A field study on the conversion ratio of phytoplankton biomass carbon to chlorophyll-α in Jiaozhou Bay, China*

LÜ Shuguo (吕淑果) †, ††, †††, WANG Xuchen (王旭晨) †, HAN Boping (韩博平) ††††, **
† Key Laboratory of Marine Ecology and Environmental Sciences, Institute of Oceanology, Chinese Academy of Sciences, Qingdao 266071, China
†† Graduate School, Chinese Academy of Sciences, Beijing 100039, China
††† Hainan Research Academy of Environmental Sciences, Haikou 570206, China
†††† Institute of Hydrobiology, Jinan University, Guangzhou 510632, China

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Abstract A one-year field study was conducted to determine the conversion ratio of phytoplankton biomass carbon (Phyto-C) to chlorophyll-α (Chl-α) in Jiaozhou Bay, China. We measured suspended particulate organic carbon (POC) and phytoplankton Chl-α samples collected in surface water monthly from March 2005 to February 2006. The temporal and spatial variations of Chl-α and POC concentrations were observed in the bay. Based on the field measurements, a linear regression model II was used to generate the conversion ratio of Phyto-C to Chl-α. In most cases, a good linear correlation was found between the observed POC and Chl-α concentrations, and the calculated conversion ratios ranged from 26 to 250 with a mean value of 56 μg μg⁻¹. The conversion ratio in the fall was higher than that in the winter and spring months, and had the lowest values in the summer. The ratios also exhibited spatial variations, generally with low values in the near shore regions and relatively high values in offshore waters. Our study suggests that temperature was likely to be the main factor influencing the observed seasonal variations of conversion ratios while nutrient supply and light penetration played important roles in controlling the spatial variations.

Keyword: chlorophyll-α; Phyto-C/Chl-α ratio; suspended particulate organic carbon; Model II regression; Jiaozhou Bay

1 INTRODUCTION

Field measurement of phytoplankton carbon (Phyto-C) is important for estimating the contribution of primary production to particulate organic carbon (POC) (Wienke et al., 1987; Chang et al., 2003). As the primary food source of zooplankton in the ocean, phytoplankton biomass is often expressed as its carbon content when quantitatively determining and estimating the predator/prey relationship and carbon flow through the food chain in the ocean (Atkinson, 1996; Legendre et al., 1999). In the field, however, due to the overlap in the size of phytoplankton and other suspended particulate matter (SPM) such as zooplankton and other non-living organic particles, it is impossible to separate phytoplankton completely from other SPM by filtration methods. Up to the present, Phyto-C content still cannot be determined directly in field. To quantitatively determine the Phyto-C content remains a challenge for many marine biologists.

Early in 1966, Mullin et al. (1966) estimated Phyto-C from cell volume by using a conversion factor. Since then, the conversion factor method based on phytoplankton enumerations, calculation of bio-volume and application of certain equations has been used in many studies over several decades (Strathmann, 1967; Eppley et al., 1977; Holligan et al., 1984; Furuya, 1990; Montagnes et al., 1994; Sun et al., 1999; Chang et al., 2003). The advantages and disadvantages of using conversion factor method based on the cell volume were discussed by Mullin et al. (1966) and Banse (1977). One advantage is that the calculated conversion ratio can be less affected by alterations in the environment and interference...
produced by detritus and zooplankton carbon in comparison to the method of field direct measurement of Phyto-C to Chl-α ratio. However, the cell volume conversion method is a time-consuming approach involving counting and measuring algal cells with a microscope. In addition, sampling with a phytoplankton net may miss some phytoplankton whose cell size is less than the pore size of the net. It appears that there is no convincing way to collect and preserve all cells in water samples during field studies (e.g. naked flagellates are not easily preserved but are dominant in some sea waters). In many cases field-measured Phyto-C values could be underestimates.

The ratio of Phyto-C to Chl-α can also be estimated from linear regression analyses of chemically determined POC and Chl-α concentrations based on large field samples and measurements (Hung et al., 1980; Schaefer et al., 1984; Wienke et al., 1987; Taylor et al., 1997; Chang et al., 2003). Since the concentrations of POC and Chl-α can be measured routinely with high accuracy, this method is relatively easy and convenient in practice.

Besides the linear regression method of POC against Chl-α, there are other two chemical methods used to calculate the Phyto-C. One is by regressing POC concentration against ATP (Adenosine Triphosphate) concentration and the conversion ratio of Phyto-C/ATP can be then obtained to estimate the phytoplankton biomass carbon (Hewes et al., 1990; Cai et al., 1998). The other approach is to use 14C radio-labeled chemicals in culture incubation to determine the in situ Phyto-C/Chl-α ratio and the Phyto-C can then be calculated from the concentration of Chl-α multiplied by the conversion ratio (Redalje et al., 1981; Welschmeyer et al., 1984; Gieskes et al., 1989; Malone et al., 1993).

For the methods mentioned above, selecting an appropriate statistic regression model is important for obtaining a valid conversion ratio for Phyto-C. Linear regressions mainly include Model I and Model II, namely ordinary predictive regression and functional regression, respectively (Ricker, 1973). Based on least square linear regression, the former is more commonly available in computing programs. However it requires fixed or targeted predictor (independent) values and sampling methods that violate this criterion often produce unreliable slopes (Baruch, 1996a, b). In contrast, the model II can be applied when the independent variable is not controlled (Ricker, 1973; Laws et al., 1981). Laws et al. (1981) suggested that the Model II should be used to estimate the Phyto-C/Chl-α ratio when using the concentration plot of Chl-α versus POC because both the dependent (POC) and independent (Chl-α) variables are uncontrolled and subject to natural variability and measurement error (Ricker, 1973; Laws et al., 1981; Wienke et al., 1987).

Using different experimental methods and statistical approaches, many studies have been conducted to measure the Phyto-C/Chl-α ratios in different oceanic regions. In this paper, the Geometric Mean (GM) linear regression method of Model II was applied to estimate the conversion ratio of Phyto-C, based on a 12-month field investigation of POC and Chl-α concentration in Jiaozhou Bay, China.

2 MATERIALS AND METHODS

2.1 Research area

Jiaozhou Bay is a semi-enclosed coastal embayment located on the northeast coast of China and adjacent to the South Yellow Sea (Fig.1). It covers an area of about 400 km² with an average water depth of 7 meters. In the last ten years, the rapid urbanization along Jiaozhou Bay has affected the bay’s ecosystem dramatically. Three major rivers (Haibo River, Licun River and Loushan River) flow directly into the east and northeast bay. These carry large amounts of untreated urban waste waters and affect the nutrient distribution and phytoplankton production significantly (Shen, 2002). Due to its ecological and economic importance, since 1991, Jiaozhou Bay has been chosen as a long-term ecosystem study area for the Chinese Ecosystem Research Network (CERN). The aim is to monitor and assess its biological, chemical and ecosystem changes in response to the anthropogenic impacts in the bay.

2.2 Sample collection and analysis

Chl-α and POC samples were collected in surface waters from fourteen stations (Fig.1) monthly from March 2005 to February 2006 during the routine cruises of monitoring studies in the bay. Chl-α and POC were collected on 47 mm and 25 mm glass fiber filters (Whatman, GF/F; 0.7 μm), respectively. For Chl-α, 0.3 to 0.5 L of seawater was filtered. For POC, 0.15 to 0.25 L of seawater was filtered, depending on particle concentration. The filters used for POC collection were pre-combusted at 450°C for 5 h. After filtration, the filters for Chl-α were wrapped in clean tinfoil and filters for POC were kept in glass