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ECOSYSTEM-BASED MANAGEMENT APPROACHES FOR CONSERVATION OF GLOBALLY IMPORTANT LAKE URMIA AND ITS BASIN IN IRAN

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Abstract: *Lake Urmia is a Salt Lake and at its full capacity consider as the sixth largest saltwater lake on Earth with the surface area of over 5,000 km2, 140 km length, 55 km width and 16 m depth. It is situated in alluvial gravel deposited plains. Because of high salinity, the lake contains simple ecological food chain. The observation shows, from a decade ago the Lake Urmia began shrinking, with an annual evaporation rate of almost 1.0 m. Since Lake Urmia surface water depend on groundwater resources and watershed into basin, it is expected to disappear entirely if the proper management measures extensively not taken to reverse the condition. In this paper besides considering the multi-stresses involved upon lake, the present condition of lake will be evaluated and suggestions for restoration would be discussed and listed out.*

Keywords: Lake Urmia, Artemia Urmiana, Ecosystem-based management approach

Introduction

Lake Urmia is a vast hyper-saline lake with total dissolved salts reaching 200 g/l compared with a normal seawater salinity of about 35 g/l, located in north-western side of Iran between west and east Azerbaijan provinces, near Iran's border with Turkey. At its full capacity the lake considers as the sixth largest saltwater lake on earth, and the biggest lake in the region with the surface area of over 5,000 km2, 140 km length, 55 km width and 16 m depth. Lake Urmia with its 102 islands accepted and endorsed as a national park. It was established as a protected area in 1967, and then upgraded to wildlife reserve in 1972. The lake was declared a wetland of international importance by the Ramsar Convention in 1971 and designated a UNESCO Biosphere Reserve in 1976. The lake itself is home to a unique brine shrimp species, **Artemia urmiana**, and along with the surrounding islands and upland habitats, supports diverse species of reptiles, birds, amphibians and mammals. The watershed of the lake is an important agricultural zone with a population of around 6.5 million people; and 70-75 million people has been estimated to live within a radius of 500 km from lake. The long-term national vision is the restoration of Lake Urmia to its full capacity, to become resilient in maintaining aquatic ecosystem integrity by multi-sectoral strategy and multi-level settings approaches.

Lake Characteristics

Lake Urmia is an endorheic or terminal lake, that do not flow to the sea and water leaves the lake only by evaporation. As is generally the case, this leads to a saltwater body and in the case of Lake Urmia, salinity is extremely high. The lake has dramatically decreased in volume over the past two decades, further concentrating salts content in the lake, raising salinity to more than 300 g/L or 8 times as salty as typical seawater. Aquatic biodiversity is limited by the lake's salinity and Lake Urmia does not support any fish or mollusk species and no plants other than phytoplankton within the lake. Wetlands surrounding the lake support a variety of salt tolerant plant species. There is significant phytoplankton growth, with reports of some dense algae blooms occurring during years with low salinity. The most significant aquatic biota in the lake is a brine shrimp species, **Artemia urmiana**. This macro-zooplankton species has several adaptation capacities that help organism to survive in an extreme environment and it is the key link in the lake's food chain, consuming algae and in turn being consumed by several bird species including the Lake's migratory flamingo population. The diverse bird population of Lake Urmia and its associated wetlands was documented in a series of surveys in the 1970s which recorded an impressive list of species. Lake Urmia like other Wetlands in well-healthy condition can provide significant support to traditional infrastructure for water treatment, water supply, drought mitigation and flood control. Lake Urmia can slow down flood waters, minimize the potential flood damage

downstream and increase resilience to storms, thereby avoiding potential damage to infrastructure and human lives. In periods of drought, it could function as “retention basin”, providing water through slow release of the stored water. Beyond the immediate water quantity and quality related benefits, Lake Urmia offer recreational value and support livelihoods through e.g. traditional contributions and tourism activities. Additionally, it provides habitat for a number of native and migratory bird species, delivering some of the highest biodiversity benefits among all green infrastructure. It may also play an important role in climate change adaptation.

Geographical Location

Lake Urmia is formed in a natural depression at the lowest point within the closed Lake Urmia basin, where water comes in through 14 rivers and tributaries but leaves only by evaporation. It is located about 70 km south-west of Tabriz, East-Azerbaijan province, in north-western Iran and west of the southern portion of the Caspian Sea. The Lake Urmia basin is generally mountainous, containing two major Iranian volcanic peaks (Sahand, 3,707 meters and Sabalan, 4,810 meters), and its altitude is 1,126-1,526 m from the sea level.

Figure 01: Lake Urmia

Source: Department of Environment, Iran

Lake Hydro-Climatic condition

- Average precipitation of the basin 350 mm;
- Mean annual temperature varies between 6.5^0 C in higher altitudes to 13.5^0 C in lower altitudes;
- Annual evaporation from the lake vary between 900 to 1170 mm;
- Water supply to the lake is provided through 14 rivers with permanent flows and a number of tributaries with seasonal flows;
- Average annual inflow into the Lake is estimated at 5,300 mcm, and varies from 760 to 15,260 mcm; and,
- Water volume in normal condition is 32 bcm

Lake physical and chemical properties

The Lake is extremely saline. It is situated in an area of alluvial gravel plains. Most of the islands are small, but the largest Kabudan comprises 3,125 ha of hilly terrain. Temperature range is from -18 0C to +39 0C, causing high evaporation rates in summer season. The lake water contains

major cation as Sodium, Potassium, Calcium, Magnesium and Lithium, while the major anion includes: Chloride, Sulfate and Bicarbonate. The level of Sodium Chloride concentration is almost five times as high as the concentration of seawater and it is the major dissolved salt in the lake, so lake consider as thalassohaline. The lake is divided into north and south parts by a causeway in which a 1,500 meters gap provide minor exchange of water circulation between the 2 parts. Due to construction of more than 40 dams on 14 major rivers, drought and unsustainable agricultural practices, the level of water in lake has dropped to such extend that the salinity of lake has risen to a range of 300-500 gr/liter, and major areas of the lakebed has been completely desiccated. It is considered that the construction of dams and the causeway and bridge, along with a series of hydro-ecological factors, will eventually lead to the complete drying up of the lake, turning it into a salt marsh which will directly affect the micro and macro climate of the region and bring ill-health to people in vicinity and far away from the source. The observation shows, from a decade ago the Lake Urmia began shrinking, with an annual evaporation rate of almost 1.0 m. Comprehensive measures though presently are being taken to reverse the negative trend [10], but only 5 percent of the lake's water still remain, and the lake has shrunk by over 80 percent. It is expected to disappear entirely if the proper scientific measures not taken appropriately and intensively.

Lake Bio-ecological Property

Lake Urmia is home to more than 200 species of birds, 40 species of reptiles, 7 species of amphibians and 27 species of mammals, including the Persian fallow deer (**Dama mesopotamica**), a rare ruminant species belonging to the family Cervidae. Due to increased salinity of lake water, the viability of lake to host thousands of migratory bird species including the large flamingo populations has drastically decreased. The salinity particularly in the north part of the lake reported more. The lake is surrounded by more than a hundred small rocky islands which serve as touching and resting station during the wild birds' migration including: flamingos, pelicans, spoonbills, ibises, storks, shelducks, avocets, stilts, and gulls. The natural vegetation has largely been lost. Around the lake shore, salt flats stretch for several hundred to thousand meters. Beyond this, low vegetation dominated by Chenopodiaceae grows, and there are brackish marshes with typical communities of rushes **Juncus spp**., and reeds **Phragmites communis**. Because of very high salinity, the lake no longer sustains aquatic community. Besides, Lake Urmia is considered a significant natural habitat of Artemia, which serve as food source for the migratory birds such as flamingos and others. Due to high salinity and hydro-ecological disturbances the existence or extinction of **Artemia Urmiana** from lake is of much debate among concerned authorities.

Paleoecology

A palynological investigation on long cores from Lake Urmia has revealed the vegetation has changed from the Artemisia/grass steppes during the glacial/stadial periods to oak-juniper steppe-forests during the interglacial/interstadial periods. The lake seems to have had a complex hydrological history and its water levels have greatly fluctuated in the geological history. Very high lake levels have been suggested for some time intervals during the two last glacial periods as well as during both the Last Interglacial as well as the Holocene. Lowest lake levels have occurred during the last glacial periods.

Current Condition

Lake Urmia water level has faced some changes in the course of time, but these changes usually had a fluctuating trend, and because of the lake resiliency capacity led the level back to normal condition. This time it is more than a decade that due to severe drought and human made pressures, like water extraction and dam construction, and loss of the resiliency capacity the level of the lake has constantly dropped down. The present water level of the lake is 1270.6 meters above sea, which is 4.65 meters less than the average level and more than 3.5 meters under ecological sustainability of the lake. It is currently in a state of ecological crisis with major impacts on biodiversity and socio-economic conditions of people, living in surrounding area. The water level has continuously decreased and salt concentration increased. The main reasons for this situation are:

- Reduced precipitation through long-term climate change;
- Excess water abstraction from rivers and ground water resources;

- Development of water and land dependent projects;
- Enhancement of agricultural activities;
- Irrigation through traditional massive water use system;
- Withdrawal by unauthorized irrigation wells;
- Water intensive crop cultivation;
- Unsustainable urban development around the basin;
- Unsustainable conservation management approaches;
- Urban, industrial and agricultural pollution load;
- Unsustainable utilization of biodiversity resources and ecosystem services; and,
- Land degradation and flow of sedimentation load

Ecological Impacts

Reduced water level of the lake has already concentrated the existing salts to 300-500 g/L in many locations with remarkable impact on ecological conditions. Sodium Chloride concentrations higher than 320 g/L is believed to be fatal to the lake's brine shrimp. Optimal conditions for Artemia urmiana appear to be at salt concentrations well under 200 g/L and as salinity rises much above this level, there is a measured negative impact on growth rate, reproduction, egg laying capacity and mortality. Based on in situ observations of the brine shrimp populations under varying salinities in Lake Urmia, it has been suggested that a concentration of 240 g/L or less would be required to sustain a viable population. The lake's brine shrimp are the sole link between the primary production of the lake's algae and the diverse migratory bird population which feeds on this species. Because the brine shrimp occupy this crucial link in the ecosystem their extinction would likely create disappearance of Lake Urmia's migratory bird populations and affect the entire ecosystem's sustainability. Any current or future tourist activities focused on bird populations would likely also decline dramatically. Though climate change plays a great role on water level, its effect on the lake considering its bathymetry has not yet been studied. As lake levels decline, the exposed lakebed is left with a covering of salts, primarily Sodium Chloride, making a great salty desert on much of the 400 km2 of lost surface area. These salt flats will not support agriculture and inhibit growth of most natural vegetation. The salts are also susceptible to blowing and likely will create salt-storms like the ones that have resulted from the drying of the Aral Sea, located 1,200 km to the northeast of Lake Urmia. Blowing salts from the Aral Sea have been linked to vegetation mortality in some cases or, more frequently, reduced vegetation growth, reduced crop yields, ill effects on wild and domestic animals, respiratory illness, eye problems, and throat and esophageal cancer. Based on the experience of the Aral Sea salt storms, it is likely that many of the tens of millions of people who live within a few hundred kilometers of the lake will be close enough to experience the impact of these salt storms. With present condition and further degradation, Lake Urmia will no longer support biological diversity, landscape integrity, climate regulation, pollution and sediment retention, groundwater recharge, fishery, migratory birds and bird's habitat, medicinal herbs, ecotourism, recreation, cultural heritage and soon.

New approach to wetlands Restoration/Conservation management in Iran

Wetlands restoration is the renewal of wetlands that have been drained or partly lost as a result of natural or human activities. Wetlands that have been drained and converted to other uses often retain the characteristics of soil and hydraulics and therefore can be restored. In general, the best way to prevent further loss of ecological and economic value due to degradation of wetlands is by eliminating the pressures driving the negative impact on wetlands.

Current progress of ecosystem approach in Lake Urmia Basin:

- Developing the watershed integrated management plan;
- Budget allocation review and approval of priority projects;
- Environmental water right calculation and approval;
- Water shares calculation and approval with regard to water resources utilization by the provinces located in the basin and securing the lake environmental water rights;
- Developing management plans for satellite wetlands;
- Moratorium on all new dams and irrigation projects;
- Training, participation, provision of equipment, developing capacity among stakeholders;

- Intense supervision on water utilization in the basin and control of illegal water exploitation by Ministry of Energy and Ministry of Agriculture;
- Cloud Seeding in the Basin;
- Developing Drought Risk Management (DRM) plan; and,
- Developing sustainable agriculture practices in demonstration sites

Ecosystem-based Management Roadmap

An Ecosystem-based Management (EbM) approach is being used to develop a watershed management plan by integrating natural, social, economic and cultural factors to develop a mechanism for achieving a sustainable future in the Lake basin. Achieving sustainability in our economies, communities, and natural environment requires rethinking traditional, fragmented approaches to managing complex and interrelated problems. EbM is an emerging, integrated approach that considers the entire ecosystem, including humans as part of the ecosystem, to achieve improved environmental conditions and sustained ecosystem goods and services that support human needs and social goals. EbM develops and transfers scientific understandings to policy-makers of how wetland ecosystems function across a wide continuum of scale and scope. Scientific information should create roadmap and adaptive measures, as new information becomes publicly available. EbM considers the interdependency of impacts to different sectors, including human, social, and economic domains. Moreover, an ecosystem approach is, by design, interdisciplinary in nature and benefit from the coordination and cooperation of stakeholders at all levels. Integrate ecological, political, legal, and administrative information through proactive inter-sectoral coordination and cooperation. Department of Environment in Iran developing ecosystem-based management approaches as the conceptual framework to better manage local activities that affect the states of Lake Urmia and its basin. A guiding principle for this Action Agenda is sustainability.

Wetland Ecosystem-based Management principles

1. Place-based focus and tailored approach;
2. Scientific foundation for decision-making;
3. Measurable objectives to direct and evaluate performance;
4. Adaptive management to respond to new knowledge and information;
5. Recognition of interconnections within and among ecosystems; and,
6. Involvement of all possible stakeholders

Proposed Method

To incorporate EbM into Lake Urmia conservation program we need to create both educational and applied programs. EbM education is necessary for both Department of Environment (DoE) employees and the civil society to maintain healthy ecosystems and economies within the Lake basin. The applied program incorporates EbM into Lake Urmia existing conservation and restoration programs. Staff trainings are based on the 6 EbM principles mentioned above. The specific programs are tailored to facilitate EbM understanding and how it relates job duties by staff. This enables DoE staff to implement EbM into everyday conservation actions. Moreover, employees apply EbM into their specific task by considering EbM principles for each departmental field activities and applying them where appropriate**.**

Result and Discussion

Annually more than 10 BCM (Billion Cubic Meter) extra water withdrawals from groundwater basins occur in Iran. Ministry of Energy, IRI has got measurement (hallmark) on quantity of renewable water for each groundwater basin. When extra withdrawal from each basin happen, that basin consider as red area. Presently more than half of the total 600 plain areas in Iran has got red signal indicating no further extra groundwater withdrawal possible in those basins. For compensating the last 4 decades mismanagement on excessive groundwater withdrawals, at least 2 decades for recovery will take time, provided not only we don't withdraw anymore, but also with good integrated watershed management program and appropriate water allocation and prizing system for each sector, inject some quantity of water annually to the red area basins. Agricultural water use must reduce to its maximum amount by changing crop cultivation variety from high water usage to low water usage in some intense areas. With present agricultural product and crop cultivation, agricultural sector consumes 85 percent of available allocated

freshwater in Iran, while the industrial and domestic sectors together consume the rest 15 percent of the available allocated freshwater. From the total amount used, wastage of water from agricultural sector is almost 70 percent and that from industrial and domestic sectors together the wastage stands as 20 percent. Very limited water resources with uneven distribution, and growing demands with high wastage of water are the main water challenges this generation face in Iran.

Regarding Lake Urmia, it is apparent water level has rapidly declined since the mid-1990s after having remained relatively stable over the 30 prior years. Construction of dams more than 40 dams and diversion of surface water for agriculture, along with reduced precipitation and warmer temperatures over the basin, and reduced inflow of groundwater are generally accepted as the causes. Reduction in water volume concentrates the salts in the lake making it too saline for the Artemia which being somewhere at the bottom of the simple ecological pyramid that support the very diverse bird population for which the lake provides important habitat specially during winter season. The surrounding brackish wetlands with productive and diverse plant population also have ill-ecological condition. As the lake retreats from its original shoreline it leaves a dense layer of salt, primarily sodium chloride, which leaves the land unusable for agricultural practices and threatens to unleash damaging storms of wind-blown salt on the surrounding area. The lake's salinity has reached 300-500 g/L saturation level and threatens to decimate the lake's Artemia population which is a key link in the ecology of the lake and surrounding wetlands. While effective integrated water management is called for by many, there are no easy implementing approaches yet. The lake's surface area has been estimated as large as 5000-6000 km2 but since 1995 it has declined and was estimated from satellite data to be only 2,366 km2 in August of 2011 (Landsat data).

As a general rule the lake water level and salinity are influenced by how much water flows in and out. In this case the decline is caused by combination of factors which include dam constructions on rivers, drought, increased water diversion for irrigated agriculture within the lake's watersheds and also mismanagement. In addition, a causeway has been built across the lake with 1,500 m gap for water to move between the northern and southern halves of the lake [5] and has been suggested that, this has decreased circulation within the lake and altered the pattern of water chemistry. Evidence suggests the impact of the causeway on the uniformity of water chemistry in the lake has been minimal.

The Lake Urmia ecosystem is largely shaped by its physical environment, such as climate, geology and mineral content. These non-living factors determine which organisms survive and thrive in lake's ecosystem. However, the unfolding ecological disaster threatens to leave much of the lakebed a salt-covered wasteland. The continued decline would lead to increased salinity, collapse of the lake's food chain and ecological system, loss of wetland habitat, loss of biological support especially for migratory birds, loss of nutrient cycling and sediment retention capacity, wind-blown "salt storms", alteration of local climate and serious negative impacts on local agriculture and livelihoods as well as regional health and well-being. Green Infrastructure (GI) solutions for water management are also at the heart of Ecosystem-based Adaptation, defined as "biodiversity and ecosystem services as part of an overall adaptation strategy to help people and communities adapt to the negative effects of climate change at local, national, regional and global levels" [26]. The growing interest in GI is being driven by a combination of factors, including the need to improve water management, owing to a growing demand for and a scarcity of freshwater, and the increasing impact of climate change, including extreme events such as floods and droughts. In the past decade continuous drought has occurred in the Urmia Lake Basin accompanied by increasing water demands, resulting in decrease of the amount of runoff in the basin from about 7 billion m3 to less than 3 billion m3, and the inflow to the lake which has usually been 4.5 billion m3 /year, has decreased to less than 1 billion m3 in some successive years. These factors along with human activities have contributed to the crisis in the basin.

Considering reduction of water level (more than 5 meters from the average level, and almost 4 meters from the minimum ecological level), the amount of water which should be provided to the lake to get to the minimum level is estimated 20 billion m3. This is not easy to reach in short-term. So, the high priority action is to avoid more reduction of the water level and

stabilize the water level. The mid-term and long-term goals then will be achieving minimum ecological level in 5 years and average level in 10 years. Now by promoting capacity building there is a better inter-sectoral understanding and cooperation at the national and provincial level. Raising the level of public awareness also increased participation of local communities. Since the restoration program has been kept at the high national priority level, there is a great hope of improvement in the basin. Given the international and regional importance of the lake, Government of Iran is maximizing its efforts for capacity building in order to recover the lake. It is obvious inter-sectoral implementation for restoration of the lake will encounter obstacles, since it is a new approach. But considering the management potentials in different sectors of the basin, achieving this, is not far from reality.

Ecosystem-based Management (EbM) is an adaptive approach to management, ensuring the coexistence of healthy, functioning ecosystems with human communities. This management structure differs from others in that it uses a holistic approach to management, incorporating an ecosystem perspective, of which people are an integral part of the program. The goals of EbM integration within Lake Urmia is to conserve, maintain, and restore lake ecosystem and its watersheds so it can become healthy, productive, and restore its resiliency while being able to deliver the resources people want and need. EbM provides an excellent framework for collaborative science and evidence-based co-participatory management that is adaptive and driven by measurable objectives. To address the threats to Lake Urmia, co-management program may improve lake ecological health and provide economic security through Ecosystem-based Management to local community for present and future generations.

Conclusion

- The application of EbM improves governance quality and environmental sustainability;
- Lake Urmia EbM approach provide framework for assuring environmental sustainability;
- Incorporating EbM into DoE may be conducted by science and evidence-based approach;
- Balancing ecosystem sustainability and human activities need collaboration with private sectors and civil society;
- Incorporating EbM into national conservation policies and programming is in an on-going process that will continue to restore ecosystems and support human well-being;
- EbM is an adaptive process which needs to be locally tailored;
- There is firm evidence on a consistent direct relationship between community willingness and participation, and improved wetland condition outcomes;
- While there are many examples of devolving management rights to local levels, few cases handover the full bundle of rights to local levels to use, manage and transfer resources;
- Evidence show the efficacy of co-management participatory arrangements for lake restoration; and,
- There is a need to assemble and examine the long-term social and biophysical datasets to build this evidence-base-ecosystem-based participatory management.

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