Eutrophication and Phosphate Detergents

A report by Mitchell entitled "Eutrophication of lake water microcosms: Phosphate versus nonphosphate detergents" (1) contains both errors in logic and factual misrepresentations. The ecological significance of several water treatment—a synthetic waste effluent treatment, treatment of the waste effluent with a phosphate detergent, and two treatments of waste water with nonphosphate detergents—were assessed in terms of the resulting algal diversity as determined by Shannon's diversity index:

\[ H_i = - \sum P_i \log P_i \]

where \( P_i = n_i / N \), \( n_i \) is the population of the \( i \)th species, and \( N \) is the population of the total community. Mitchell states that this index "ranges from zero for unialgal populations to unity for very diverse communities." The lower limit of this index is indeed zero: the upper limit is not unity. Pielou (2) has demonstrated that the greatest value of \( H_1 \) is a nondecreasing function of the number of species. In my own experience with Shannon's index using logarithms to the base 10 (3), I have found that \( H_1 \) is usually greater than unity for natural communities. With logarithms to other bases (e or 2), the index is even greater for the same community. It is possible to obtain index values as low as those reported by Mitchell but these must be the result of either extreme dominance or very small samples. A statement of sample size or calculation of "evenness" or "equitability" would have clarified this.

Mitchell then attributes the statement "the diversity of a lake's algal community diminishes with eutrophica-
tion" to Wilhm and Dorris (4). This particular paper, in fact, makes no mention of algae, lakes, or eutrophication. It is concerned only with the diversity of benthic macroinvertebrates in polluted streams. Following that, Mitchell states: "Thus, oligotrophic lakes would probably have diversity indices of from 0.7 to 1.0 and, as the lakes become eutrophic, the diversity index would drop to 0.3 or less." By prefacing the statement with "thus," Mitchell conveys the impression that the idea originated from the work of Wilhm and Dorris (4). This is not the case. They proposed no such classification.

The appropriateness of Shannon's diversity index in this study is questionable. In a study of artificially enriched ponds, Ewing and Dorris (5) found that "diversity did not parallel nutrient concentration." The appropriateness and meaning of most popular diversity indices is also very much in question (6). Their indiscriminate use should be discouraged.

The reader is deceived into thinking that these microcosm studies in some way represent actual conditions in real lakes. The use of microcosms to simulate lakes has many faults but I will not discuss these. Rather, I would like to direct attention to the effective microcosm concentrations of phosphate and nitrate. From table 2 of Mitchell (1) we see that the simulated waste effluent without detergents after activated sludge treatment contains 790 \( \mu \)g per liter of phosphate phosphorus and 10 mg per liter of nitrate nitrogen. The phosphate detergent plus waste water effluent contains 2800 \( \mu \)g per liter of

References and Notes

6. Supported by the Robert A. Welch Foundation and PHS research grant RR-0188.
7. Contribution of the Department of Pediatrics, Baylor College of Medicine, Houston, Texas 77025 (1972).
phosphate phosphorus and 9.5 mg per liter of nitrate nitrogen. These are di-
luated with “oligotrophic” lake water in a 1 to 9 ratio. The resulting concentra-
tions (accounting for initial concentra-
tions in the lake water) are as follows:
- waste effluent, 70 µg per liter of phos-
phate phosphorus and 1.045 mg per liter of nitrate nitrogen; phosphate
degradant plus waste effluent, 280 µg per liter of phosphate phosphorus and
0.995 mg per liter of nitrate nitrogen; nonphosphate degradant plus waste efflu-
ent, 50 µg per liter of phosphate phosphorus and 1.145 mg per liter of ni-
trate nitrogen. In Vollenweider’s compi-
lation of information regarding eu-
rophication (7), there is only one lake
with nitrate levels higher than these—
Lago d’Orta, Italy. It is heavily pol-
luated by industrial wastes containing
large amounts of ammonium salts. The
phosphate concentrations produced by
the phosphate degradant and waste
effluent exceed those in all but the
most grossly polluted lakes of the world (7).

Even the western basin of Lake Erie
contains only 120 µg per liter of phos-
phate phosphorus during the period of
highest concentration (8). Phosphate
concentrations in the microcosms
treated with only the synthetic waste
exclude the highest concentrations re-
corded for Lake Washington (9), a
well-known case of cultural eutrophication.

These concentrations may be high
enough to produce initial toxicity to
algae conditioned to an oligotrophic
lake. With such gross excesses of phos-
phate and nitrate, this experiment has
no meaning for the study of lake eu-
throphication.

Further criticism of this paper might
be possible if sufficient data had been
displayed on sampling of the micro-
cosms, nutrient levels in the micro-
cosms during the experiment, mea-
surements of total phosphorus, species
identifications of all algae instead of
just the dominant ones, and chemical
content and contribution of the mud,
to name a few.

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References
2. E. C. Pielou, An Introduction to Mathematical
3. P. J. Godfrey, thesis, University of Massa-
4. J. L. Wilham and T. C. Dorris, BioScience 18,
477 (1968).
5. M. S. Ewing and T. C. Dorris, Amer. Midl.
6. L. L. Eberhardt, Ecology 50, 503 (1969); S. H.
Hurlbert, ibid. 53, 577 (1971).
7. R. A. Vollenweider, The Scientific Basis of
Lake and Stream Eutrophication, with Parti-
cular Reference to Phosphorus and Nitrogen
as Eutrophication Factors (Technical Report
DAS/CS1/68.27, Organization for Eco-
25 (No. 2), 31 (1971).
9. W. T. Edmondson, in Eutrophication: Causes,
Consequences, Correctives (National Academy of

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I thank Godfrey for so ably re-
emphasizing the prime point of my re-
port: domestic waste water is such a
rich source of nutrients that the simple
elimination of phosphates from deter-
gents is unlikely to significantly de-
crease the rate of eutrophication caused
by the resulting waste waters. Godfrey
is quite correct regarding the upper
limit of Shannon’s diversity index. I
am at fault for not having emphasized
that my observation was based on ex-
perience, not on mathematics. I should
have said “the index ranges from zero
for unialgal populations to near unity
for the most diverse planktonic algal
communities that I have encountered
during my several years of observation
in the natural environment and in the
laboratory.” According to the Shanno-
non formula, a diversity index of unity
requires the presence of at least ten
algal genera, and even this number is
not sufficient if all ten do not have
deidentical populations. In my experience
it is very rare to find identical popu-
lations for planktonic algae, although
enumeration of the total biota pres-
et may give much higher diversity
indices.

Some information relating to the
“richness” and “evenness” of the micro-
cosms is given in my report (table 3
and the fourth paragraph from the end).
Obviously dominance is the pri-
mary factor responsible for the low
diversity indices developed, as is com-
mon in algal blooms. Further details
on the principles and practice of the
microcosm algal assay procedure are
given in the reference originally cited
(1), which in turn refers to still further
details (2). The numbers of genera and
their individual populations shown
are typical of those encountered
in the detergent study. Whether or not
the Shannon diversity index is the ideal
way of describing algal communities, it
has been very useful for comparing
these systems with each other and thus
for estimating the effects of the vari-
ables tested. The 98 and 95 percent con-
fidence levels quoted for the differences
in the results in the detergent work
came from a statistical analysis by Rus-
sell and Mitchell (3).

I regret any seeming attribution of
my own statements regarding eutrophi-
cation to Wilhm and Dorris. I was well
aware that their paper deals with the
diversity of the invertebrate com-
munity. However, their discussion of
the use of biological parameters for as-
sessing water quality is the clearest
explanation for the general scientific
audience that I have seen. For that
reason I included it as a reference ther-
er than others which also support the
interrelationship between reduced di-
versity and eutrophication (4).

Although Godfrey chooses to dis-
count the pertinence of the diversity
index to environmental research,
many others have found it to be ex-
tremely useful. Likewise, the micro-
cosm is certainly not an exact model
of a real lake, yet it does offer a means
of comparing the effects of variables
of interest while others are kept more
or less under control. This approach is
much closer to reality than a study of
unialgal cultures in synthetic media.

Further improvements are greatly to be
desired, and the opportunity is open to
all.

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References and Notes
2. D. Mitchell, thesis, Washington University,
St. Louis (1969) (69-22578, available from Uni-
versity Microfilms, Ann Arbor, Mich.).
3. Our procedure (R. A. Russell and D. Mitchell,
unpublished data) was to first fit the data
(Shannon’s diversity index versus time) to a
first-order decay model
\[ Y = a e^{-rt} + c \]
where \( Y \) is the number index per time \( t \)
and the index number and \( t \) is the

where \( x \) is the coefficient and \( S_0 \) is the
standard error of the coefficient. The
degrees of freedom were taken to be the sum
of the degrees of freedom for the control
set (\( a_1 \) and \( a_2 \)) plus the degrees of freedom
for the set of data (\( a_n \) and \( S_n \)). Similar
\( t \)-tests were of course also carried out for
the coefficients \( b \) and \( c \). The results from
these tests were then confirmed by paired
\( t \)-tests applied to the data on weeks 6 through 14.
This procedure showed that the test to be
significantly worse than the other for a low
degree of means. Further confirmation of
the \( t \)-tests on the coefficients was obtained
by applying Duncan’s multiple range test [D. B.
Duncan, Biometrics 11, 1 (1955)] on the
means for weeks 6 through 14.
4. L. G. Williams, Biology 45, 899 (1964); R. W.
Crippen and D. J. Reish, Bull. S. Calif. Acad.
Sci. 68, 169 (1969); L. G. Williams, BioScience
18, 849 (1968).

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