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CONSERVING AQUATIC ECOSYSTEMS AND BIODIVERSITY UNDER CLIMATE CHANGE

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Abstract. A river or lake can still hold water after it has ceased to provide suitable habitat for some species. This review draws on the scientific literature to examine how temperature, dissolved oxygen, seasonal flow, and salinity interact in inland waters. It compares findings from long-term lake observations and a global assessment of freshwater animals with evidence from wetlands in Uzbekistan. For the Aydar-Arnasay, Sudochye, and Tudakul–Kuymazar systems, it identifies ecologically important seasons and proposes monitoring indicators. Aligning water allocations with fish spawning and bird migration, conserving shoreline habitats, and pairing hydrological measurements with biological surveys would help managers assess conservation outcomes.

Keywords: climate change, wetlands, inland waters, freshwater biodiversity, environmental flows, dissolved oxygen, habitat, Aral Sea region, Uzbekistan.

Introduction

Keeping a lake at a constant level throughout the year may seem convenient for water managers. Yet fish need access to shallow shoreline areas to spawn, while birds may need exposed mudflats for feeding. These habitats require different water levels at different times. A conservation plan must therefore specify where water is needed, when it must be present, and for how long [1, 2].

This review covers rivers, lakes, reservoirs, and adjoining wetlands. It compares climate assessment reports, studies based on long-term measurements, global assessments of species extinction risk, and official Ramsar site descriptions. Global observations are used to explain ecological processes, while local descriptions guide the choice of conservation objectives. The monitoring approaches outlined for Uzbekistan are the author's proposals.

Water Temperature and Dissolved Oxygen

Combining field measurements with satellite observations, O'Reilly et al. found that summer surface water temperatures in the lakes studied rose by an average of 0.34 °C per decade between 1985 and 2009. Warming rates varied considerably among lakes. Differences in depth, wind exposure, and mixing can produce different responses even at the same air temperature. Meteorological records

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from the catchment therefore need to be supplemented with direct measurements of water temperature [1, 3].

Jane et al. analyzed 45,148 temperature and oxygen profiles collected between 1941 and 2017. Across 393 temperate lakes, surface oxygen losses were associated with the lower solubility of oxygen in warmer water. In deeper water, reduced mixing between warm and cold layers and changes in water clarity were important. Surface oxygen concentrations rose in some productive lakes. A single daytime surface sample therefore gives an incomplete picture of conditions for organisms living near the lake bed [4].

Fish that require cold, oxygen-rich water may experience warming and oxygen loss simultaneously. When surface water becomes too warm and deeper water contains too little oxygen, the layer a fish can occupy narrows. A lake may still hold a large volume of water even as the volume suitable for a particular species shrinks. In such cases, water-level records should be supplemented with temperature and dissolved oxygen profiles at multiple depths [1, 4].

Seasonal Streamflow and Habitat Connectivity

Seasonal variation in discharge matters for river ecosystems. Rising spring flows temporarily connect the channel to its floodplain, giving some fish access to spawning sites and their young access to feeding grounds. During low flows, deep pools and cool tributaries provide refuge. Water withdrawals or dam operations that alter the timing of these events can intensify the effects of drought. Environmental flow planning therefore considers the timing, duration, and quality of flows as well as their volume [1, 2].

Grill et al. assessed 12 million km of river networks. Only 37% of rivers longer than 1,000 km remained free-flowing along their entire length [5]. Where a migration route has been severed, increasing discharge alone cannot restore access to upstream spawning grounds. Managers must identify which barrier cuts off an important tributary, which species need to pass it and when, and whether fish can return downstream [5, 6].

Assessing Risks to Biodiversity

Sayer et al. assessed freshwater fishes, decapod crustaceans, and dragonflies and damselflies using data on 23,496 species. Across the three groups, an estimated 24% of species were threatened with extinction [7, 8]. This estimate reflects the combined effects of water withdrawals, pollution, dams, habitat change, and other pressures. It cannot be attributed to climate change alone.

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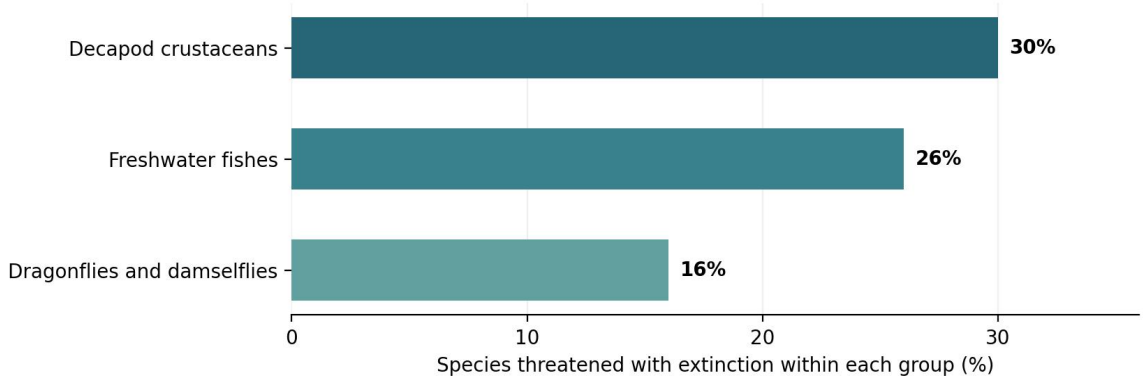


Figure 1. Extinction risk in three groups of freshwater animals. Each bar shows the percentage of threatened species within that group. Sources [7, 8].

Assessing conservation outcomes requires tracking which species are present and whether they reproduce, as well as counting species. The total can stay constant when a widespread species replaces a native one. Finding adult fish at a site does not establish that young fish are being produced there. Likewise, during a drought, birds may concentrate at the last remaining water body and raise the count at that site. Such counts should be interpreted alongside surveys of neighboring water bodies and measurements of the shallow habitat available.

Distinguishing Climate Effects from Other Pressures

The history of the Aral Sea illustrates the importance of distinguishing causes. NASA's review of observations identifies the diversion of much of the flow of the Amu Darya and Syr Darya for irrigation, beginning in the 1960s, as the main driver of the sea's historical contraction [9]. Estimating the additional effect of a hot or dry year requires records of precipitation and air temperature, river withdrawals, flows reaching the delta, and drainage water entering the lake. Satellite imagery can reveal shoreline retreat. Determining its causes requires a water balance for the same period.

Conservation Priorities for Wetlands in Uzbekistan

The Convention on Wetlands country profile lists five wetlands of international importance in Uzbekistan, with a combined designated area of 739,115 hectares [10]. Site boundaries may encompass reed beds, shallows, and other habitats as well as open water. The areas below refer to the designated Ramsar sites. The area covered by water varies over time.

Table 1. Ecological functions of three Ramsar sites and proposed monitoring activities [11–13].

Site and designated area	**Ecological features in the Ramsar description**	**Proposed monitoring**

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Site and designated area	Ecological features in the Ramsar description	Proposed monitoring
Aydar-Arnasay Lakes System 527,100 ha	Migratory routes intersect here. Waterbirds stop and winter at the site, and fish use it for spawning.	Record the area of shallow habitat and sources of disturbance during bird counts.
Sudochye Lake System 84,000 ha	A former bay of the Aral Sea. Water levels depend on inflows from the Amu Darya and irrigation canals.	Compare inflow volume, electrical conductivity, and the duration of inundation at the reed-bed margin.
Tudakul and Kuymazar Reservoirs 32,000 ha	A stopover for migratory birds. Kuymazar supplies drinking water. Tudakul supports aquaculture and agriculture.	Compare the withdrawal schedule with wintering bird counts and conditions in undisturbed shoreline areas.

At Aydar-Arnasay, conservation can focus on an individual bay where birds feed or a shallow fish spawning area, as well as on the lake system as a whole. At the same average water level, two bays with different shore gradients and vegetation cover may offer different areas of open habitat for waterbirds. Linking seasonal count stations to shoreline profiles can reveal this variation and help identify where to manage water levels and where to reduce disturbance from human activities [11].

At Sudochye, the boundary between reed beds and open water provides a practical monitoring location. In a year of reduced inflow, observations should establish whether a shift in this boundary coincides with a change in salinity. Simultaneous measurements of electrical conductivity at the inlet and in the open lake can help distinguish the influence of incoming salts from the effects of evaporation within the lake. Water level and sampling time should be recorded at both locations [12].

The Tudakul and Kuymazar reservoirs serve different purposes. At Kuymazar, for example, incorporating ecological requirements into the drinking-water withdrawal schedule means considering water levels at wintering sites alongside continuity of supply. The Ramsar description notes the site's importance for the white-headed duck (Oxyura leucocephala). Following the same winter survey routes each year and recording observation time would make comparisons more reliable [13].

Selecting Conservation Measures and Evaluating Outcomes

Restoration can begin with a measurable objective for a particular species or habitat. For example, managers can check whether a seasonal bay retains water long enough for young fish to return to the river channel. This objective can guide the timing of environmental flow releases. If a structure blocks access to the floodplain, it may also need to be adjusted to improve passage. These decisions should be agreed upon with the water allocation authority, local ecologists, and water users [2, 6].

Table 2. Proposed monitoring protocol for evaluating adaptation measures in a water body.

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Conservation objective	Where, when, and what to measure	Outcome indicators
Detect summer oxygen depletion	Measure temperature (°C) and dissolved oxygen (mg/L) profiles in a deep lake and a shallow bay during the warm season.	Thickness of the layer suitable for a native species and duration of oxygen depletion.
Protect fish spawning habitat	Record river discharge (m^3/s) and days of floodplain inundation before and after spawning.	Presence of young fish on the floodplain and an open route back to the channel as water recedes.
Conserve waterbird habitat	Count birds and map water cover at fixed sites during migration or wintering.	Area of shallows used by the target species, number of birds counted, and observation time.
Reduce nutrient inputs	Measure phosphorus, nitrogen, and discharge simultaneously upstream and downstream of a wastewater discharge point.	Nutrient load entering the water body, water clarity, and changes in the seasonal dissolved oxygen minimum.

Some monitoring can be carried out remotely. Using Landsat imagery, Pekel et al. mapped the months in which surface water was present and how long it persisted, at a spatial resolution of 30 m [14]. This approach can help identify when shallow areas dried out. Field observations remain necessary to detect water in narrow tributaries or dense reed beds. Comparing baseline measurements and subsequent changes with observations from a similar site surveyed in the same season can help distinguish the effects of a wet year from those of restoration.

Conclusion

Biological outcomes should guide water management as the climate changes. Relevant measures include the timing of floodplain inundation in rivers, the thickness of the lake layer with suitable temperature and oxygen conditions for fish, and the area of shallow wetland habitat available during bird migration. Target 2 of the Kunming–Montreal Global Biodiversity Framework calls for at least 30% of the area of degraded ecosystems to be under effective restoration by 2030 [15]. At selected sites in Uzbekistan, recording biological indicators on the same day as water levels and discharge would allow managers to assess what restoration achieves in practice.

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