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Relationship between Observed and Estimated Chlorophyll *a* Concentrations from the Secchi Depth in the Central Subarctic Pacific

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Abstract

The correlations between chlorophyll *a* concentrations calculated from Secchi depth and observed *in situ* were investigated in the central subarctic Pacific. For the relationship between the observed chlorophyll *a* concentrations and transparency, negative non-liner correlations were revealed. Estimated chlorophyll *a* concentrations were positively correlated with observed chlorophyll *a*. However, the estimated chlorophyll *a* from the Falkowski-Willson's (1992) equation are overestimated about 0.5–0.6 mg m^{-3}. It is necessary to pay attention to primary productivity for estimation of chlorophyll *a* concentrations from the transparency.

Key words: Chlorophyll *a* concentration, Secchi depth, Transparencey, Subarctic Pacific

Recently, interdecadal variabilities of oceanic ecosystems are concerned in relation to the climate 'regime shift' in the North Pacific (e.g. Venrick et al., 1987; Brodeur and Ware, 1992; Falkowski and Wilson, 1992; Roemmich and McGowan, 1995; Brodeur et al., 1996; Sugimoto and Tadokoro, 1997). Lower trophic conditions are basic insight to understand the long-term changes of ecosystems. However, there is little time-series data on chlorophyll *a* concentrations as an index of phytoplankton standing stock in the oceanic areas. Since last decade, it has been reported that chlorophyll *a* concentration could be calculated from transparency data, using empirical equations between them (Megard and Berman, 1989; Lewis et al., 1988; Falkowski and Wilson, 1992). Estimation of chlorophyll *a* from the transparency data may be an useful method for the time-series research for phytoplankton standing stock, because Secchi depth has been measured routinely in the oceanographic observation since early 1900's (Lewis et al., 1988). However, there would be geographical and seasonal variations in the relationship between transparency and chlorophyll *a* concentrations, as suggested by Nagata (1996) and Sugimoto and Tadokoro (1997). In this study, we investigated the correlation between the calculated chlorophyll *a* concentrations from Secchi depth and the measured chlorophyll *a* concentrations *in situ* water samples in the central subarctic North Pacific to assess the validity of the chlorophyll *a* estimation by means of transparency.

Observations were carried out at along 180° longitude in the central North Pacific during mid-June of 1986, 1987, 1997 and 1998 (cf. Faculty of Fisheries, Hokkaido University, 1987, 1988, 1998, 1999). Transparency was measured in 42 stations during the day time from the subarctic region to the north of the Subarctic

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Boundary defined by Favorite et al. (1976). Water samples for chlorophyll *a* concentration were collected from 10 different depths (0, 10, 20, 30, 50, 75, 100, 125, 150 and 200 m), using 1.8 liter Niskin bottles fitted with the CTD system. Each water sample (500-1,000 ml) was filtered through Whatman GF/F filter. The filters were stored in a desiccator at $-20°C$ for fluorometric analysis using the procedures of Parsons et al. (1984). Also chlorophyll *a* concentration ($mg\ m^{-3}$) was estimated from the empirical equation used by Falkowski and Wilson (1992), as follows:

$$\text{Chlorophyll } a \text{ concentration} = 457\ Z_d^{-2.37} \qquad (1)$$

where Z_d is in Secchi depth (m). Compensation depth was calculated from the equation

$$I_z = I_0 e^{-kz} \qquad (2)$$

where z is compensation depth (m), I_z is derived as 1% I_0 in solar radiation intensity at the surface and k is extinction coefficient (m^{-1}) calculated from the following equation (Walker, 1980)

$$k = 1.45/Z_d \qquad (3)$$

This compensation depth defines the lower boundary of the euphotic zone. The mean chlorophyll *a* concentration within the euphotic zone was calculated by trapezoidal integration from the surface to the depth of the euphotic zone. The depth of the euphotic zone ranged from 28.6 to 63.5 m in the study area.

For the relationship between the observed chlorophyll *a* concentration and Secchi depth, negative non-liner correlations were revealed (Fig. 1). The regression curves for the observed chlorophyll *a* concentration (y : $mg\ m^{-3}$) against the Secchi depth (x : m) are as follows:

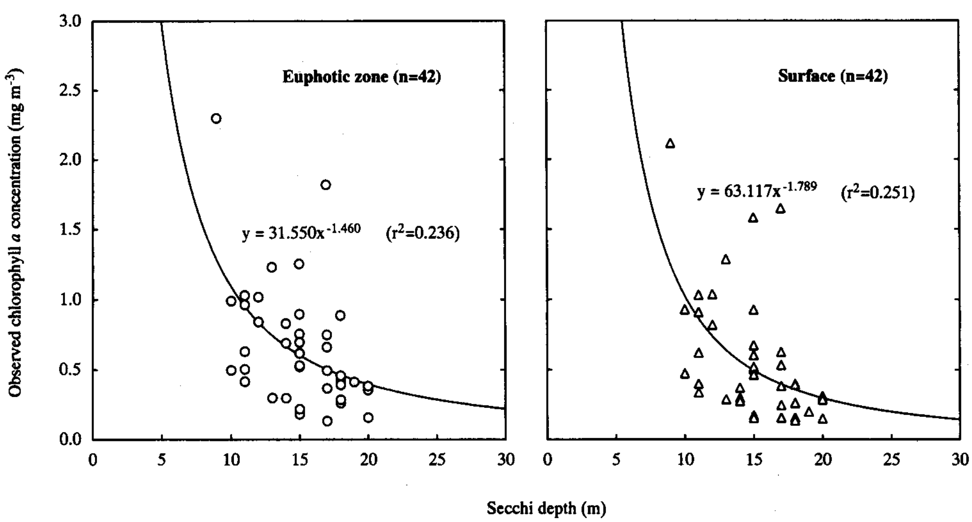

Fig. 1. Observed chlorophyll *a* concentration (y : $mg\ m^{-3}$) in euphotic zone (left) and at surface (right) plotted against Secchi depth (x : m) during summers in 1986, 1987, 1997 and 1998 in the central subarctic Pacific.

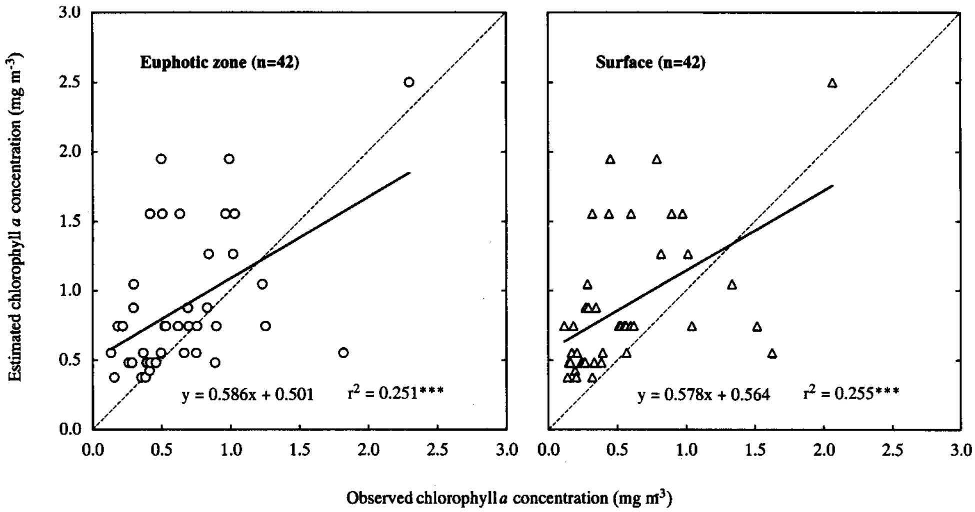

Fig. 2. Chlorophyll *a* concentrations estimated from Secchi depth (y : mg m^{-3}) plotted against observed chlorophyll *a* concentration (x : mg m^{-3}) in euphotic zone (left) and at surface (right) during summers in 1986, 1987, 1997 and 1998 in the central subarctic Pacific. Broken lines show 1 : 1 correlation between estimated and observed chlorophyll *a* concentrations. *** : $p<0.001$

Within euphotic zone : $y=31.550x^{-1.460}$ ($n=42$, $r^2=0.236$, $p<0.01$) (4)
Surface : $y=63.117x^{-1.789}$ ($n=42$, $r^2=0.251$, $p<0.01$) (5)

From the equations, 23-25% of variance in the observed chlorophyll *a* concentrations could be explained using Secchi depth. The estimated chlorophyll *a* concentrations were positively correlated with the observed chlorophyll *a* (Fig. 2). According to single regression analysis, there were statistically significant regression equations between the estimated chlorophyll *a* from Secchi depth (y : mg m^{-3}), and the mean observed chlorophyll *a* concentrations (x : mg m^{-3}) within the euphotic layer and the surface :

Within euphotic zone : $y=0.586x+0.501$ ($n=42$, $r^2=0.251$, $p<0.001$) (6)
Surface : $y=0.578x+0.564$ ($n=42$, $r^2=0.255$, $p<0.001$) (7)

However, only 25-26% of variance in the observed chlorophyll *a* concentrations could be explained using the estimated chlorophyll *a*. Especially, the estimated chlorophyll *a* tended to disperse widely at the stations where the observed chlorophyll *a* concentrations were high (>1.0 mg m^{-3}).

There are somewhat differences between estimated and observed chlorophyll *a* concentrations during early summer in the subarctic Pacific, i.e. the chlorophyll *a* calculated from the Falkowski-Willson's (1992) equation are overestimated about 0.5-0.6 mg m^{-3}. These dissimilarities may be attributed partly to large-sized particles (e.g. diatoms, herbivorous copepods) in the subarctic Pacific rather than those in the temperate and tropical regions. Therefore, it is necessary to pay attention to the primary productivity in the study site when we estimate the chlorophyll *a* concentrations from the transparency, using the Falkowski-Willson's

(1992) equation. If more transparency and observed chlorophyll *a* data are accumulated, the useful empirical equation could be established for the subarctic Pacific.

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