Journal of Lake Sciences, Vol. 10, Suppl., pp247-250, 1998.

Environmental Fate of Biogenic Carbon in Lakes*

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A model was recently proposed to analyse the food-web mediated flux of carbon in pelagic ecosystems (Legendre and Rassoulzadegan, 1996). According to these authors, the flows of biogenic carbon (BC) within ecosystems (defined as exchanges of BC among trophic compartments of the food web) are largely determined by the size structure of primary producers and the matching between primary production and grazing. The authors used the ratio P_L/P_T to quantify the size structure of primary production [P_L/P_T: production of large (L) to total (T) phytoplankton; according to studies, the threshold between large and small phytoplankton varies between 1 and 5 μm, see Table 1 in Legendre and Rassoulzadegan, 1996] and they represented the spatio-temporal coupling between primary production and grazing by the matching [M; a dimensionless number ranging from 0 to 1] between these two rate processes. They developed a food-web mediated carbon flux model which considers the partitioning of phytoplankton production among three BC fluxes in ocean: euphotic-zone remineralization (R), food-web transfer (F), and sinking to depth (D). Using data from the literature, they showed that, in oceans: (1) the export characteristics of pelagic ecosystems are largely determined by the size structure of primary production and the matching between primary production and grazing; and (2) total export from the euphotic zone is a function of the delivery of mechanical energy to the upper water column, whereas the partitioning of total export between food-web transfer and sinking of particulate organic carbon (POC) is controlled by temporal variations in depth of the surface mixed layer. Food-web transfer is significant for marine resources and sinking of POC may contribute to the regulation of climate change (BC sequestration at depth).

Several of the topics addressed by Legendre and Rassoulzadegan (1996) for oceans are pertinent to lakes. These include: the broad channelling of phytoplankton production into euphotic-zone remineralization and export; the partitioning of export between food-web transfer and sinking to depth of organic particles (in lakes, the latter may not necessarily lead to BC sequestration, but it is nevertheless a significant ecological process); the effects, on BC flows within ecosystems, of the size structure of primary production and the matching between

* Received 1997-02-25; accepted 1998-03-27.

primary production and grazing; the overall food-web mediation of BC fluxes.

The present paper applies to lakes the approach developed by Legendre and Rassoulzadegan (1996) for oceans. The paper shows how the model can be used to determine the environmental fate of BC in lakes, and it provides insight into the food-web controls of BC fluxes during phytoplankton blooms (Legendre, 1999).

In order to exemplify the application of the model to fresh waters, values of P_L/P_T, M, R_T/P_T, F_T/P_T, and D_T/P_T were derived from the literature for three temperate lakes and various ecological conditions (Tab. 1). Parameters of the model were computed using these data and the equations of Legendre and Rassoulzadegan (1996). Figure 1 illustrates the responses of R_T/P_T, F_T/P_T, and D_T/P_T to the combined effects of P_L/P_T and M. The seven lakes and ecological conditions in Table 1 are located on the Figure according to their P_L/P_T and M co-ordinates. The Figure shows that R_T/P_T is almost independent from M (isopleths nearly parallel to the ordinate), and that F_T/P_T is nearly independent from P_L/P_T (isopleths almost parallel to the abscissa). In contrast, D_T/P_T depends on both P_L/P_T and M. Three groups of lakes and ecological conditions are identified on the Figure: spring bloom (A, E), autumn bloom (C), and summer (B, D, F, G).

Tab.1 Ecosystem characteristics for three temperate lakes and various ecological conditions, based on data from the literature. Symbols are: P (phytoplankton production), *M* (degree of matching between primary production and grazing), R (remineralization within the euphotic zone), F (food-web transfer), D (downward POC flux), E total export from the euphotic zone (E =F+ D), T (total phytoplankton assemblage), L (large size fraction).

Lake and ecological condition	P_L/P_T	M	R_T/P_T	F_T/P_T	D_T/P_T
A. Lake Biwa, spring bloom	0.95	0.10	0.10	0.00	0.90
B. Lake Biwa, summer	0.85	1.00	0.25	0.70	0.05
C. Lake Biwa, end of autumn bloom	0.85	0.50	0.30	0.20	0.50
D. Lake Biwa, picocyanobacterial bloom	0.75	1.00	0.40	0.25	0.35
E. Lake Kinneret, spring bloom	0.85	0.10	0.10	0.15	0.75
F. Lake Kinneret, summer	0.50	1.00	0.20	0.30	0.50
G. Lake Constance, high summer	0.85	0.90	0.25	0.60	0.15

Both the model (Fig. 1) and the data (Tab. 1) show that there is an increasing gradient in *M* values, from spring bloom to autumn bloom and to summer conditions, with a corresponding increase of F_T/P_T. The relatively small range of P_L/P_T values (a single case <0.75) does not permit to draw a conclusion concerning the effect of this food-web variable in lakes. During blooms, the combination of high P_L/P_T and low or intermediate M is accompanied by high

D_T/P_T; during summer, high P_L/P_T and M are associated with low D_T/P_T. It is concuded that the combination of food-web variables P_L/P_T and M can be used to compute the three BC fluxes in lakes, i.e. euphotic-zone remineralization (R_T/P_T), food-web transfer (F_T/P_T), and export to depth (D_T/P_T). Similar information can also be obtained from the M-P_L/P_T diagram (Fig. 1). In order to get generally applicable results, however, parameters of the model must be estimated on a larger sample of lakes and ecological conditions than that used in the present study. The resulting model would provide a general framework for investigating food-web controls of BC fluxes in lakes.

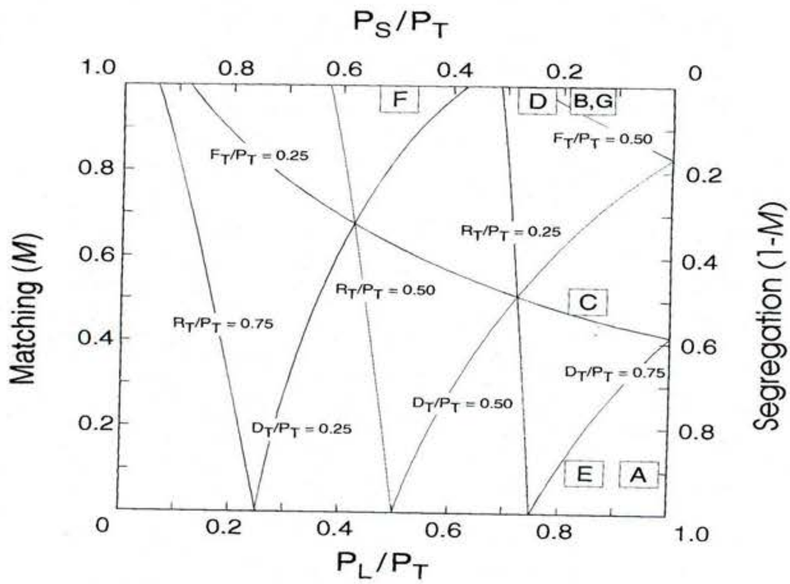

Fig. 1 Three BC fluxes in temperate lakes, i.e. remineralization within the euphotic zone (R), food-web transfer (F), and downward POC export (D), are plotted as functions of the size structure of primary production (P_L/P_T or P_S/P_T) and the matching (M, or segregation 1 - M) between primary production and grazing. P_L/P_T and P_S/P_T refer to the shares in total primary production (P_T) of large and small phytoplankton (P_L and $P_S = P_T - P_L$), respectively, and M is given on a scale of 0 (no matching) to 1 (perfect match). R, F, and D are expressed as proportions of P_T. Isopleths are plotted for values of R_T/P_T, F_T/P_T, and D_T/P_T = 0.25, 0.50, and 0.75. At any point in the diagram, $R_T/P_T + F_T/P_T + D_T/P_T = 1$. The various lakes and ecological conditions (identified by letters A to G, as in Table 1) are positioned according to the P_L/P_T and M values, listed in Table 1. Three groups of lakes and ecological conditions are identified: spring bloom (A, E), autumn bloom (C), and summer (B, D, F, G) (From Legendre, 1999).

References

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