THE PROCESS OF EUTROPHICATION AND CRITERIA FOR TROPHIC STATE DETERMINATION

A panel position paper

by

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THE PROCESS OF EUTROPHICATION

The classification of "harmonic" lakes in the oligotrophic-mesotrophic-eutrophic series originated with Naumann in 1919 and has since been developed and used by numerous investigators. The concept was originally developed for the classification of lakes per se in relation to natural eutrophication. In attempting to apply the trophic scale to modern problems of cultural eutrophication a number of difficulties arise:

1. Investigators in different regions have divergent concepts of the oligotrophic-eutrophic scale. An oligotrophic lake in southern Canada, for example, might be classified as mesotrophic if in Norway.

2. Natural eutrophication is a slow process in relation to cultural eutrophication. Although the results in both cases are similar in many ways, the former in a given lake is largely a function of morphometric change, whereas the latter occurs without significant change in morphometry and is largely determined by increases in nutrient load.

3. There has been a confusion in the limnological literature between definitions of trophic state based on causes (e.g. nutrient supply, nutrient concentrations, climate, etc.) and effects (e.g. abundance, production and composition of planktonic algae, benthic vegetation, bacteria, benthic animals, fish, etc.).

4. With the present need for control of cultural eutrophication and models to facilitate an understanding of control mechanisms, there is a priority on measurements in c.g.s. units so that effects can be linked directly to causes and expressed as functions of causes. Indicator species or associations, though extremely useful, do not fulfill this requirement.

In discussing the above one member of the panel (Shapiro) made a case for the development of a eutrophication scale based on several criteria (e.g. Secchi depth, species, algal abundance, etc.), comparable in some ways to the Richter scale used in seismology. After much discussion it was generally agreed that the "Shapiro scale" would be useful in providing the public with a meaningful guide-line, but it would not be useful in modeling because of the confusion that would result from the addition of "apples and oranges".

The panel and audience, after much heart-rending discussion including diverse arguments of the "But that does not account for" type, came to the following general conclusions:

1. The concept of trophic state as described in the limnological literature (e.g. oligotrophy, mesotrophy, eutrophy) is too multi-dimensional and too susceptible to individual interpretation to be of value to model makers. Nevertheless, limnologists should establish criteria for oligotrophic, mesotrophic, and eutrophic waters, both in terms of lake classification per se and problem-oriented classifications independent on morphometric change. Both have predictive value.

2. Criteria for the assessment of lakes in relation to human use must be based on the biological effects that constitute the problems, rather than on chemical and other causes that accelerate or initiate biological processes and changes. The reason for this is very simply that no one has as yet been able to quantitatively relate causes to effects for lakes in general. Thus, while nutrient loading rates and the relative percentages of natural and man-derived nutrients provide the best available criteria for control at the present time, they do not permit any assessment of effects on water use.

3. The panel agreed that with regard to biological effects in lakes the most useful measurements at the present time are as follows:

(1) Standing crop of algae in units of chlorophyll or chlorophyll a (mg/m^3) and in units of cell volume (cm^3/m^3). These measurements should refer only to the euphotic zone with checks made occasionally to make sure in the case of chlorophyll that the proportion of phaeophytins and pheophorbides is low.

(2) Primary production of algae in units of mg C/l.day both as a productive season average and during blooms. Primary production in units of mg C/m^2.day was considered of much lower significance in relation to human use of water. This is because of the tendency for clear waters with low phytoplankton concentrations and few eutrophication problems to yield relatively high production values when integrated over depth. More attention should be given to assessment of primary production by benthic algae.

(3) Secchi depth in meters in cases where turbidity due to mineral matter or low light penetration as a result of dissolved humic materials do not constitute major interferences. In this sense Secchi depth is a rough index of algal biomass in the upper water layers. It is a simple and useful measure that can be applied by unskilled personnel.

Guide-lines demarcating acceptable and dangerous levels (Productive seasons) of the above are: (1) 5-10 mg chl a/l, 3-5 cm^3/m^3; (2) 0.20-0.4 mg C/l.day; (3) 3-6 m listed in Table 1.

Some weighting for lake morphometry should be taken into consideration in using these guide-lines. In very large lakes, for example, overall water usage decreases exponentially from the shore-line to the geographic

center. In such cases lake-average data may be less meaningful than along the waterfront or at beaches.

A variety of other indicators are available for assessment of parameters of "trophic state", but for one reason or another these are not so useful as the above in relation to modeling. Among these are:

1. Oxygen depletion and oxygen depletion rates in the hypolimnion. In general when the average dissolved oxygen level in the lower half (by volume) of the hypolimnion is less than 3-5 mg O_2/l during conditions of restricted circulation, repercussions to cold-water fish populations can be expected even though the fish may have a refuge in more highly oxygenated waters of the upper part of the hypolimnion. In bodies of water too shallow for a hypolimnion, pronounced oxygen depletion can occur in bottom layers during prolonged periods of calm weather at the sediment-water interface - even though those waters are initially near saturation.

2. Sawyer's rule that algal problems can be expected whenever the concentrations of inorganic-N (ammonia, nitrite, nitrate) and inorganic-P (orthophosphate) exceed 300 μ g-N/l and 10-15 μ g P/l at the time of spring turnover.

3. Shape of primary production vs. depth curves. Curves without pronounced maxima in the upper layers are generally characteristic of clear waters without algal problems, whereas those with maxima in the upper layers tend to be associated with algal problems.

4. A variety of indicator species and species associations are available which can delineate stages in eutrophication. Thus, waters with algal problems generally have high blue-green algal populations (e.g. Anabaena spp., Anacystis spp., Aphanizomenon spp.). Also, some diatoms are indicative

of early stages in eutrophication, increasing in frequency prior to major deleterious changes. Comparable indicators of "trophic state" exist among benthic plants (Cladophora) and animals (oligochaetes, midges). These can be most useful in general assessment of pollutional levels, but have the disadvantage in relation to model studies that the data cannot at present be given in cause-and-effect terms, nor expressed in c.g.s. units.

The panel believed that more attention should be devoted to developing eutrophication criteria based on sediments and sedimentation rates (P, N, well-preserved organisms or their parts, etc.) since they offer a time-dampened and space-dampened source of information. Also, recent trends can often be established from near-surface sediment cores, i.e. information relating past to present conditions.

Finally, the panel stressed that the assessment of "trophic state" and the interpretation of the parameters cited above requires much biological insight, particularly in rapidly changing situations. In this sense, interpretation and assessment demands the expertise of a broadly diversified limnologist familiar with the analysis of biological communities at the species level.

DISCUSSION

THE PROCESS OF EUTROPHICATION AND CRITERIA FOR TROPHIC STATE DETERMINATION

SHAPIRO: We are not trying to ascertain the trophic state to determine whether or not we do anything about the lake. That is another matter. What creates that trophic state is really secondary to giving it a name or a number. No matter what the morphology of the lake is, it is what it is, and that is what we are trying to describe. We are trying to describe it so that we can say that at this moment in time it is such and such. And whether it is that, may be because it is a shallow lake. If we want to establish the trophic state in the context of doing something about the lake, then I think you also have to go back and find out: What was that lake like before it was disturbed? Therefore, we have to find out how far back we hope to get, what the ultimate limit would be to recover this lake, and this opens up a whole new conception of things. The potential trophic state. Maybe we can define the trophic state as a point in time.

VALLENTYNE: What limnologists were doing years ago was classifying lakes just to be classifying lakes, clarifying in their minds their purposes, against the interest and importance that attaches to the subject today.

SHAPIRO: You want to assess the present status of this lake for this year. You want to know how it has changed from last year. To do this we must come up with some objective statement. We must have some way of comparing this lake with another. We must be able to say, this lake is better than that one, and this one is a little worse than that one. If there are enough gradations on the scale, it doesn't matter whether it is 22nd or 29th. It is a way of finding out where you are in the ball park.

SHANNON: I agree with Dr. Shapiro, we should have one number, I think one

of the disadvantages in considering all of these different criteria is that we get different results. If we properly weigh the criteria we can compensate with give and take. This is the sort of situation where we can give a little in one criteria, and so on, until we get one number that will prevent some sort of conflict in the various criteria.

WATTS: How does this explain numbers to me?

SHAPIRO: How does a seismologist explain an earthquake to you? He tells you the earthquake is monitored on a scale of ten. You see it somewhere in limbo. If you hear that there has been an earthquake somewhere in terms of the Richter Scale you just know there has been an earthquake. You don't have to model it, you know it.

VALLENTYNE: What you are talking about here is the value of such a scale in explaining the situation to the public.

SCHAAKE: There must be some measure that needs to be explored to decide whether certain kinds of lakes are desirable or undesirable, for one reason or another, and that needs to be done as part of this, perhaps some scale of measure, something that has a scalar measure to it of some sort. If you want to talk about lakes in terms of their desirability, one should investigate what about a lake makes it desirable or undesirable. If it is a scientific value, then I think that needs to be considered. It takes a combination. You have to validate something.

BEETON: I think that limnologists simply use the terms eutrophic, mesotrophic - I think we have an obligation at this point to define these a little bit more precisely. We find that they are being used now by many people. Whether or not you want to throw these out, that's all beside the point. You still have this obligation to define them. You have to find

criteria for at least these categories, if we don't do anything more. But as far as going to some compound index or something, this might be useful in terms of establishing waterflow criteria, or something like that, and as I stated earlier, I think we have got to follow two things, and one of them is the practical application. The other is, what we would want as a scientific community. I think, as a limnologist I wouldn't be unskeptical. I wouldn't want to accept somebody's index for a lake, because I would like to know just what he found and what he based this on.

SHAPIRO: You are finding fault with something that doesn't exist yet. This could be moderately sophisticated. For example: You could have a method of determining whether or not a lake has phosphate. Do the algae have alkaline phosphatase? This sort of thing could be run into it. This could be a metabolic analysis of the health of the lake. There needn't be something where people could make a great big mistake. I think we've got to come up with some objectivity in this.

FOX: As far as a way of communication between scientists by using this, not as an index number, but as a code like a ten digit number which would give us a range of all of the parameters of a lake.

VALLENTYNE: That would be useful. This might be good as an index to scientists who weren't particularly involved in the maintenance of records. For the ones who did, it could be rather confusing.

SHAPIRO: We need a code. A code could embody an awful lot of information. Some of these things could be fairly simple, for example: In this particular lake you may be using the rate of oxygen depletion, or whether the oxygen disappeared the first, second, or third month after stratification

or something.

BARTSCH: I think we've perhaps exhausted this aspect of things. Where some of this approaches communication with the public, I think the public is becoming aware that there is a word, eutrophication. I think the public is approaching the point where we need something more than simply saying that this lake is eutrophic. We may need advice to see how the public is better informed. We need to know something more than that this lake is eutrophic. If we begin to classify lakes in terms of the system, or on the semi-Richter scale, or whatever you want to call it, I think the second point is that we seem to be confusing the point with the question of whether this is the best way of communicating among limnologists, or among other scientific people who are concerned with eutrophication. I think it helps that a limnologist, or the guy who is interested in lakes, or in eutrophication, is not going to take the number, however it is constituted, and say, I accept this and I am going to use it from here on. He is going to go back and look at the basic information upon which this number was derived. I think the third point is whether or not we are really talking about this in terms of the basic theme of this session, which is, How do we use this, or how can we use it, or what is the nature of the information we need in order to feed it into the modeling process?

BREZONIK: I agree that one number to classify a lake, say to classify lakes on a scale from one to ten, would not be too meaningful, but I think if you take three things: and one of them would be the chemical nature of the water, another would be climatic and morphometric properties, the third would be productivity, type of organisms, perhaps something like this

would be meaningful as a short term handle on the lake.

BEETON: Criteria for classifying lakes are: mean depth; transparency; average dissolved oxygen in bottom waters during the late summer; the total dissolved solids. For some reason this seems to relate quite well to fish productivity in British Columbia. We can present another criteria: the average dry weight of plankton; the average dry weight of benthos; and then fish production. I looked at a number of criteria of what people thought were acceptable levels for classifying lakes in terms of eutrophic, non-eutrophic and mesotrophic, and tried to classify the Great Lakes in terms of these. I included the same things that Rawson had done, but I also included total phosphorus; silica, sulfate and conductivity; and then the species that were dominant in the benthic growths, as well as the species that were dominant in the phytoplankton community and the fish community. These are the criteria that have been used in many environments throughout the world, and people have published on these.

VALLENTYNE: We need to develop an index, not so much for the benefit of scientists and limnologists, as for the general public.