Relationship between sedimentary pigments and primary production: evidence from core analyses of twelve Italian lakes

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Abstract

A statistically significant correlation of the type $y = ax^b$ between sedimentary plant pigments and contemporary algal primary production has been found in a study of the recent trophic evolution of twelve Italian lakes. The equation is used to assess baseline production levels in periods (50–70 years ago) when human influence was low.

Introduction

The record of pigment degradation products laid down in lacustrine sediments allows historical changes in lake primary production to be determined, adding greatly to our understanding of the natural development of lakes and the process of eutrophication. Such an understanding is necessary for enlightened lake management.

Wetzel (1970) has documented the usefulness of sedimentary pigment analysis in the back-calculation of primary productivity through the entire post-glacial period.

In a previous study (Adams *et al.* 1978) data on sedimentary pigments and recent primary productivity from several northern Italian lakes were gathered. A good correlation was found between pigment concentration per unit organic matter in the 0–10 cm sediment depth and contemporarily derived data on primary productivity from six lakes. In this regard a more detailed study was made on Lake Mergozzo, situated near Lake Maggiore (Guilizzoni *et al.* 1981).

When surficial sedimentary phaeophytin from recent sediments of six cores from Lake Mead, Nevada, were regressed against annual primary production data, the correlation was highly significant (.001 level), indicative of the potential application of this method (Adams, pers. comm.).

In this paper data are presented from additional twelve northern Italian lakes with very different trophic and morphometric characteristics (Guilizzoni *et al.*, in press). Analyses of sediments were made to evaluate as accurately as possible the relationships between plant pigment derivatives in the surface sediment layers and corresponding primary production levels. The results shown are a part of those gathered during a more comprehensive study designed to identify trophic changes from both core data and limnological data (Guilizzoni *et al.*, in press).

Material and methods

From summer 1978 to 1980 a crust freezer (Adams *et al.* 1978) was used for collecting sediment cores of about 1 m from the deepest zone of the lakes. In Lake Como an additional core was taken at a depth of 40 m in a zone close to the town of Como. Sections of the crust were removed every 2 cm in the first 10 cm of the core, every 5 cm down to 20 cm, and every 10 cm in the remaining part. Extraction of the chlorophyll derivatives and carot-

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enoids was performed following Sanger & Gorham (1972). Sedimentary pigment degradation units ($SPDU_{665}$ and $SPDU_{445}$) relative to the content of organic matter in the sample were defined as arbitrary units, according to Wetzel (1970). Reproducibility of the results (C.V. % on 10 replicates) was 4.8 and 13.5 for $SPDU_{665}$ and $SPDU_{445}$, respectively.

Results and discussion

Depth distributions of chlorophyll and carotenoid degradation products for the lakes are shown in Fig. 1. The trend of pigment concentration within the sediments of the various lakes is similar. In general, from the oldest layers to a level of about 20–30 cm, all the lakes, with the exception of Lake Mezzola which has a short residence time, show a gradual increase in pigment concentration, followed by a sharper rise in the most recent sediments. As this rise is mainly due to recent eutrophication, the pigment concentrations in the lower part of the curve may be considered as the expression of a baseline trophic status for the lakes considered. Using this criterion a ranking of the lakes from the most to the least productive would be: Alserio, Varese, Como (40 m depth), Segrino, Pusiano, Endine, East and West Annone, and the deep lakes Como (400 m depth), Maggiore, Garda, and Iseo.

There are large differences in the pigment concentration between the lakes, the mean value of $SPDU_{665}$ in the surface sediment varies from ca. 1300 for Alserio to ca. 60 for lakes Garda and Pozzo di Riva. Although the deep Lake Garda is the least productive among the investigated lakes, its core analysis displays a clear recent increase of algal pigments and it consequently suggests an increase in lake productivity.

The primary production data for the single lakes, as shown in Fig. 1, were obtained in different years within the last ten years but for Lake Maggiore older data are also included. Because of bioturbation it is difficult to establish a year to year correspondence between deposited pigments and primary production. We have therefore averaged pigment values from two or three different levels around the one theoretically corresponding (on the basis of the calculated sediment accumulation rates) to the production data. Data from Lake Mergozzo (Guilizzoni *et al.* 1981) are also included in the regression analysis.

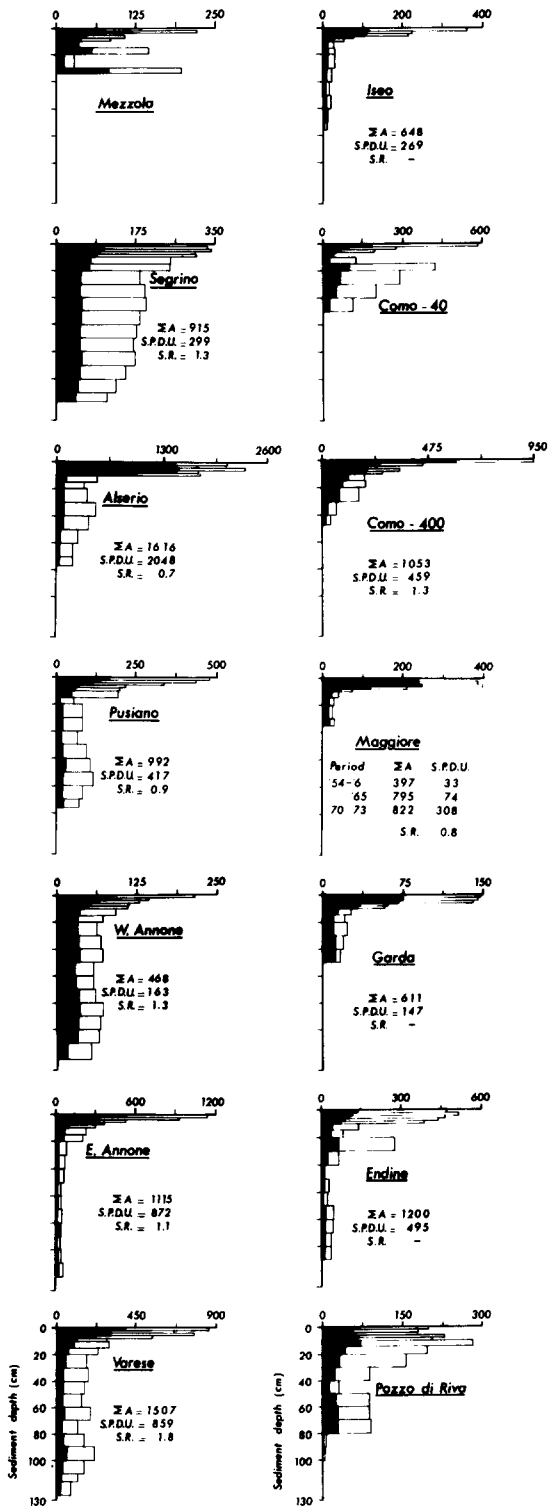

Fig. 1. Depth distribution of chlorophyll (black) and carotenoid (white) derivatives in sediment cores. Average daily primary production (Σ A, in mg C . m^{-2} . d^{-1}), SPDU (chlorophyll plus carotenoid derivatives/g organic weight) and S.R. (sediment accumulation rate, in cm . a^{-1}) are also shown.

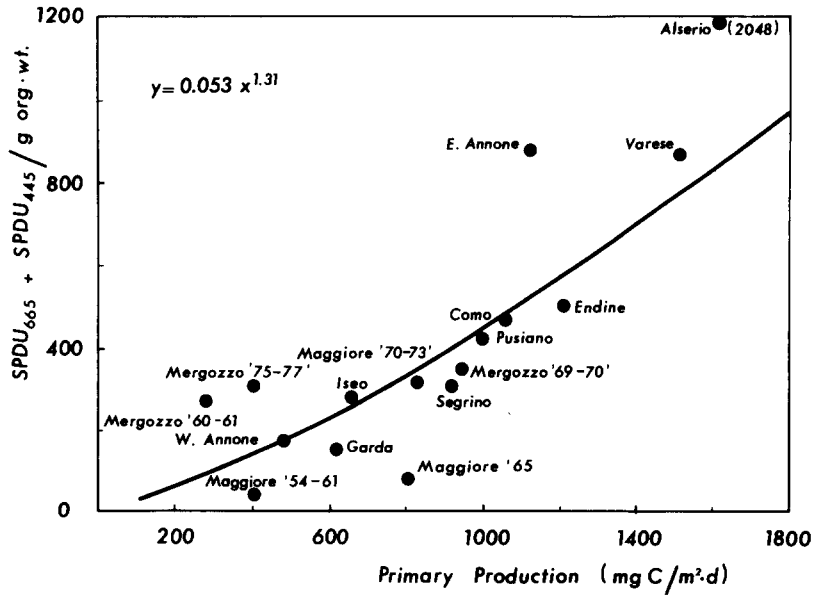

Fig. 2. Relationship between phytoplankton primary production and chlorophyll plus carotenoid derivatives in lake sediments.

Significant regressions ($P \leqslant 0.01$) of the type $y = a\,x^b$ were found between sedimentary pigments and primary production. The equation shown in Fig. 2, takes into account the sum of the two categories of pigments and was used to calculate approximate present primary production values for lakes Pozzo di Riva and Mezzola, lakes for which algal production data were not available. The values obtained were 521 mg C . m^{-2} . d^{-1} and 490 mg C . m^{-2} . d^{-1}, respectively. Although tentative, these values are in accord with the meso-eutrophic condition of the lakes as indicated by chemical and biological studies (Baudo *et al.* 1979; de Bernardi *et al.*, in press).

Table 1. Recent measured annual (g C . m^{-2} . a^{-1}) algal production (a) and calculated past production (b) prior to 50–70 years ago. Per cent difference is also indicated.

Lake	(a)	(b)	$\frac{(a)-(b)}{(a)} \cdot 100$
Varese	550 (1979)	159	71
E. Annone	407 (1972–73)	72	82
W. Annone	171 (1972–73)	83	51
Pusiano	362 (1972–73)	108	70
Alserio	590 (1972–73)	295	50
Segrino	340 (1972–73)	169	50
Endine	438 (1973)	57	87
Garda	223 (1970–72)	31	86
Como –400 m	384 (1970–71)	58	85
Iseo	237 (1971–72)	31	87
Maggiore	300 (1970–73)	44	85

On the basis of accumulation rates calculated using the ^{137}Cs method (Premazzi 1978 and pers. comm.) the equation of Fig. 2 can be used to back-calculate production levels for the period prior to 50–70 years ago, when human impact on the lakes was much less severe than at present (Table 1). These values should correspond to baseline productivity levels, associated with general morphometric and climatic characteristics.

From Table 1 it can be seen that the past annual production of the large, deep lakes Garda, Iseo, Como and Maggiore was in the range of 31–58 g C . m^{-2}, corresponding to a daily average production of 85–160 mg C . m^{-2}. These values are in good agreement with the expected values for oligotrophic lakes. The table also shows that, of the shallow lakes, Endine and East and West Annone were essentially oligotrophic, whereas the rest were mesotrophic or eutrophic.

Despite differences in factors that may be expected to affect the preservation of pigments in sediments and to cause variations in the amount of allochthonous pigments, the correlation seems to be of general applicability to Italian subalpine lakes. From a practical point of view, the difference

between present and past production rates indicates the changing degree of human impact on the lakes in the last few decades; on the other hand, the calculated values for the past indicate what could be achieved, in terms of productivity reduction, following nutrient abatement with the use of suitable treatment plants.

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