Accelerated eutrophication in Lake Titicaca: Historical evolution, mechanisms, monitoring, and observatory approach

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Abstract :

During 1970-1990's, deep Lago Mayor and most of shallow Lago Menor were oligotrophic with high water transparency and strong nitrogen limitation. Greens and cyanobacteria (*Anabaena*) dominated the phytoplankton, except diatoms during the dry season, with low biomass and primary production. Windy and rainy periods drove nutrient enrichment seasonality. Discharges from Puno-Juliaca, the most populated urban center (< 350,000 inhab. in 2007) made Puno bay the most eutrophicated area, with floating *Lemna* proliferation.

Currently, the deep pelagic areas of Lago Mayor remain oligotrophic. However, shallow littoral areas of Lago Mayor and Lago Menor are becoming meso- to eutrophic. In Lago Menor, northern littoral villages generate diffuse and point sources of human contamination, while El Alto is responsible for the overwhelming uncontrolled contamination of Cohana bay. The 2015 extended rainy season provoked the first major phytoplankton bloom event, spreading harmless green *Carteria* unicell over Lago Menor northern part in March-April. Anoxy killed tons of *Orestias* fish, giant frogs *Telmatobius*, and aquatic birds. Blooms have been spotted since the 2000s on images from LANDSAT satellites and NASA International Earth Observatory Orbital Station. Yet, blooms cannot be predicted because they are not studied, nor their emerging conditions. Dinoflagellate *Ceratium*, an invasive species in South American freshwaters favored by climate warming, and a problem for water treatment, is increasing in outer Puno bay, Lago Mayor and Lago Menor, occasionally forming blooms. Cyanobacteria *Limnoraphis* (syn. *Lyngbya*) predominate in Puno bay. Regime shifts occur between phytoplankton and macrophytes as typical in shallow lakes. Controlling accelerated

eutrophication requires studying Lake Titicaca biogeochemical and ecological functioning, food web topology between plankton, fish, and macrophytes, and the drivers of regime shifts.

Facing the urgency, the e-TTKK consortium is implementing a comprehensive program combining high-frequency *in situ* monitoring, biannual whole-lake campaigns, innovative state-of-the-art high-precision Sentinel satellite imaging, GIS GeoVisor IIGEO/UMSA, and Lake Titicaca Binational Observatory. This will improve our knowledge on Lake Titicaca eutrophication, anticipate extreme events, and advise decision makers, scientists, and the general public to take the best-coordinated actions for resources management and restoration of degraded areas, in response to global change.

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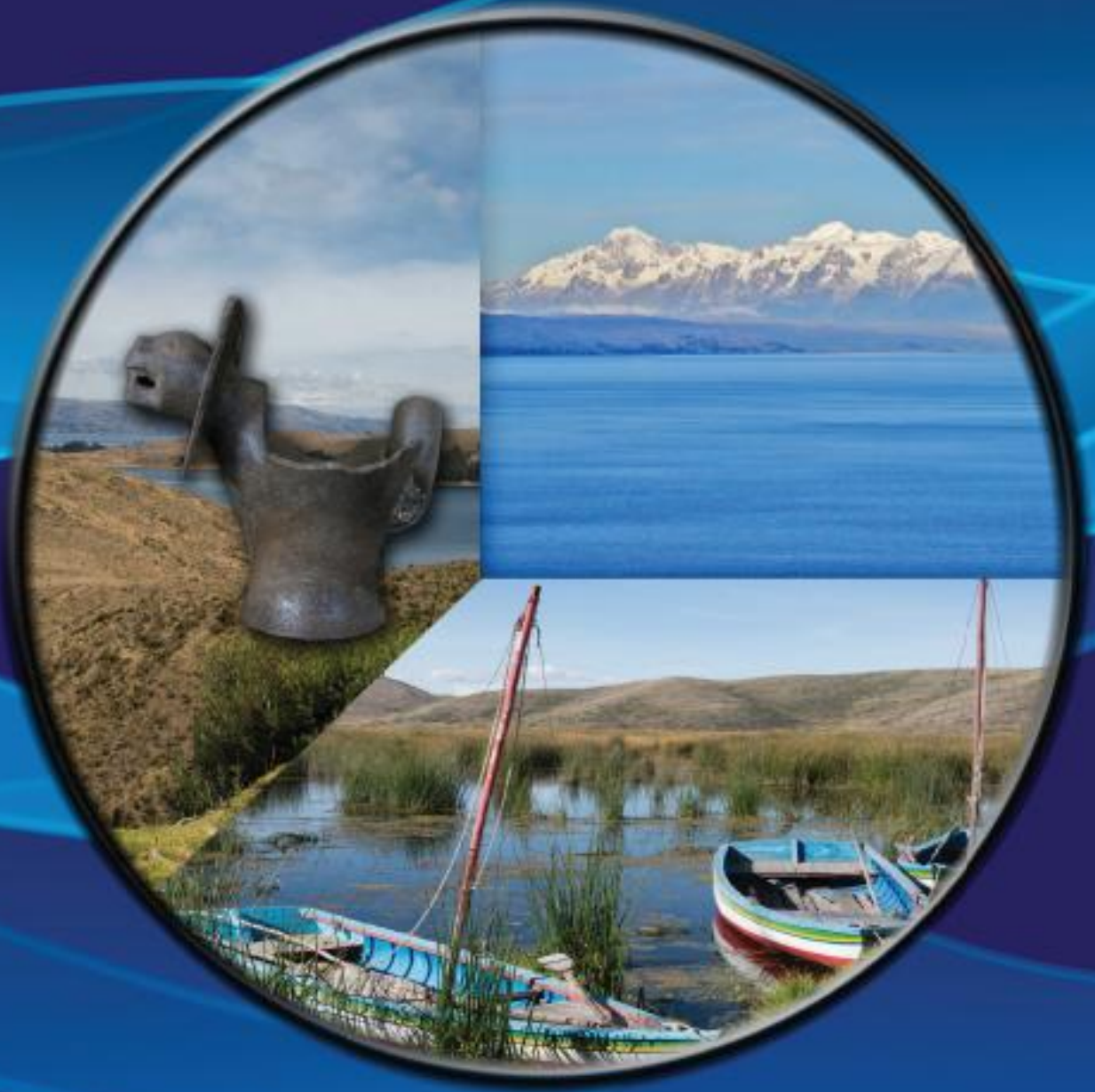

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General Planning

- **May 3rd 2016: Contamination and eutrophication of Lake Titicaca**

AM session: Mercury biogeochemistry and contamination of aquatic ecosystems of the Andes region
Keynote Lecture: Hg contamination in Latin America: the past is not what we think, nor the future (J.-R. Davee Guimarães).

PM session: Chemical contamination, eutrophication and monitoring of Lake Titicaca and its watershed
Keynote Lecture: Eutrophication of the Cohana Bay (D. Acha).

- **May 4th 2016: Arsenic issues in the Andes**

AM session: Arsenic biogeochemistry and contamination of aquatic ecosystems of the Andes region
Keynote Lecture: Arsenic contamination of groundwater (Chile) (G. Lobos).

PM session:
Workshop 1: Arsenic and mercury speciation.
Workshop 2: Paleoenvironmental studies in the Andean altiplano.

- **May 5th 2016: Historical reconstructions of the human-climate interactions in the altiplano: implication of archeological purposes**

AM session: Paleo-environmental reconstruction of Altiplano's archives
Keynote Lecture: Holocene Paleoclimatic and Paleoenvironmental History of the Lake Titicaca Basin (S. Fritz & P. Baker).

PM session: Archeology: historical human – environment interactions
Keynote Lecture: Recent contribution of terrestrial and subaquatic archeological investigation in Lake Titicaca (C. Delaere & M-A. Vella).