lower salinity (Fig. 1) nor recover Artemia or flamingo populations. A higher lake level is needed.*
3. *Lake ecosystem services do not converge neatly to a single lake level (Fig. 2). Tradeoffs are murky.*
4. *To procure more ecosystem services, lake managers can track services and intentionally vary lake level over time.*

## BENEFITS

- Support ongoing restoration efforts—Our results show that raising the lake level to 1273 m by 2021 as part of Phase 2 restoration efforts will reduce dust, protect threatened and endangered sheep and deer on islands, and promote recreation.
- Achieve more restoration objectives—Identifying the lake levels that support/impair more diverse ecosystem services will allow managers to provide more services as they seek to raise lake level, lower salinity, and recover *Artemia* and flamingo populations.
- Adapt over time—Lake managers can more flexibly adapt water allocation, agricultural development, and restoration strategies over time as they learn more about salinity, salt precipitation, salt dissolution, inflows to reservoirs, illegal water withdrawals, agricultural runoff and returns to rivers, flooding, evapotranspiration, food webs, and other important lake system processes.

## LIMITATIONS

- 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 do not consider interactions between ecosystem services. For example, rising $Mg_{2+}$ concentrations may be toxic for *Artemia*.
- We lack data to include climate and wetland services.

**BOX 1:** The 8 ecosystem services

| | |
|---|---|
| Water Quality | 1. Maintain salinity below saturation. |
| Ecology | 2. Sustain adult *Artemia urmiana*.<br>3. Sustain indicator bird species.<br>4. Increase water level to separate islands from each other.<br>5. Increase water level to remove bridges from islands to land. |
| Human Health | 6. Reduce dust from the dried lake bed. |
| Economy | 7. Maintain valuable ionic composition. |
| Recreation | 8. Decrease the distance between historic resort shoreline and water with a suitable boating depth. |

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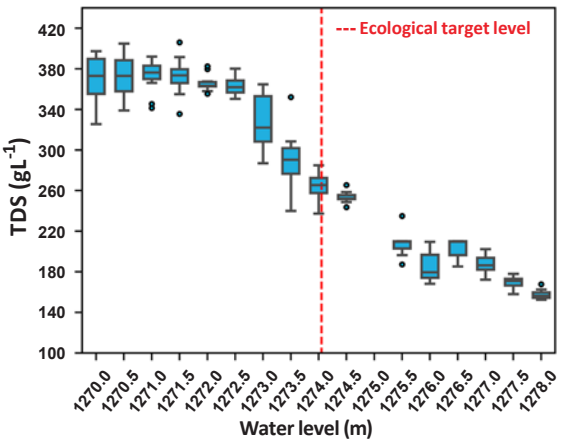


**Figure 1:** Total dissolved solids (TDS) vs. Lake Urmia level from 1977–2017. Boxes depict the 25th, 50th, and 75th percentiles of measurements between indicated lake level and next highest lake level. Bars and diamonds show the range of TDS data and outliers. For comparison, the TDS of seawater is near 35 g $L^{-1}$.

## 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).
- Mismatch between observed level and lake level calculated from water balance and bathymetry.
- 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.

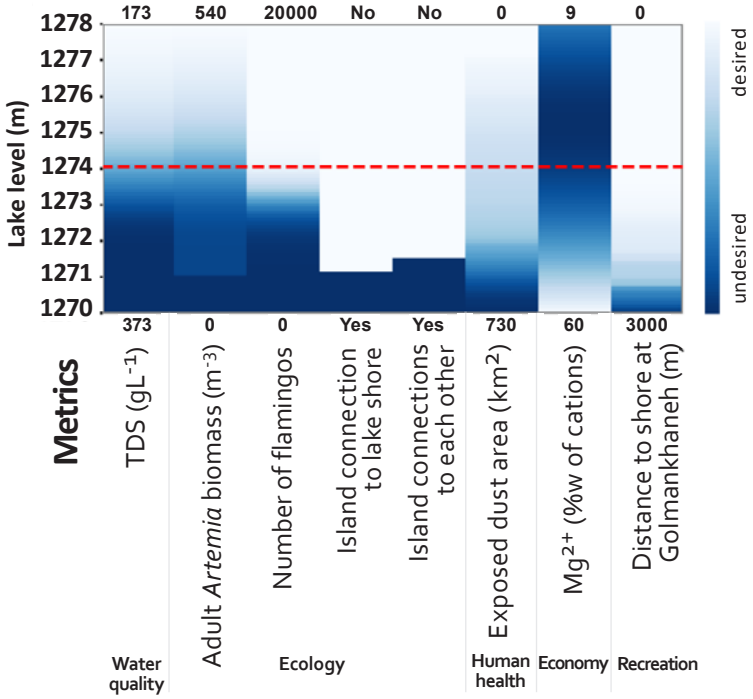


**Figure 2.** Variation of eight ecosystem service metrics with lake level in comparison to the ecological target (dashed red). Numbers on top and bottom axes show the range of each service at minimum and maximum lake levels.

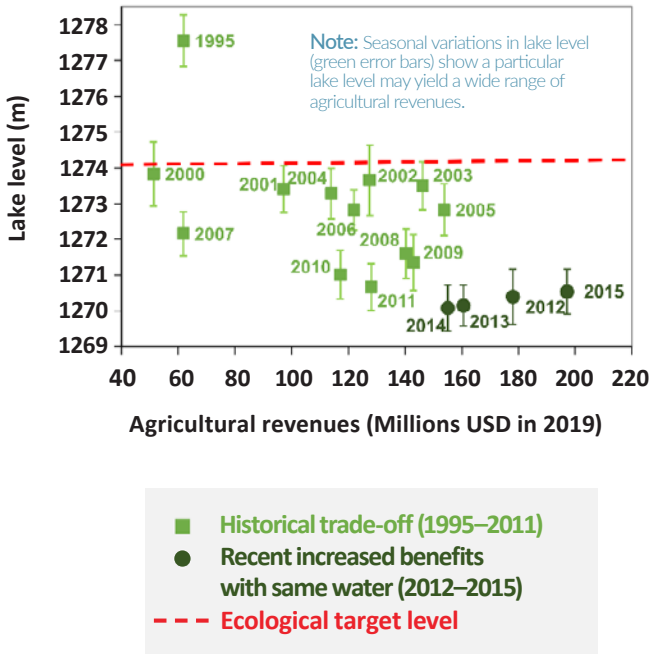


**Figure 3.** Tradeoff between lake level and agricultural revenues before (light green squares) and after (dark green circles) the 2012 Iranian currency devaluation.

## WHAT CAN I DO?

- **READ** "Restoring diverse ecosystem services for Lake Urmia, Iran: Moving beyond a uniform target lake level" (Sima et al. 2020)

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

- **ENCOURAGE** researchers and managers to include more lake level scenarios in their new work.
- **JOIN** this ongoing collaboration between U.S. and Iranian researchers.

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