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Research Article

Evaluation on 2002-2021 CHL-A Concentrations in the Sea of Marmara with GEE enhancement of satellite data

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Abstract

Remote sensing data, especially satellite observations make available large databases related to marine biosphere. This tremendous amount of the data causes a difficulty to acquisition, processing and evaluation processes. Google Earth Engine (GEE) platform make possible to overcome this difficulty by its state of art structure. Thus, GEE platform was included to study to process and evaluate the chlorophyll-a data for the sea of Marmara. The Sea of Marmara was considered in 2 main parts as North and South Marmara. These parts also divided into 6 sub-regions and analyzed as 12 different regions in total. MODIS (Moderate Resolution Imaging Spectroradiometer)-Aqua data were acquired between the years 2003-2021 with the GEE platform for all examined sub-regions and make them available for analysis. Approximately 19 years of arranged chl-a concentration data were visualized and evaluated by grouping them according to sub-regions, months and years. As expected, the highest concentration of chl-a was observed in the Sea of Marmara in square KM6, which includes the Gulf of Izmit and has limited regeneration The lowest concentration values throughout the years were found in the areal average values of the KM4 square under the influence of the jet stream formed by the upper water from the Black Sea. When the monthly data are examined, it can be said that the primary production in general takes place intensively in the whole of the Marmara Sea in the spring season. In the context of this study, the accuracy of the division of the Sea of Marmara in two main axes as North and South is clearly seen in the analyzes within the time series. We evaluate that the similarity of chl-a concentrations in the Marmara Sea to the period before 2007 and 2020 requires a special attention as evidence of a repetitive process rather than an ecological coincidence.

Keywords: GEE; chl-a; MODIS-Aqua; Marmara Sea

Introduction

The increase in phytoplankton masses, which provides primary production on sea surfaces, brings with it an increase in chlorophyll-a (chl-a) pigments responsible for photosynthesis (Dierssen and Randolph 2013). An increase in blue wavelength absorption or a decrease in reflectance relative to the green part of the spectrum is empirically related to the concentration of chl-a, which is an indicator of phytoplankton activity (O'Reilly et al. 1998; Dierssen and Randolph 2013). This makes it possible to estimate chl-a concentrations and phytoplankton masses on the surface with remote sensing methods, especially satellite images (Dierssen et al. 2003). Primary production is under the influence of many limiting parameters below 20 m in the Sea of Marmara (Yilmaz 2008), and it is possible to monitor surface activity with remote sensing technologies.

Increasing open-access remote sensing data and the open-source technologies to process it are enabling the capacity to interpret the marine biosphere in ways that are inaccessible to traditional sampling methods (Werdell et al. 2009). This convenience has led to a tremendous increase in the size of the data provided and a search for a solution on how the data can be accessed and processed more easily (Acar et al. 2021; Kavzoğlu et al. 2021; Rigaux et al.2002; Gazioğlu, et al. 2022; Kayalık and Çorumluoğlu, 2022).

Within the scope of the study, Google Earth Engine (GEE) platform and many MODIS-Aqua images were used. It is aimed to provide approximately 19 years of arranged chl-a concentration data for the whole of the Sea of Marmara and evaluate them.

Materials and Methods

In the study, chl-concentrations were compiled from the images obtained by the MODIS device located on the Aqua satellite of NASA (The National Aeronautics and Space Administration) (Werdell et al. 2009). MODIS device can perform measurements in a total of 36 different spectral band ranges (Barnes, et al. 1998). It can reach a spatial resolution of 1 km^2 for the spectral band ranges used to obtain Chl-a concentrations. It completes its observations over all the Earth's waters in 16-day periods (Wang and Liang 2009). Data can be accessed through the Aqua-MODIS database since July 2002, the date the platform started to work. The database includes measurements at different daily intervals against desired locations throughout the year due to acquisition period and weather conditions.

GEE is a cloud computing platform designed to store and process large datasets (at petabyte scale) for analysis and final decision making (Mutanga and Kumar 2019). Due to the fact that the platform is free and provides great convenience, it facilitates the processing of large geographical data in large areas and the monitoring of the environment for long periods of time (Amani et al. 2020; Gorelick 2013).

In the study, the Sea of Marmara was basically considered in 2 parts as the North and the South Marmara. These two parts were divided into 6 sub-regions and examined in 12 different regions in total (Figure 1). In order to include the whole of the Marmara Sea in the designated grid system, the squares were formed from areas of 50 km x 50 km for North Marmara and 40 km x 40 km for South Marmara. All MODIS-Aqua images covering the determined grid areas and in the date range 01/07/2003-01/07/2021 were processed with the help of GEE, and the average chl-a concentration data observed in the areas were listed as mg/m^3. The listed values consist of a total of 31,448 average chl-a concentrations for all areas. The annual distribution of the data is given in Figure 2. After obtaining the data, it was examined by subjecting it to processes such as historical and/or regional grouping, visualization and determination of extreme values.

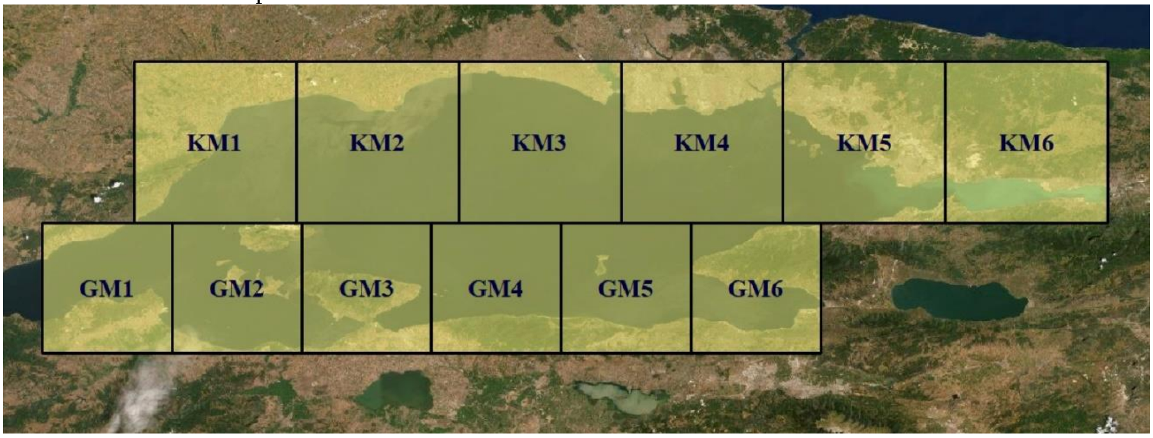

Figure 1. Study Area and Applied Grid System.

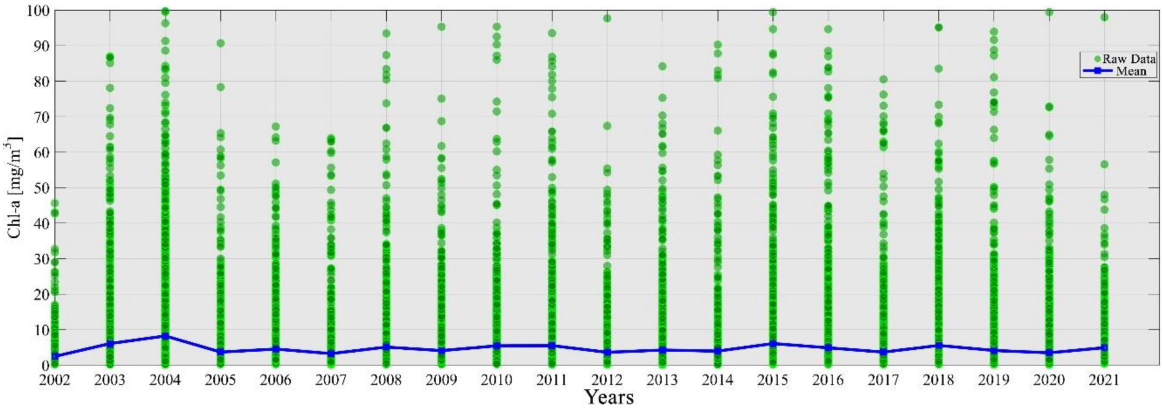

Figure 2. Annual Distribution of Data for All Grid Areas.

Results and Discussion

The highest annual mean chl-a concentration in the Sea of Marmara was observed in 2004 as 8.24 mg/m^3 and the lowest as 3.26 mg/m^3 in 2007 (Figure 2). As expected for all the years studied, the highest concentration of chl-a was observed in the Sea of Marmara in square KM6, which includes the Gulf of Izmit, which has limited regeneration (Appendix-A.6). Similarly, high concentration results were seen in the GM6 grid average covering the Gemlik Bay, which has higher regeneration than the Izmit Bay (Appendix-B.6). The lowest concentration values throughout the years were found in the areal average values of the KM4 square under the influence of the jet stream formed by the upper water from the Black Sea (Appendix-A.4). The same situation is evident in the results produced by the GEE systematic in areas where the highest and lowest concentrations are expected.

When the monthly data are examined, it can be said that the primary production in general takes place intensively in the whole of the Marmara Sea in the spring season. As a result of evaluating the circulation and hydrographic features of the Marmara Sea in terms of surface currents, regions with high concentrations may develop along the northern coasts from time to time. However, in the southern part of the Marmara Sea, where the surface current vectors are generally weaker, the concentration can be observed to be consistently high. In the exception region for northern part (K4), primary production is limited during the seasons when the Istanbul Bosphorus

Jet is strong enough to occasionally cause it to reach the shores of Imrali island or crash into the shores of the Armutlu Peninsula. Another negative effect of this jet is that it causes the surface waters to be trapped in the Gemlik and Bandirma Bays. The dynamic processes of the longshore currents of the Sea of Marmara ensure that the gulfs are renewed rapidly from time to time.

The high concentration in the archipelago region in the West of the Kapidag Peninsula and in the South of the Marmara Island is due to the processes developed by the influence of the Mediterranean water.
This part is more effective on the oceanography of the region compared to other parts of the Marmara Sea, due to the undercurrent.

Monthly distribution charts for all regions are presented in detail in Appendix-A for Northern Sea of Marmara and Appendix-B for Southern Sea of Marmara.

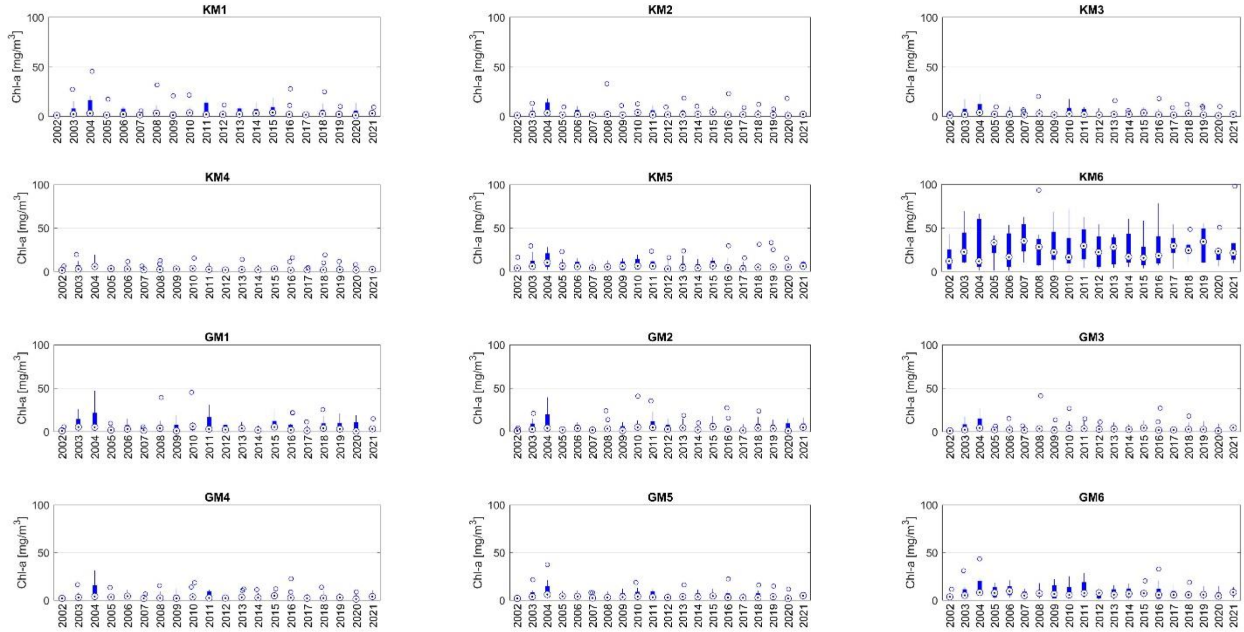

Figure 3. Distribution of Monthly Averages Corresponding to Regions and Years.

Conclusion

Within the scope of the study, 19-year chl-a concentrations were obtained across the entire Marmara Sea by using the GEE platform and MODIS-Aqua data. The data are presented by grouping them to correspond to the sub-regions, years and months. Further reproduction of data analysis is possible using data obtained by remote sensing and statistical methods. As it can be understood from the results of this study, the oceanography of the Marmara Sea is under the influence of dynamic forces that are strongly related to each other or completely independent. It is obvious that GEE platforms produce very efficient results in revealing general features.

Regarding these valuable results, the findings related the chl-a concentration distribution in the surface waters of the Marmara Sea is important. While Phosphorus (P) is the limiting factor for chl a concentration in the eutrophication regions of the Marmara Sea, Nitrogen (N) in general limits primary production. Due to the indented structure of the South of the Marmara Sea and the abundance of stream inflows, the lower slope and shallowness of the submarine topography ensure that the chl-concentrations are high in all periods. In the context of this study, the accuracy of the division of the Sea of Marmara in two main axes as North and South is clearly seen in the analyzes within the time series.

It has been clearly understood in the mucilage incident that took place in the entire Marmara Sea in 2021 that there is a need for higher temporal and spatial resolution remote sensing data, more than ever, in order to analyze distributed and point loads more clearly. In this study, we evaluate that the similarity of chl-a concentrations in the Marmara Sea to the period before 2007 and 2020 (Figure 2) attract attention to special findings as evidence of a repetitive process rather than an ecological coincidence.

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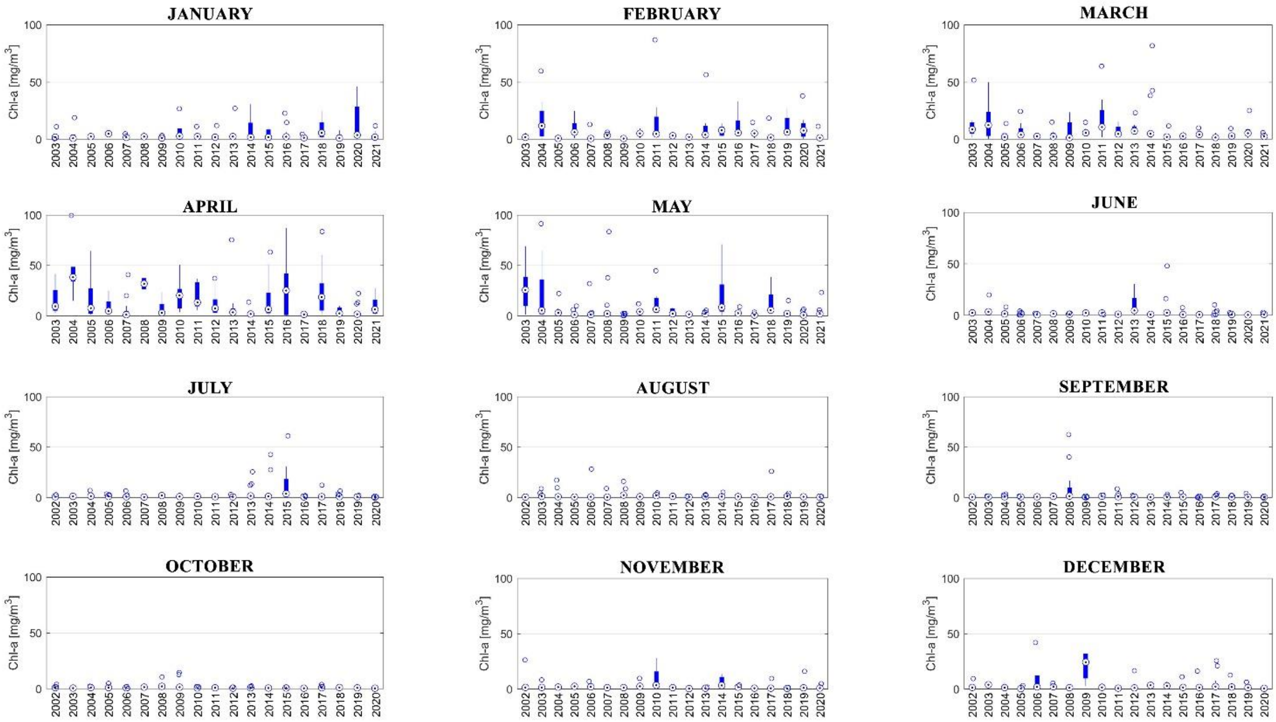
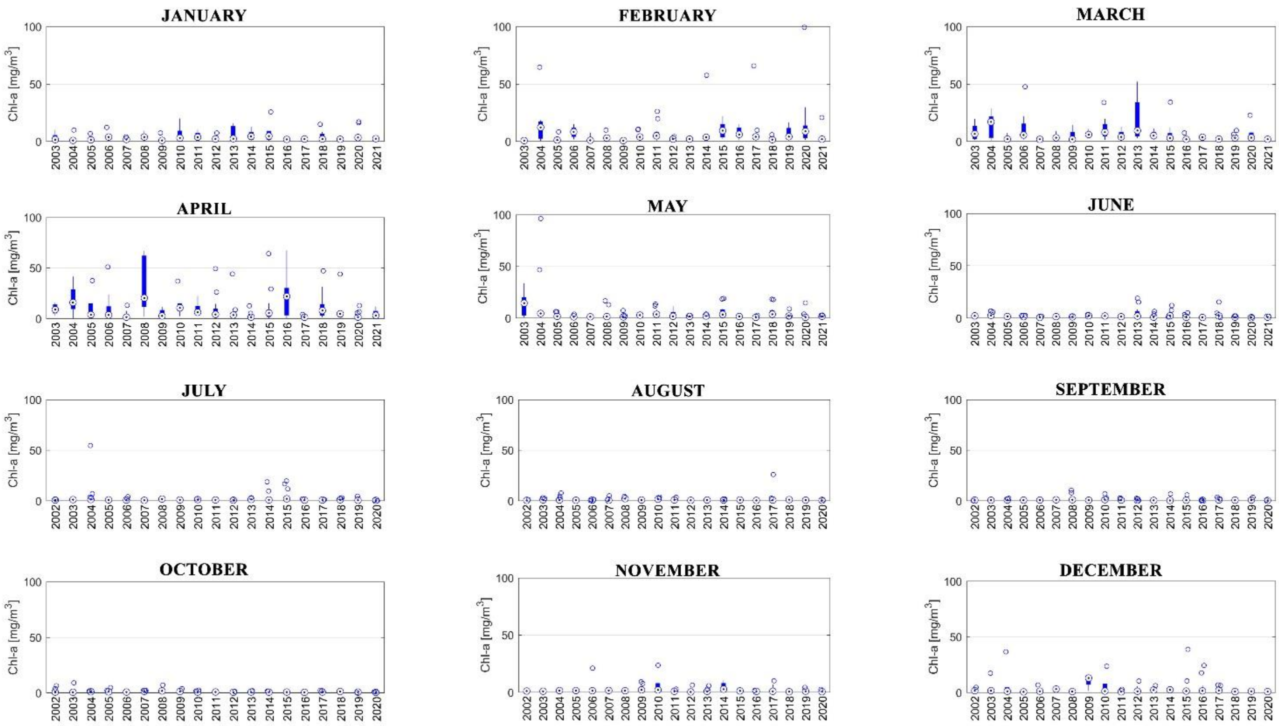
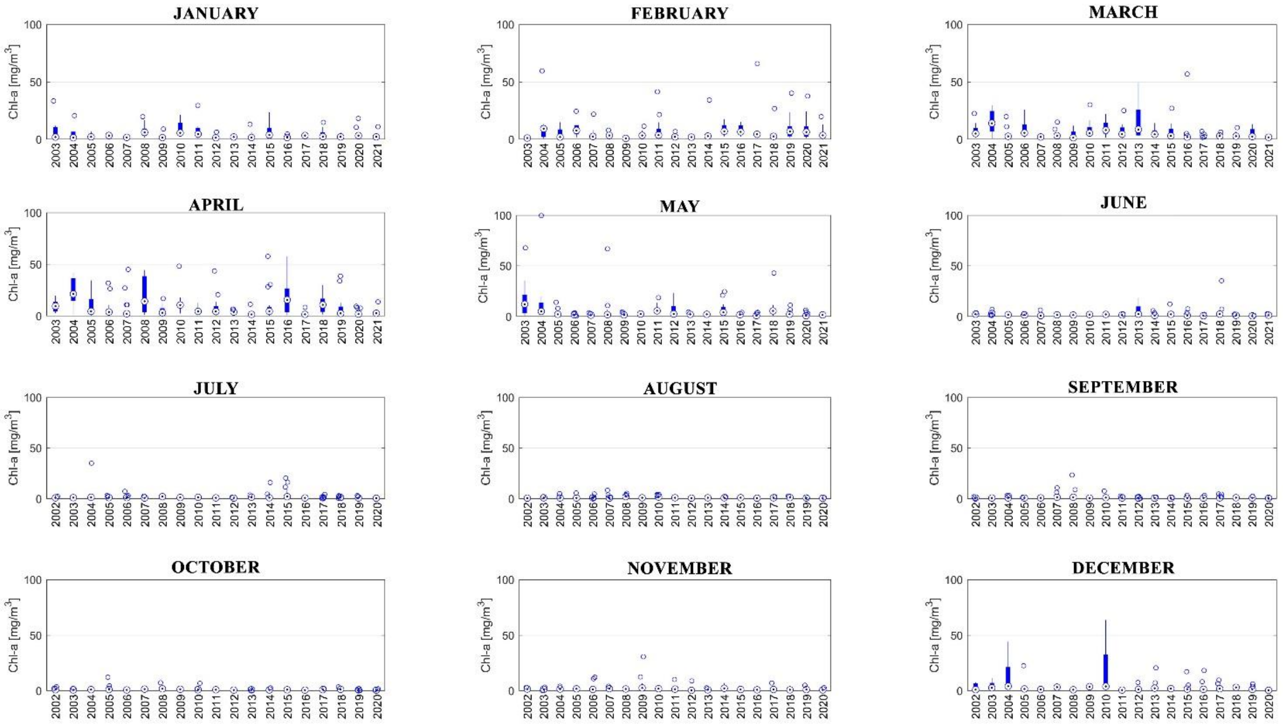
Appendix-A



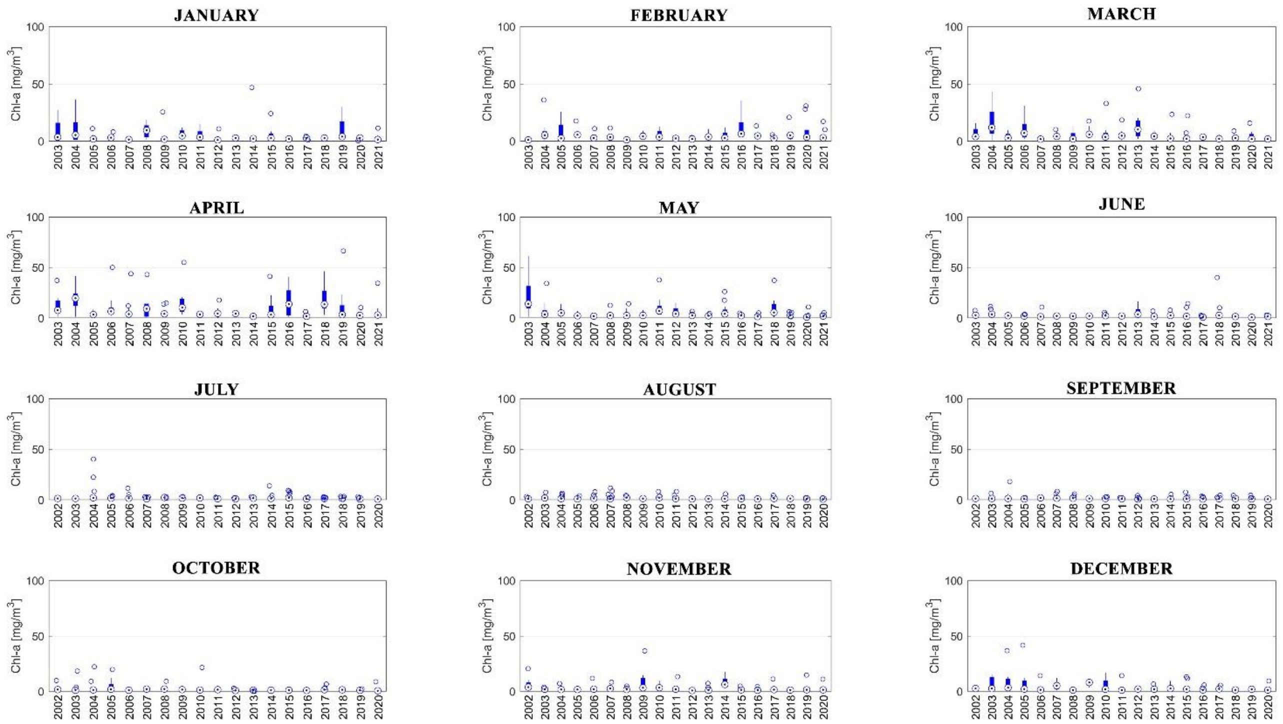
A 1. KM1 Monthly Chl-a Distributions Corresponding to Years.



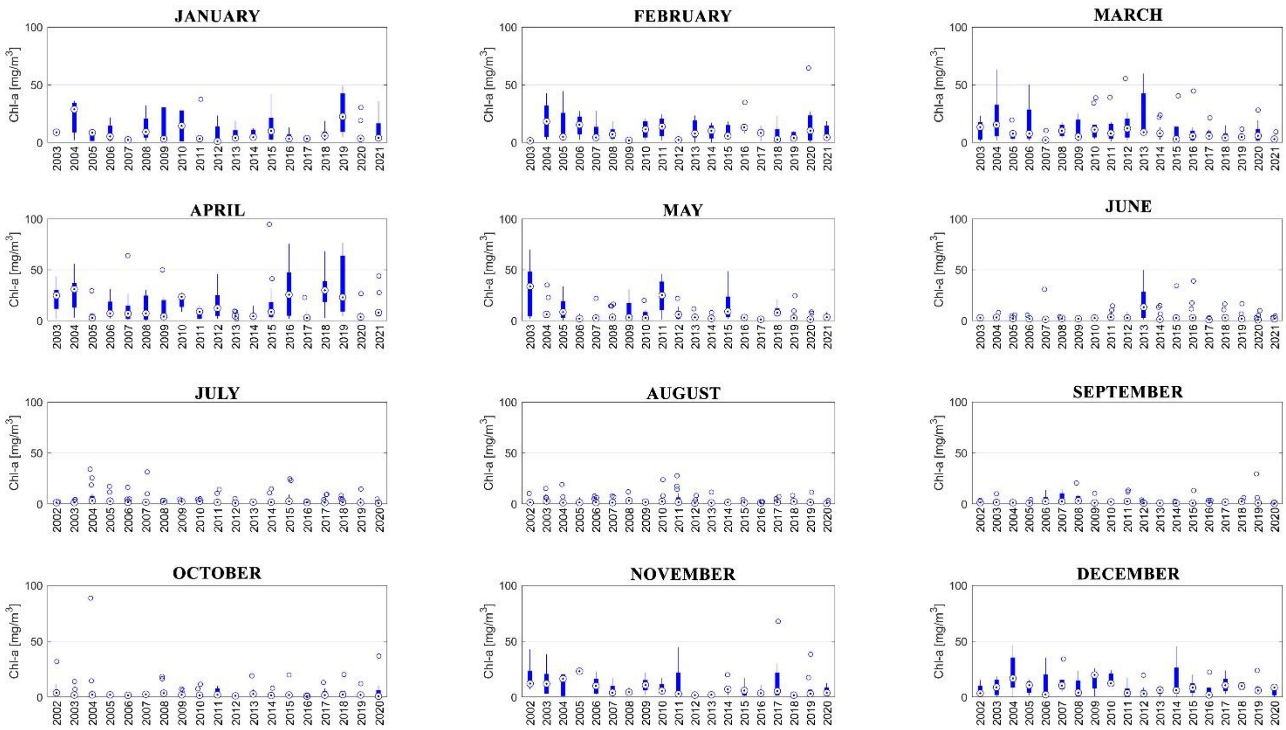
A 2. KM2 Monthly Chl-a Distributions Corresponding to Years.



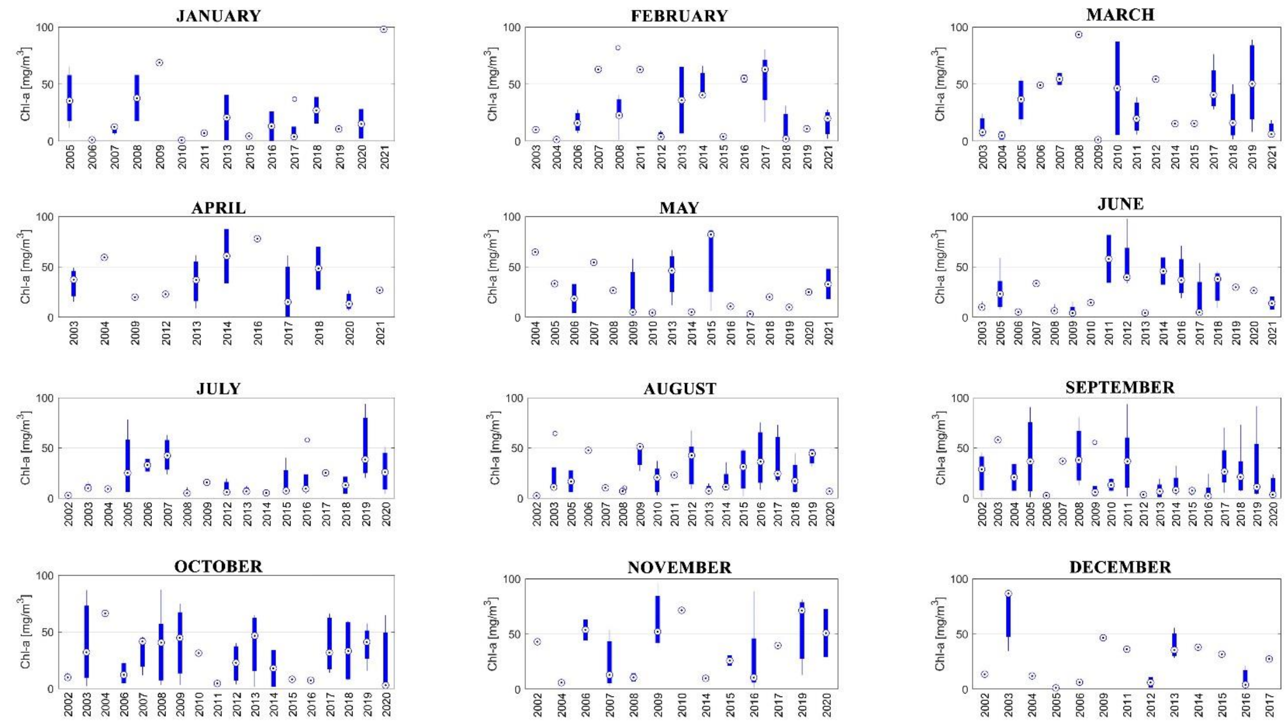
A 3. KM3 Monthly Chl-a Distributions Corresponding to Years.



A 4. KM4 Monthly Chl-a Distributions Corresponding to Years.

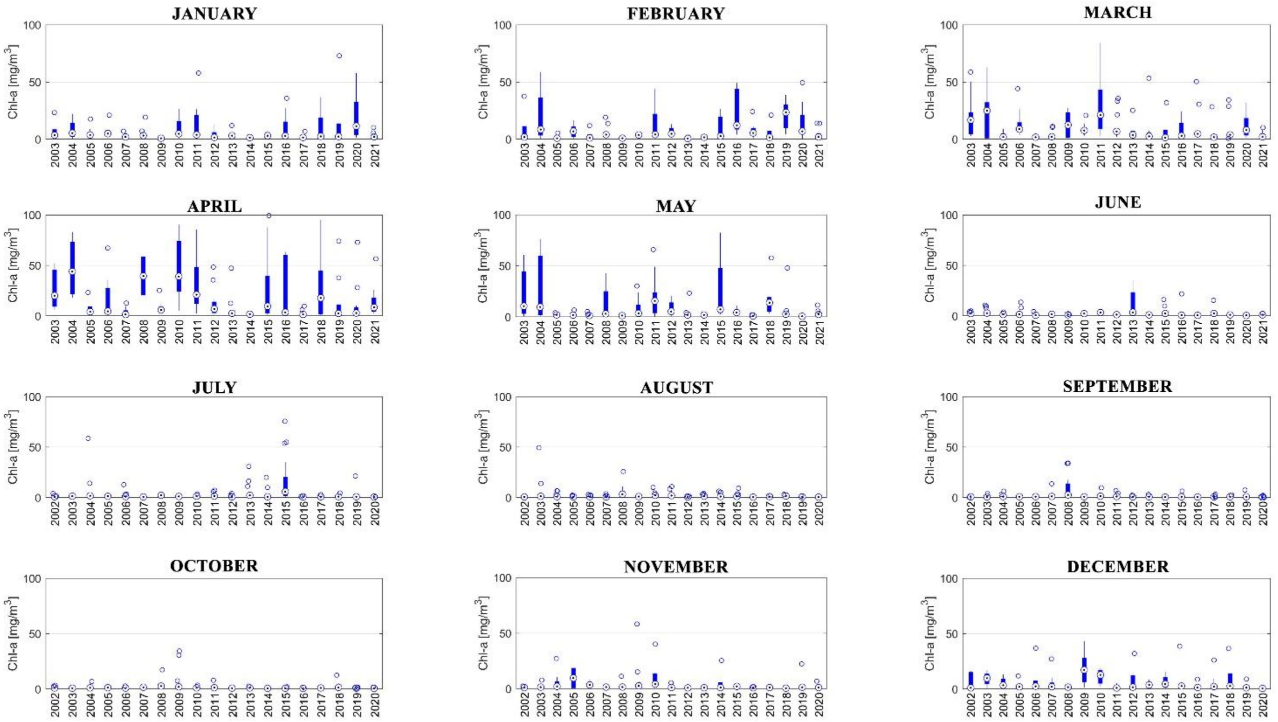


A 5. KM5 Monthly Chl-a Distributions Corresponding to Years.

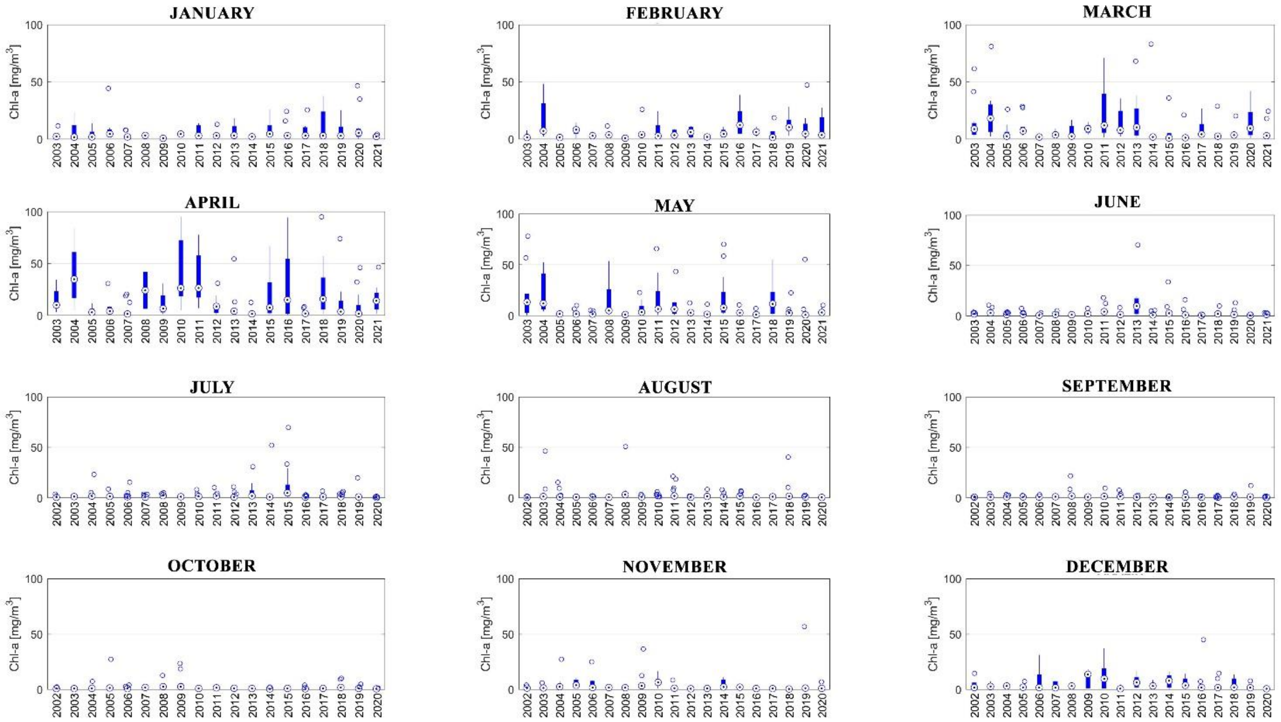


A 6. KM6 Monthly Chl-a Distributions Corresponding to Years.

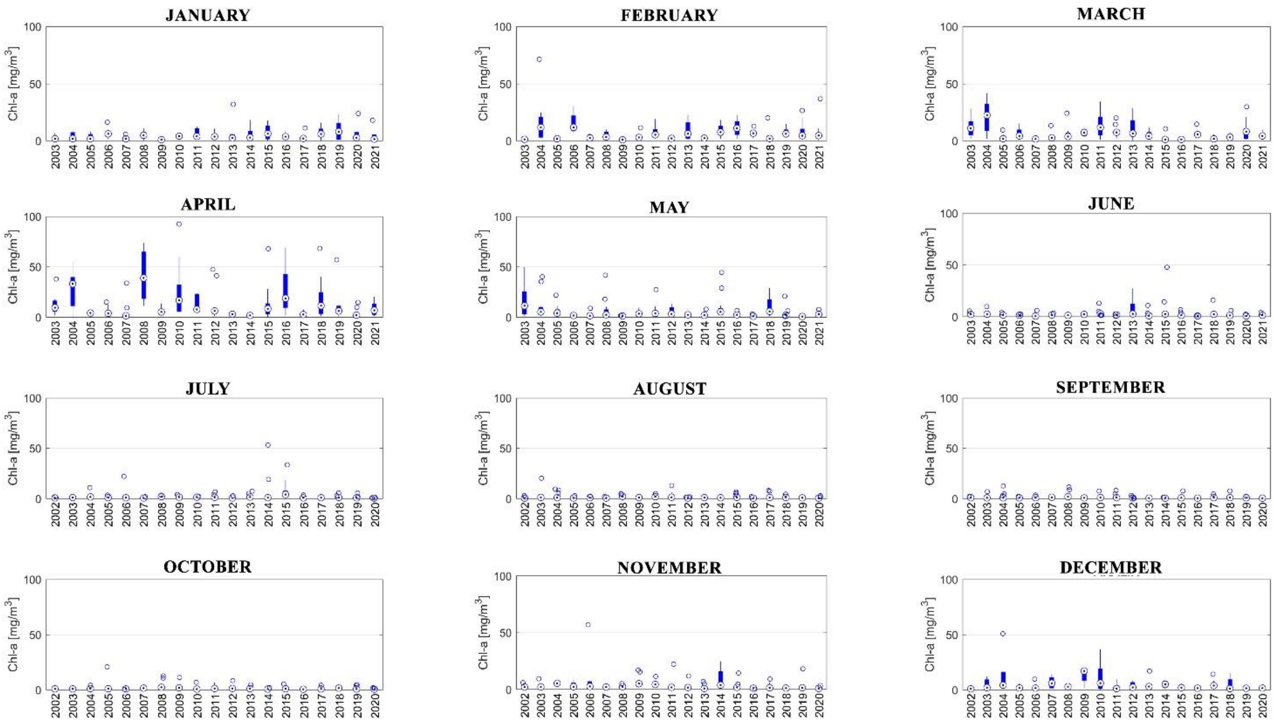
Appendix-B



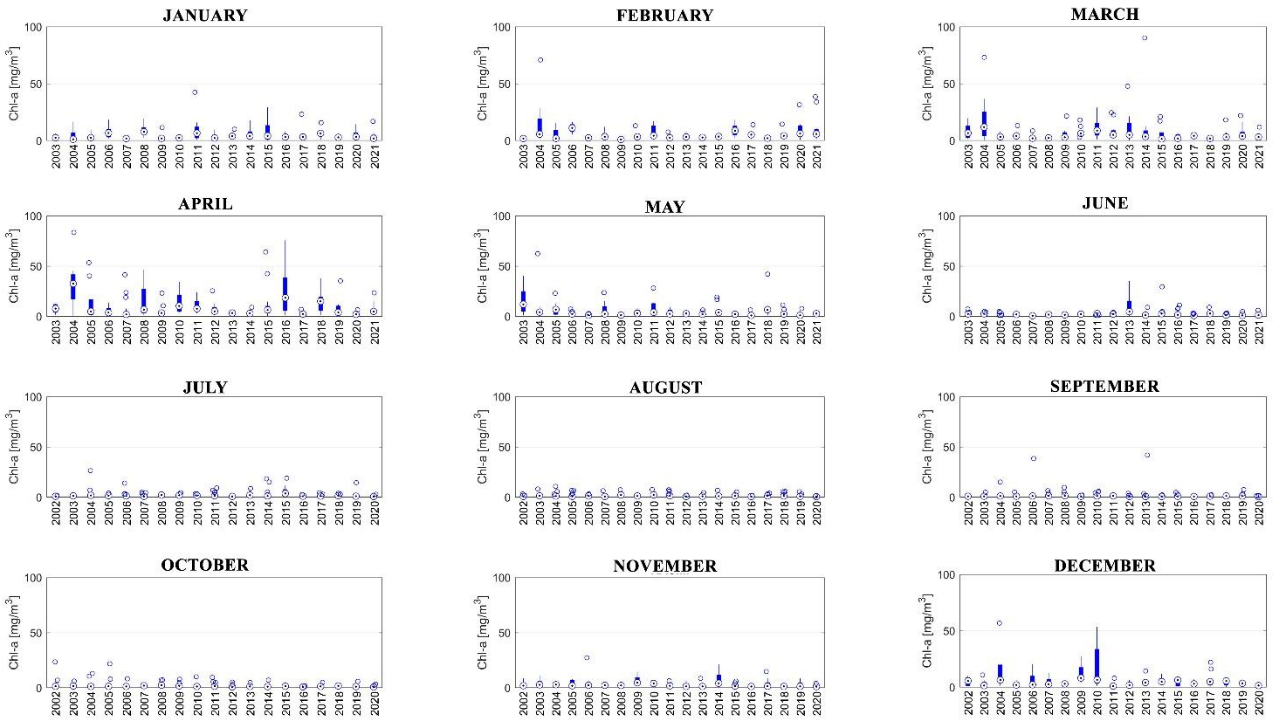
B 1. GM1 Monthly Chl-a Distributions Corresponding to Years.



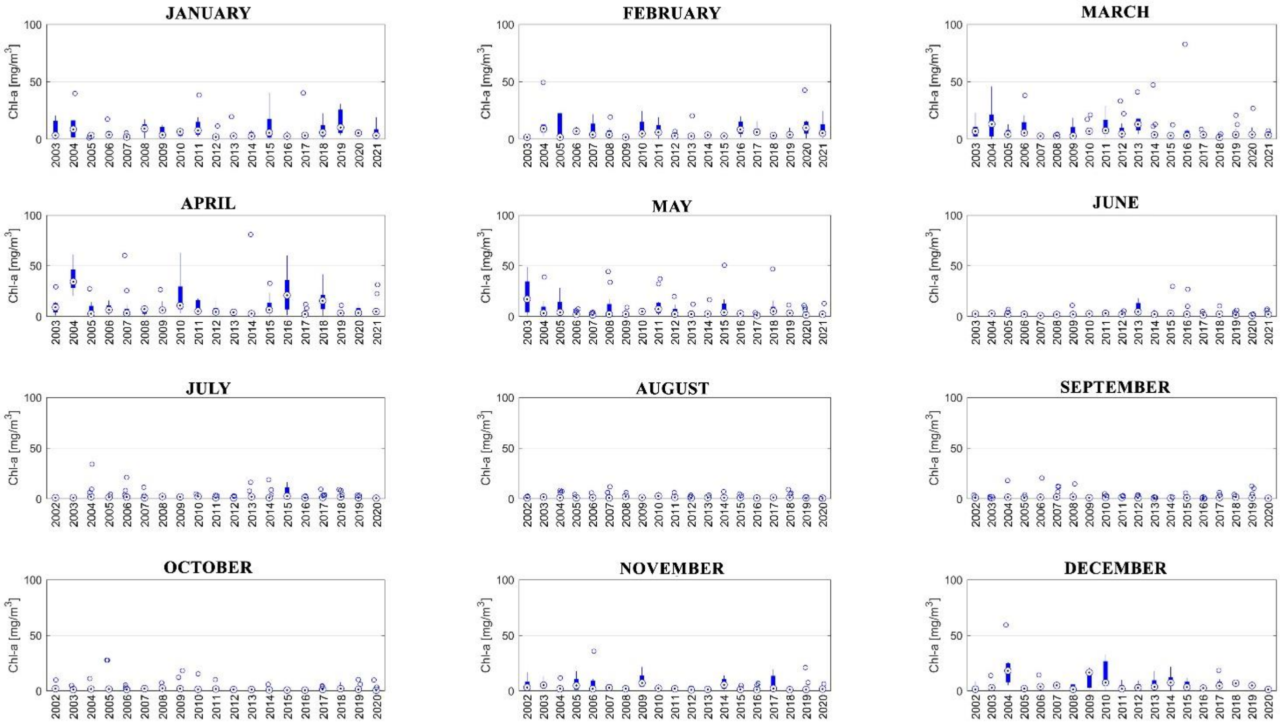
B 2. GM2 Monthly Chl-a Distributions Corresponding to Years.



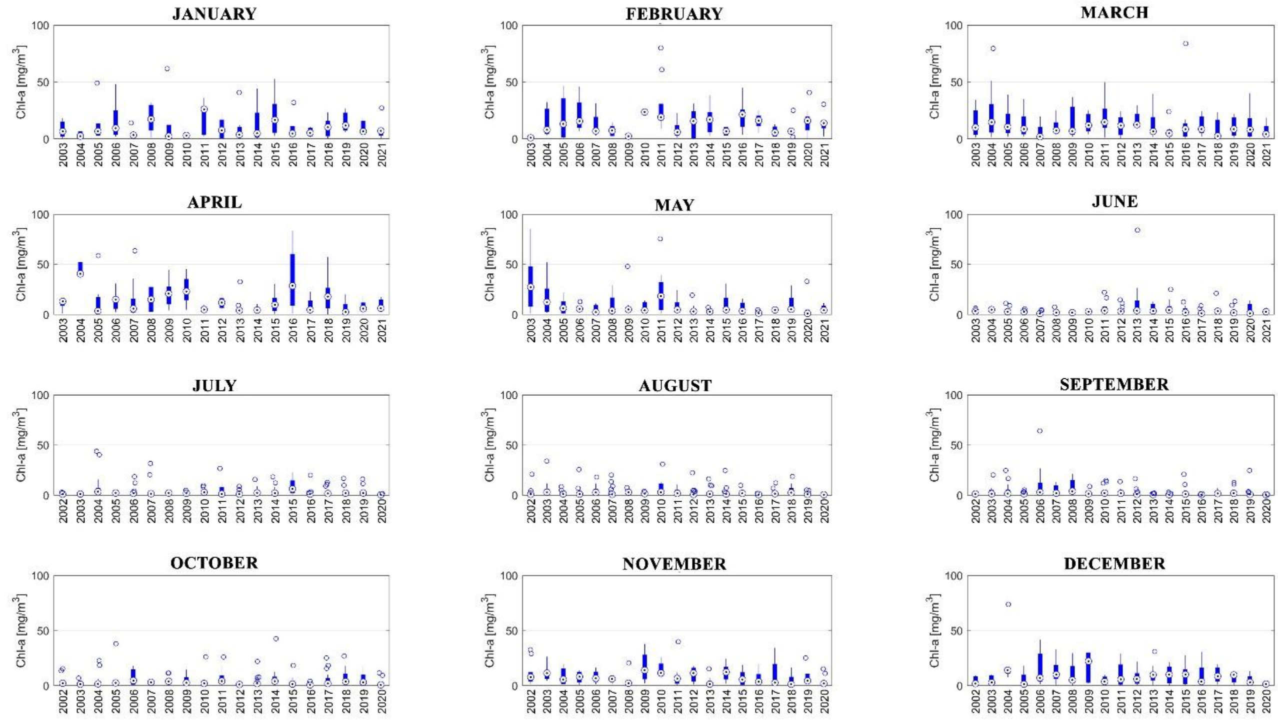
B 3. GM3 Monthly Chl-a Distributions Corresponding to Years.



B 4. GM4 Monthly Chl-a Distributions Corresponding to Years.



B 5. GM5 Monthly Chl-a Distributions Corresponding to Years.



B 6. GM6 Monthly Chl-a Distributions Corresponding to Years.