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Underwater light climate, thermal and chemical characteristics of the tropical soda lake Chitu, Ethiopia: Spatio-temporal variations

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ABSTRACT

Soda lakes are known for their extreme environmental conditions and unique assemblage of biota and provide great ecological and economic values. Although they are highly sensitive to environmental changes, soda lakes are among the least frequently studied inland water bodies. In this study, temporal and spatial (vertical) patterns of underwater light climate, thermal and chemical characteristics of a little known soda were studied. Parameters of underwater light climate showed light-limited conditions with more marked inter-monthly variations, associated with the accumulation of *Arthrospira* biomass in the shallow trophogenic zone. Water column conditions indicated superficial thermal stratification (0–3 m depths) with weak temperature gradients and weak mixing pattern. Dissolved oxygen (DO) varied considerably among months, ranging from subsurface supersaturation on certain occasions to persistent deoxygenation of most of the water column on other occasions, with the variations being attributable to the high productivity, high metabolic rates of microbes and weak vertical mixing. Alkalinity, conductivity and pH were generally high with moderate temporal and vertical variations, which were presumably associated with precipitation, evaporation and high algal biomass. In most cases, CO_3^{2-}:HCO_3^- was high (>1), suggesting lower concentration of HCO_3^-. Most of the major algal nutrients showed considerable inter-monthly and vertical variations. NO_3^- and NH_3 in the euphotic zone were often very low or undetectable while soluble reactive phosphate (SRP) and total phosphorus (TP) were considerably high throughout the study period. The observed dramatic increase in the levels of NH_3 and SRP with depth is attributable to internal loading, which is enhanced by increased microbial activities and largely anoxic water column. The concentration of SiO_2 was remarkably low, which was probably due to organic matter accumulation within the lake that tends to preclude internal loading. In general, the notable temporal and vertical variations in physicochemical parameters, associated chiefly with the lake's productivity, microbial activity, anoxic water column and meteorological conditions, probably suggest that Lake Chitu is sensitive to perturbations and that any environmental changes occurring in the lake are likely to affect the key planktonic alga (*Arthrospira*) and its ecosystem values.

Introduction

Owing to their unique characteristic composition and nature of biota, extreme environmental conditions and closed hydrological systems, soda lakes are among the inland water bodies suited for the study of vital ecosystem processes. They are among the most productive water bodies in the world and are considered important natural resources providing great ecological, economic, recreational and scientific values (Williams, 2002). The soda lakes of East Africa are typical examples of such lakes and are peculiar in having extremely high primary productivity and algal biomass associated with the superabundance of *Arthrospira* (Talling and Lemoalle, 1998; Jones and Grant, 1999; Oduor and Schagerl, 2007a; Krienitz and Kotut, 2010) and supporting the huge flocks of the Lesser Flamingos. In such lakes, all aquatic biota and ecological processes (*e.g.* nutrient cycling) are highly dependent on pelagic primary production by *Arthrospira* as they support little growth of other primary producers (*e.g.* macrophytes). Compared to other aquatic ecosystems, soda lake ecosystems are highly sensitive to changes in the environmental conditions resulting from natural or human-induced effects. However, there is limited scientific information on the basic ecological processes and patterns of their temporal fluctuations in soda lake ecosystems, which may assist in the understanding of their ecological functions and

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prediction of future trends (Talling and Lemoalle, 1998; Williams, 2002).

Studies on African soda lakes have shown that variability of some environmental factors could be of prime importance in regulating biological community structure and diversity (Wood and Talling, 1988; Oduor and Schagerl, 2007b; Krienitz and Kotut, 2010; Talling, 2010). Increase in salinity, for example, has been demonstrated to cause a reduction in biological diversity, leading to the dominance of organisms with high adaptive capacity to osmotic stress (Hammer, 1986; Williams, 1998; Jones and Grant, 1999). Such fluctuations of salinity in soda lakes were also reported to have caused variability of biomass of *Arthrospira* despite its ability to grow over a wide range of salinity (Vareschi, 1982; Melack, 1988). Studies made on Ethiopian rift lakes (Wood and Talling, 1988; Kebede et al., 1994) and some Kenyan soda lakes (Melack, 1988; Schagerl and Oduor, 2008) have also reported shifts in phytoplankton community assemblages associated with variations in salinity and alkalinity, mainly due to seasonal and inter-annual variations in precipitation and evaporative events. Apart from salinity, seasonal changes in such environmental variables as nutrients, stratification and mixing patterns, and underwater light climate have also been shown to affect phytoplankton composition and biomass in tropical African lakes (Talling and Lemoalle, 1998; Gebre-Mariam, 2002; Oduor and Schagerl, 2007a). The function of soda lake ecosystems is generally linked to the seasonal alteration of hydrological events and the resulting physical, chemical and biological processes taking place within the lake and in the entire watershed. Human-induced disturbances on the watershed, diversion of surface inflows and salinization, for example, can exacerbate the natural changes with further degradation of values related to soda lakes (Williams, 2002).

Soda lakes are well represented in Ethiopia and are exemplified by Lake Chitu, which is of high economic and ecological values. This lake primarily provides a preferred habitat for huge flocks of the Lesser Flamingos that has made the lake one of the well-known tourist attractions of the country. The lake also supports superabundant population of *Arthrospira*, the main diet of the flamingos and the alga of high nutritional values for humans. However, this lake is among the Ethiopian Rift lakes, which are currently facing ecological degradations (Gebre-Mariam, 2002; Ayenew and Legesse 2007). Earlier studies made in the lake (Talling et al., 1973; Baumann et al., 1975; Wood and Talling, 1988; Kebede et al., 1994; Kebede, 1996; Gebre-Mariam, 2002) investigated primary productivity, algal biomass and water chemistry. These studies were, however, sporadic and based on short-term samplings made for the purpose of comparison and are thus less likely to give adequate and reliable scientific data on seasonal aspects. In light of the importance of the lake and the dynamic nature of physicochemical and biological variables, up-to-date and more comprehensive data emanating from long-term limnological study were deemed essential for sustainable management of the lake. This study, therefore, investigated the temporal and spatial (vertical) variations in physicochemical characteristics of the soda lake Chitu based on samples collected over a year.

Materials and methods

Description of the study area

Lake Chitu (Fig. 1) is a tropical soda lake located some 287 km south of Addis Ababa at a geographical position of 7°24′ N 38°25′

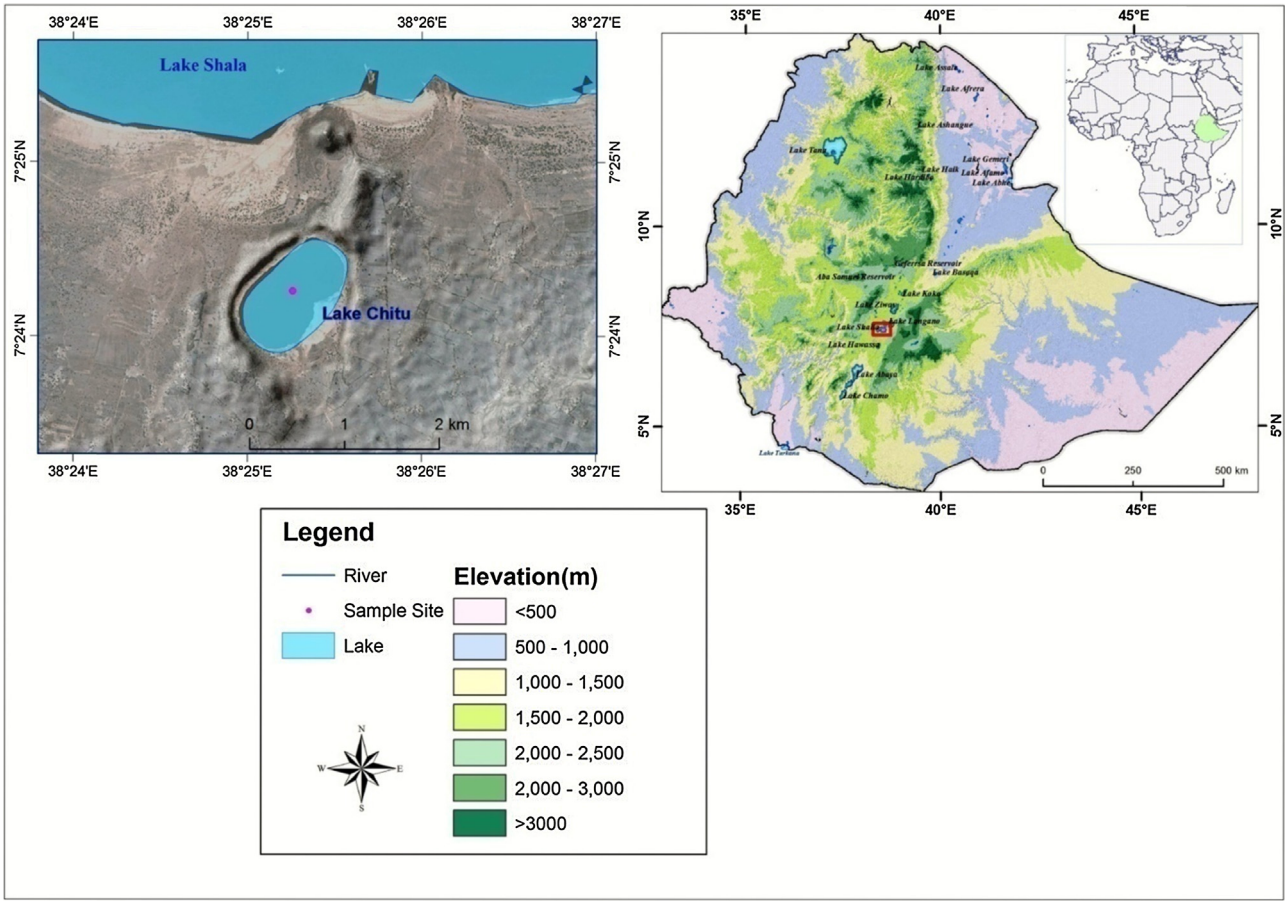

Fig. 1. Location map of the study lake, Lake Chitu.