Predicted Study of Carbon Sequestration by Phytoplankton in South Coast of Mediterranean Sea Opposite the Projected Canal Connected to Qattara Depression

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Abstract: This study was conducted to study how the development of inland oligotrophic marine ecosystem in Qattara Depression may act to mitigate the increase in the atmospheric carbon dioxide. Three sites with different nutrient concentrations were chosen at the Mediterranean Egyptian coast to study the phytoplankton composition, biomass and productivity. Site 1 was highest in nutrient concentration but least in water transparency, whereas site 2 was moderate in nutrient concentrations but highest in water transparency. Both gross and net production have a climax at site 2 with values reached up to 793.9 and 355.9 gC/m^3/year, respectively. The net primary production (C sequestration) of phytoplankton at the expected water intake of the project is $355g\ m^{-3}year^{-1}$. At filling of Qattara Depression at 60m below sea level the water volume will be 209.3 km^3, the total C sequestered by phytoplankton per year is about 700×10^5 tons of carbon, which is about 1.5% of the annual increase of atmospheric carbon dioxide worldwide. Rising temperature during summer and nutrients enrichment in Qattara Depression may increase sequestration of carbon dioxide up to 5% of total annual carbon increase in earth atmosphere.

Key words: Qattara Depression · Global warming · Phytoplankton · Primary productivity

INTRODUCTION

Anthropogenic activity has increased the carbon dioxide concentration of the atmosphere by 30% from pre-industrial concentrations averaging 270 ppm [1, 2]. CO_2 concentrations are expected to rise to 450 ppm by 2065 and to 650 ppm by 2100 [3]. These CO_2 increases may have dramatic impacts on global climate [2], global carbon cycles [1], ocean circulation [4, 5], biotic diversity [6, 7] and marine ecosystem function [8]. Elevated atmospheric CO_2 will also increase the dissolved aqueous CO_2 concentration [CO_2 (aq)] in seawater and decrease pH [9]. The resulting drop in seawater pH may cause widespread decline of carbonate accreting systems such as coral reefs [6].

Plants are known to sequester atmospheric carbon dioxide through photosynthesis resulted in the key stones of life (food and oxygen). One way to mitigate the increase in the atmospheric carbon dioxide (CO_2) concentration is to increase the carbon (C) uptake (or C sequestration) in different plant life forms. In this direction, many trials were devoted to study how

terrestrial plants [10, 11], aquatic seaweeds and sea grasses [12] and phytoplankton [13,14] can be used to mitigate the dramatic increase in atmospheric carbon dioxide.

This study was conducted to study how the development of inland oligotrophic marine ecosystem in Qattara Depression may act to mitigate the increase in the atmospheric carbon dioxide.

MATERIALS AND METHODS

Sampling Sites: Three different sites with three different trophy were selected at the south coast of Mediterranean Sea at Egypt. The locations of the three sites were presented in Table 1.

Water Sampling: Subsurface water samples were collected by a polyvinyl chloride, Van Dorn bottle. The DO was performed by azide modification whereas; different nutrient concentrations were determined using colorimetric techniques [15]. GF/F filter papers were used for chlorophyll-a (chl-a) measurments, the filters were

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Table 1: Latitude and Longitude of the selected sites

Sites	Location	Lat.	Long
1	East of Alexandria City	9,32'36º31	"51,51'56º28
2	West of Alexandria City	40,27'8º31	"10,74'49º29
3	El-Alamein City	"21,22'50º30	"51,51'56º28

socked in 10ml hot ethanol according to Nusch [16] and Marker *et al.* [17]. Phytoplankton samples were fixed with Lugol's solution enumerated and counted using the inverted microscope method [18]. Identification of the main phytoplanktonic groups was made with reference of: Cyanoprokaryotes; [19], Bacillariophyceae; [20, 21]; Chlorococcales [22, 23]. For diatoms identification for the species level, subsamples were oxidized by concentrated nitric acid and mounted in Naphrax medium [24]. Primary production was determined by oxygen light-dark bottles method [25]. Water samples were collected in 300-ml glass BOD bottles. Triplicates light (LB) and dark (DB) were incubated in the field at 50cm below the water surface. Oxygen concentration was measured (Winkler's method) at the beginning of the experiment as initial bottles (IB). After the incubation, LB and DB bottles were immediately treated to determine oxygen concentrations [26]. Which was applied for primary production calculations.

RESULTS

The different nutrient concentrations showed a significant decrease westward (Fig. 1). The maximum concentrations of NO_2, NO_3, NH_4, PO_4, TP and Silicate (19.7, 66.2, 105.6, 51.5, 147.8 and 3.5, respectively) were detected at site 1 (Fig. 1). On the other side, the minimum values of 3, 39.7, 46.6, 14.6, 43.7 and 2.8, respectively, were measured at site 3. The spatial variation of the different nutrient concentrations were highly significant ($P > 0.005$) except for silicate; where its variation was non-significant ($P = 0.08$).

The phytoplankton representation by both biomass and cell density was a mirror image to the eutrophication status represented by the nutrient concentrations. Biomass (chlorophyll a) and cell density were greatly decreased westward from site 1 to site 3 (Fig. 2). The highest phytoplankton chlorophyll a of 18.6 µg/l was measured at site 1, whereas the least biomass of 2.3 µg/l was found at site 3. The phytoplankton cell density peaked at site 1 (8326 cell x 10^3/l) whereas the density was minimum at site 3 (897.2 cell x 10^3/l).

The gross and net productions pattern at the area of investigation differ from the eutrophic status of the area of study. Both gross and net production have a climax at site 2 with values reached to 793.9 and 355.9 g C/m^3/year, respectively. The net production was least at site 3 with value of 109.5 g C/m^3/year (Fig. 3).

DISCUSSION

The policy of the Ministry of Electricity and Energy in Egypt is to increase the utilization of all natural resources for energy production, Especially the hydro-potential as the most important source (e.g. the Aswan hydro-electrical station with an installed capacity of 2400 MW). Theoretically, a big project concerning the utilization of Qattara depression for this purpose was designed many years ago. Qattara depression is located in the western desert in Egypt, about 134 m below sea level at its lowest point. At zero level, the surface area of the depression is about 19,500 km^2 representing 1/15 of the area of Egypt, whereas at filling of 60m below sea level the surface area of the depression is about 12,100 km^2 with water volume of 209.3 km^3. The depression is planned to be connected to the Mediterranean Sea either through tunnels or open canal. The discharged water will be regulated by water turbines thus utilize the difference between sea level and the depression for power production. A preliminary intake for the water canal was chosen at El Sirra area located 15 km west of El Dabaa. After the establishment of the project, the maximum annual energy forecast is about 15400 TWH. It can be noted that the surface of the foreseen formed lake at level of 60 m below sea level will be 12,100 km^2 and volume of water will amount to 209,3 cubic kilometers [27].

Depending on our finding concerning the net primary production (C sequestration) of phytoplankton at the expected water intake of the project is 355g m^{-3}year^{-1}. At filling of 60m below sea level the surface area of the depression is about 12,100 km^2 with water volume of 209.3 km^3. It is predicted that the total C sequestered by phytoplankton per year, according to this water volume, is about 700×10^5 tons of carbon which mean 70 million tons of carbon dioxide will be removed from the atmosphere. If we know that the annual increase of atmospheric carbon dioxide amount to 3.2 gigaton, Qattara Depression will be responsible for removing of about 1.5% of this increase.

In Chesapeake Bay, in the temperate eastern region of US, Harding *et al.* [28] observed a late winter minimum, average, of 325 mg C m^{-2} d^{-1}, with rising temperature they observed a summer maximum, average, of 1500 mg C m^{-2} d^{-1}. In general they observed a 2-3 fold increase in net primary production during summer compared with late winter-early spring. Similar results
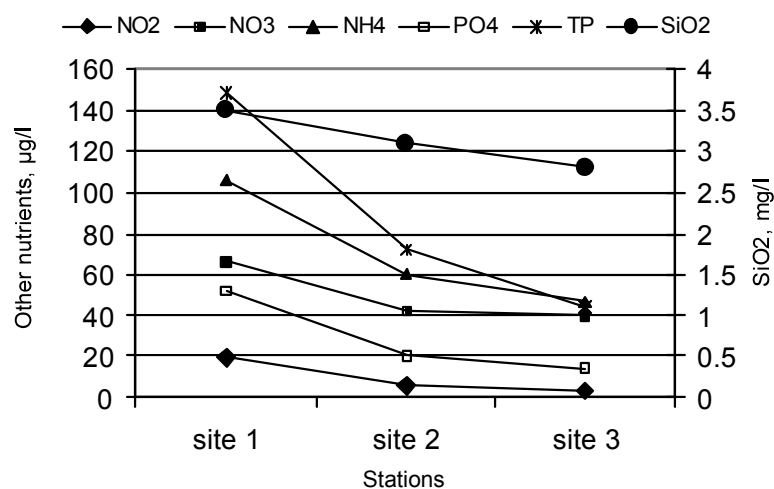
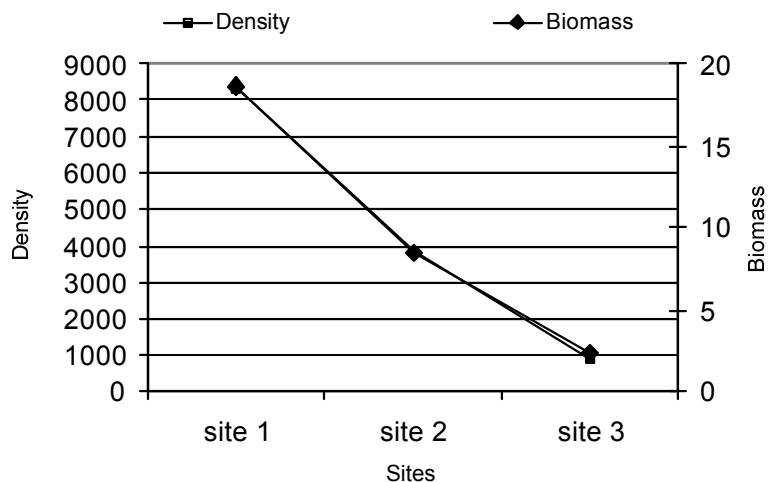Fig. 1: Different nutrient concentrations at different sites

Fig. 2: Phytoplankton population density (no of cells x 10^3/ l) biomass (μg / l)
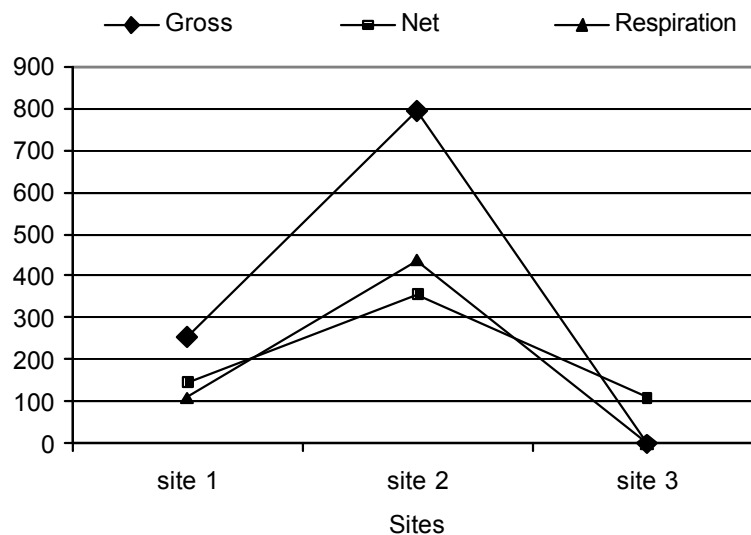

Fig. 3: Gross, net production and respiration (g C/m^3/year) at the studied area

were reported by Smith and Kemp [29]. Our measures of phytoplankton net primary production were at temperature of 17°C, mid winter and oligo-mesotrophic conditions of nutrient concentrations. In agreement with Harding *et al.* [28] and Smith and Kemp [29] rising temperature during summer will increase the net primary production in Qattara Depression 2-3 fold which means an increase from 1.5 to 3-4.5% in the annual removing of the atmospheric carbon dioxide increased per year. In the same time, nutrient enrichment in oligo-mesotrophic conditions may enhance the net primary production to levels that make Qattara Depression remove more than 5% of the annual increase of CO_2. Chen [30] studied the effect of nutrient enrichment in south China Sea and indicated that while N enrichment enhanced phytoplankton growth all year round, P enrichment only occasionally increased production. In all enrichments, whenever N was supplemented, either singly or in combination with other nutrients, phytoplankton production was greatly enhanced. The primary production for the +N treatment measured was 7.82 $mgCm^{-3}$ h^{-1}. It was 9.22 $mgCm^{-3}$ h^{-1} for the +NP treatment. These values are approximately 5–10 times greater than the control (1.66 $mgCm^{-3}$ h^{-1}) or the +P enrichment (0.89 $mgCm^{-3}$ h^{-1}). These results in combination with those of Veldhuis *et al.* [31] may support our hypothesis that using Qattara Depression as aquaculture may remove more than 5% of the annual increase of CO_2 in the atmosphere.

In conclusion, using the projected Qattara Depression for hydropower generation as aquaculture may be useful in sequestration carbon dioxide and combat global warming.

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