Potential chemical and biological indicators for Lake Akrotiri

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The European Union's Water Framework Directive (WFD) (2000) commits its member states to achieve "Good Status" in all of its surface waters, covering rivers, lakes, transitional waters and coastal marine environments. The status of each water body is assessed against physical, chemical, hydromorphological and biological quality standards, set by each country (Hatton-Ellis, 2008). The ultimate goal is to achieve good ecological status that resembles reference conditions at pristine sites, based on the community or biomass of biota present in the water body. The previous focus had been on traditional physicochemical thresholds only.

Another important aspect of the WFD is that water bodies should not be allowed to deteriorate from their existing ecological status. This may be particularly relevant for Lake Akrotiri, as it is facing increasing pressures from population growth, tourism and related development, which could increase pollution and nutrient loadings to the salt lake, thereby resulting in ecological deterioration. The lake could also be particularly vulnerable to climate change, impacting on the physical (temperature, dissolved oxygen) and hydrological conditions (area, depth, salinity) of the lake.

Biological Indicators

In the case of lakes (including salt lake environments such as Lake Akrotiri), the most common biotic indicators within monitoring plans are fish, aquatic macrophytes, phytoplankton (algae / diatoms) and benthic macroinvertebrates (AP Marine & Atlantis Consulting, 2012).

Fish

Many salt lakes (particularly those that dry up each year) are not able to sustain fish populations. However, Lake Akrotiri is large enough to retain some water through the annual drought periods, and may have fish populations that include the Mediterranean Killifish (SBAA, 2012). Fish are particularly sensitive to low dissolved oxygen levels, which is why they are a key biological indicator in lakes across Europe (UKTAG, 2008). There are problems associated with obtaining a representative fish community sample from the heterogeneous environment of a larger lake / wetland system, as multiple habitats must be sampled using a variety of fish sampling techniques to capture the full fish species range, as well as all fish life stages (Marine and Environmental Research Lab., 2016).

Aquatic macrophytes

The biomass and species composition of aquatic plants provide key information on nutrient loading and the trophic status of a lake. Large biomasses of macrophytes usually indicates nutrient enrichment. However, plant biomass can be lost if the lake becomes dominated by algae, with high densities of suspended algae shading out the higher plants. In these situations, particularly in shallow lakes like Lake Akrotiri, high nutrient concentrations and algal biomass tends to encourage a shift from submerged to emergent plants, as they are unaffected by the turbid light conditions in the water column (Hilton, O'Hare, Bowes, &

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Jones, 2006). The plant species present are also often indicative of the nutrient loadings to the water body, with some species only occurring in low-nutrient environments (Holmes, 2010). Macrophyte species assemblages are also useful bio-indicators for indicating changes in water levels / hydrology, salinity and various types of human impacts within European salt lakes (Jimenez, Martinez, Toro, & Camacho, 2011).

A comprehensive list of plant species and their distribution in the Akrotiri peninsula are given in the report by SBAA (2012).

Microbiology

Planktonic algae and diatom biomass and community composition provides the key biological indicator for nutrient / phosphorus enrichment. Phytoplankton have been widely used to assess the ecological status of salt lakes across Europe (Földi et al., 2018; Stenger-Kovács et al., 2014; van Loon et al., 2015) and nutrient limitation in the US, based on chlorophyll concentrations (Salm, Saros, Fritz, Osburn, & Reineke, 2009). Bacteria associated with various biogeochemical processes, such as denitrification and sulphate reduction, and pathogen concentrations have also been used to determine lake processes and pollution sources in European salt lakes (Lazar et al., 2017).

Phytoplankton biomass is usually estimated by regulatory authorities using chlorophyll-a concentrations within the water column. Another important assessment of ecological status that is sometimes used is by determining the percentage of cyanobacteria in the total phytoplankton biomass (Marine and Environmental Research Lab., 2016).

Zooplankton

Salt lakes that dry out during a summer drought period are not able to sustain fish populations, and so zooplankton become the principle grazer within the ecosystem. A study by Karagianni et al. (2018) has used zooplankton assemblages and biomass to assess environmental conditions in seven temporary saline lakes in Cyprus. This work has shown that zooplankton are good predictors of water level and salinity. However, zooplankton are not included as a biological element for saline lakes in the WFD, although local researchers recommend their use in ecological status assessment of Cypriot lakes in the future (Marine and Environmental Research Lab., 2016).

Benthic Macroinvertebrates

The aquatic invertebrate assemblage provides information on a wide range of environmental lake factors, such as nutrient concentrations, pollution loadings, salinity etc. In Lake Akrotiri, some of these invertebrate species, particularly the crustacean *Brachinella spinosa*, supports the large flamingo and other bird populations that use the lake over winter (SBAA, 2012), and are therefore key to maintaining this important bird foraging site. The use of macroinvertebrate assemblages in larger lakes are sometimes not used for WFD assessment, due to the heterogeneity of the lake environment and the complexity of the foodwebs. Local studies have shown that invertebrate numbers tend to be very low in these saltwater environments, which suggests that they may not be good bio-indicators in Cypriot salt lakes (Marine and Environmental Research Lab., 2016).

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