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FULL LENGTH ARTICLE

Survey to compare phytoplankton functional approaches: How can these approaches assess River Nile water quality in Egypt?

Mohamad Saad Abd El-Karim

National Institute of Oceanography and Fisheries, 101 El-Kasr El-Eny St., Cairo, Egypt

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$Q_{(r)}$ index

Abstract The phytoplankton functional group concept ($Q_{(r)}$ index) was used to assess ecological status in the River Nile. Phytoplankton Functional Groups (FGs) and Morpho-Based Functional Groups (MBFGs) were described in the whole river including the main pollution sources. A total of 273 species were classified into 25 FGs and seven MBFGs. The most dominant FGs recorded (D, P, B, M, F, P, J and F) preferred nutrient rich conditions, whereas the appearance of lacustrine groups (W1, T, Y, L_o) reflected an increase of water residence time. Between MBFG groups, VI was the most dominant. The Canonical Corresponding Analysis indicated that the variance explained from environmental conditions is highest for MBFG (78.56%) than for FG (65.57%) and individual species (51.36%). Minimum $Q_{(r)}$ index values were synchronized to spring and the southern section of the river. The least $Q_{(r)}$ values were observed at the discharging point of pollutants and increase toward the highly diluted point. The highest $Q_{(r)}$ values were mainly observed at the upstream and main channel sites. The results suggested that the morpho-functional classification of phytoplankton and $Q_{(r)}$ not only reflects successfully River Nile water quality better than the individual species composition, but can also be used as a monitoring tool to assess the ecological status in the River Nile.

Introduction

Although the water quality monitoring of streams is usually based on the composition of the macroinvertebrate and benthic diatoms, the investigation of the riverine phytoplankton for monitoring purposes is unavoidable (Borics et al., 2007). Indeed, low attentions have been paid to study the biological features of the River Nile as bioindicators and biomonitoring tools to assess the ecological status of the river. Fishar and Williams (2008) developed a biotic index to assess the river's ecological status (Nile Biotic Pollution Index; NBPI) that depended on macroinvertebrates. They concluded that NBPI has been shown to provide an excellent biological assessment of organic pollution in the Nile, but it was less useful for chemical monitoring of water quality. Belal (2012) evaluated the River Nile ecological status using epipelon diatoms. She applied four diatom indices and postulated that the diatom indices developed in Europe and elsewhere are less useful to assess water quality in the River Nile.

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Elaboration of a phytoplankton-based quality assessment method needs the evaluation of phytoplankton associations in rivers. An alternative approach to the phylogenic groups is the use of explicit functional classifications 'association' that were proposed by Reynolds (1980). He separated 14 species associations in a series of phytoplankton data from a group of lakes in Northwest England. These associations comprised 'aggregates or groups' of organisms that exist in the water at the same time and increased or decreased simultaneously. The associations themselves are based on the physiological, morphological and ecological attributes of the species that potentially and alternatively may dominate or co-dominate the system. Later, the scheme has been expanded to accommodate associations from a wider number of lakes (Padisak and Reynolds, 1998). This functional classification was refined and three functional traits were developed; one describes phytoplankton association in deep water lakes (Salmaso and Padisak, 2007), and two functional traits for the turbid shallow water. The first (Functional Groups, FGs), which was refined by Reynolds et al. (2002), Borics et al. (2007) and Padisak et al. (2009), while the second (Morpho-Based Functional Groups, MBFGs) was proposed by Kruk et al. (2010). Functional Groups (FGs) classification comprised a large number of functional groups which were labeled with capital letters, A, B, C, D, P, M…, a combination of more than one letter (MP, Lo, N_A, …) or letters and numbers (X1, X2, S1, S2, …). The Morpho-Based Functional Groups (MBFGs) comprised seven groups which were labeled with the Latin numbers; I, II, III, IV, V, VI and VII. These letters and numbers are also called coda and refer to associations or groups.

In the past decade, studies on phytoplankton dynamics have proved that the morpho-functional grouping of species may be useful for ecological purposes (Dokulil et al., 2007; Padisak et al., 2009). The functional-groups approach (sensu Reynolds et al., 2002) is one of the most widely accepted forms of grouping phytoplankton species (Padisak et al., 2009). The original idea of the phytoplankton functional group concept (Reynolds et al., 2002) was proposed as a new water quality estimation method for lake phytoplankton (Q index—Padisak et al., 2006), then for river potamoplankton ($Q_{(r)}$ index—Borics et al., 2007). The $Q_{(r)}$ index is enabled to reflect human impacts at different scales by using specific *F* factor values for the different functional groups. These factor values were calculated using the following components: (i) nutrient status (from values 0-hypertrophic to 5-oligotrophic), (ii) turbulence (from values 0-standing waters to 5-highly lotic environment), (iii) sufficient time for the development of the given assemblage (from values 0-climax to 5-pioneer assemblages) and (iv) level of risk of functional traits (from values 0-high risk indicating pollution or being able to being toxic to 5-low risk). The specified values of each component were summed, and then the *F* was calculated for each functional group ranging between 0 and 5 (Borics et al., 2007).

$$Q_{(r)} = \sum_{i=1}^{s}(piF)$$

where

$pi = ni/N$, ni is the biomass of the i group, while N is the total biomass.

F is the factor number allowing the quality index to range between 0 (the worst) and 5 (the best).

Objectives

The present study aims at, (1) comparing the individual species classification with two new phytoplankton functional classifications, (2) which classification of these systems can express more the phytoplankton distribution in the River Nile using different statistical analysis?, (3) which are the dominant functional groups along the River Nile?, (4) how do the point source effluents affect the functional groups?, (5) can $Q_{(r)}$ index be considered as a new ecological status estimation method for the River Nile?

Study area

The present study covered the Nile section from Aswan Old Dam N 23°58′20″ E 32°52′42″ till its bifurcation at El-Kanater Barrage at N 30°10′25″ and E 31°8′20″, for a distance of about 920 km. A total of 36 sites were seasonally sampled at 11 stations (Fig. 1) to represent the different ecological areas of the River Nile including five discharging points of the main pollution sources (Kema; St. 1, Kom Ombo; St. 2, Qus; St. 4, El-Minya; St. 7, and El-Hawamdia; St. 9). At the five stations that receive effluents of the pollution sources, the samples were collected at different sites as follows:

Upstream site: Tens of meters upstream to the discharging points of pollution.

D site: At the discharging points of pollution.

D1 site: Where discharging effluents are partially diluted with river water.

D2 site: Where discharging effluents become highly diluted and nearly disappeared.

At the stations that do not receive pollution effluents, one littoral site and the main channel were sampled. The river was classified into three sections, the southern section comprised stations from 1 to 4, and the middle section comprised stations from 5 to 7, whereas the northern section comprised stations from 8 to 11.

Materials and methods

Subsurface water samples were collected seasonally during 2012 and stored in 250-mL plastic bottles, preserved with 4% formalin. Utermöhl's technique (Utermöhl, 1958) was used for plankton sedimentation. Species identification and counting were performed in an inverted light microscope (Zeiss, Axiovert 25C) at 10× eyepiece and 400× objectives. Algal biovolume was estimated using formula for geometric shapes (Hillebrand et al., 1999). Phytoplankton taxa were classified into Functional Groups (FGs) according to Reynolds et al. (2002), Borics et al. (2007) and Padisak et al. (2009); and into Morpho-Based Functional Groups (MBFGs) applying Kruk et al. (2010). The ecological status was estimated using F factor values proposed by Borics et al. (2007).

Conductivity and pH were determined in the field by means of appropriate probes. Samples for water chemistry were taken simultaneously with phytoplankton samples, stored in special bottles and analyzed in the laboratory. Data of oxygen (DO), biological oxygen demand (BOD), bicarbonate alkalinity, nitrate ($N–NO_3$), nitrite ($N–NO_2$), ammonium ($N–NH_4$) soluble reactive phosphorus (SRP), total phosphorus (TP)