Research Note

DEVELOPMENT OF NUMERIC NUTRIENT CRITERIA FOR LAKES IN PUERTO RICO[1,2]

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Nutrient over enrichment of surface waters is a major source of water pollution in the United States. Approximately half of the water pollution cases reported in the United States is attributed to excess nutrients and related biological growth (Parry, 1998). Remedial action from regulatory agencies is becoming more forceful as the link between eutrophication and public health becomes more evident. The presence of elevated trihalometane levels in chlorine-treated eutrophic reservoirs and concerns over toxin-producing algal blooms suggest that nutrient pollution is not only an aesthetic issue but a public health problem as well (USEPA, 2000).

To address this issue the United States Environmental Protection Agency (USEPA) instituted the National Nutrient Criteria Program. Through this program the USEPA will establish numeric nutrient criteria for different water body types (e.g., rivers, lakes, estuaries). As an initial effort, USEPA is developing criteria for total phosphorus (TP), total nitrogen (TN), algal chlorophyll, and Secchi depth (SD). Secchi disk transparency, or Secchi depth, is commonly used in limnological studies to estimate algal turbidity. It consists of a 20-cm diameter disk that is all white or has alternating black and white quadrants. The disk is lowered into the water until it disappears and then it is raised again until it can be seen. The average depth between the depth of disappearance and the depth of appearance is called the Secchi depth (USEPA, 2000).

States and territories of the U.S. will use the numeric criteria developed by USEPA as a basis for the development of site-specific criteria to protect the designated uses of those waters. Once developed, nutrient criteria should become part of the State water quality standards (NALMS, 1992).

There are two approaches to establishing numeric nutrient criteria (Figure 1). The first uses data only from lakes that are considered minimally impacted by human activity. The upper 25th percentile value of the frequency distribution of these lakes for each parameter (i.e., TN, TP, SD, chlorophyll a) is selected as the reference condition. Another option is to plot the frequency distribution of all of the lake data available (regardless of trophic conditions) for each parameter and to select the lower 25th percentile as the reference condition for each case (USEPA, 2000). The USEPA expects a given lake to meet the numeric criteria for at least TP, TN and one of the two response variables (i.e., SD and chlorophyll a), and that a scientifically valid explanation be given for the remaining exception.

Because different regions in the U.S. differ greatly in terms of the parameters that define the limnology of a particular water body (e.g., soil type, parent material, precipitation regimes, water body morphometry), USEPA adopted a regional approach to

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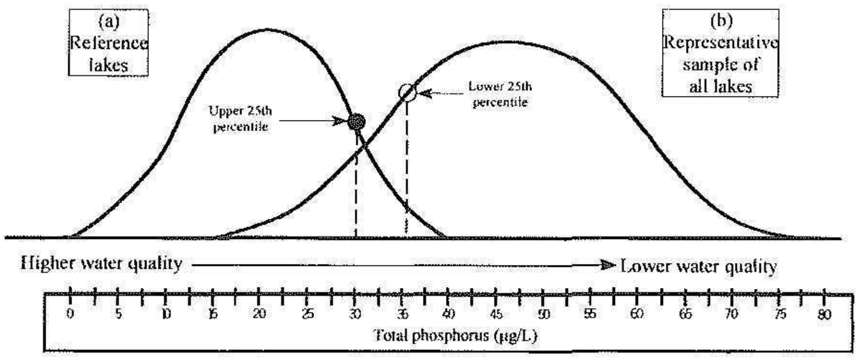

FIGURE 1. Two approaches for establishing reference conditions using total phosphorus as example (adapted from USEPA, 2000).

develop their nutrient criteria. Initially, the continental U.S. was divided into 14 separate ecoregions (ER) of similar geological and geographical characteristics. Hawaii, Alaska and U.S. Trust Territories (including Puerto Rico) will be covered under separate ecoregions. Several ecoregions have already published their numeric criteria (Table 1). The process for establishing the nutrient criteria for Puerto Rico has yet to be started. Herein I present the results of an exercise carried out to estimate the potential values for nutrient criteria in lakes of Puerto Rico.

The analysis was performed with water quality data from the USGS (United States Geological Survey) database. Specifically, I used data from fourteen lake water stations of Puerto Rico that had been continually monitored throughout the 1990 to 1999 period for the parameters of interest (Table 2).

The values for the lowest 25th percentile of frequency distribution of the different parameters evaluated in this study are 19.5 µg/L for TP, 0.48 mg/L for TN, and 7.3 µg/L for chlorophyll *a*. These values represent an estimate of the numeric criteria for lakes of Puerto Rico. The values fall within the range established by other ecoregions of the U.S. In the case of phosphorus the value differs greatly from the water quality standard established by the Environmental Quality Board of P.R. (1,000 µg/L) (Junta de Calidad Ambiental, 1990). A concentration of 1,000 µg/L P corresponds to the discharge limit established by EPA for water treatment plants. Adopting this value as a standard for lakes will underestimate the impact of phosphorus on water quality and the sustainability of the systems.

TABLE 1.—*Lake nutrient criteria for five of the 14 USEPA ecoregions*[1] *(refer to www.epa.gov for details on the ecoregions report).*

Parameter	ER II	ER VI	ER VII	ER VIII	ER IX
TP µg/L	8.75	37.50	14.75	8.00	20.0
TN mg/L	0.10	1.68	0.66	0.24	0.36
Chl *a* µg/L	1.90	8.59	5.23	2.39	5.18
SD (m)	4.50	1.36	3.33	4.93	1.53

[1]ER II (Western Forested Mountains); ER VI (Corn Belt and Northern Great Plains; ER VII (Mostly Glaciated Dairy Region); ER VIII (Nutrient Poor Largely Glaciated Upper Midwest and Northeast); ER IX (Southeastern Temperate Forested Plains and Hills).

TABLE 2.—*Description of the water stations used to determine the numeric nutrient criteria for lakes of Puerto Rico.*

Water station	USGS No.	Description
1a	50010720	Lake Guajataca No. 3 NR mouth NR Quebradillas
1b	50010790	Lake Guajataca No. 1 NR DAM NR Quebradillas
2a	50020050	Lake Garzas No. 1 NR DAM NR Adjuntas
3a	50025110	Lake Dos Bocas No. 3 At West Branch NR Utuado
3b	50027090	Lake Dos Bocas No. 1 NR DAM NR Utuado
4a	50039900	Lake Carite No. 3 on La Plata river NR Cayey
4b	50039950	Lake Carite No. 1 NR DAM NR Cayey
5a	50044400	Lake La Plata No. 5 NR mouth NR Naranjito
5b	50044950	Lake La Plata No. 3 NR DAM NR Naranjito
6a	50047537	Lake Cidra NR Bayamón river mouth
6b	50047549	Lake Cidra NR DAM
7a	50057500	Lake Loíza No. 4 NR mouth NR Caguas
7b	50058800	Lake Loíza No. 7 NR DAM NR Trujillo Alto
7c	50059000	Lake Loíza at DAM SITE NR Trujillo Alto

A closer look at the phosphorus status of different lakes of Puerto Rico reveals a contrasting scenario (Figure 2). Among the lakes evaluated, Lakes Garzas, Guajataca, and Carite appear to be the least impacted by human activity, in that order. On the other

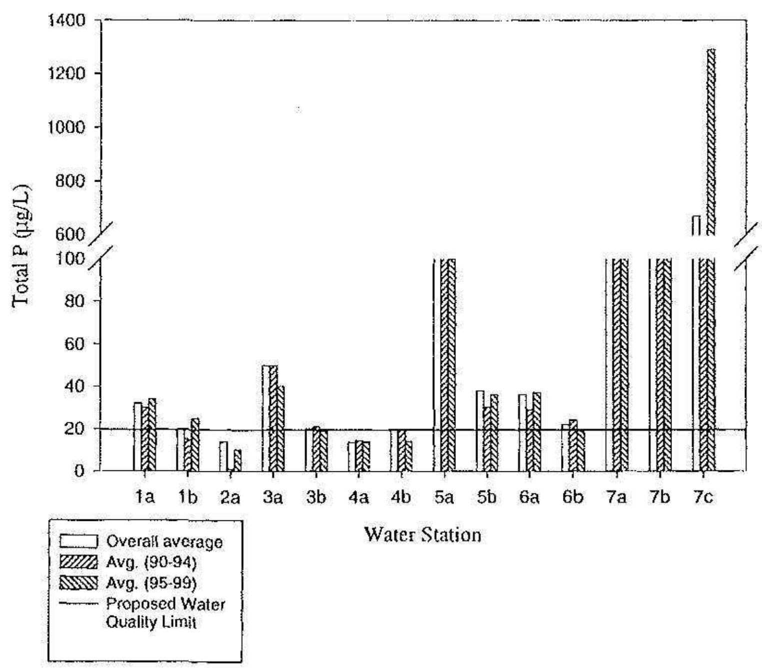

FIGURE 2. Total phosphorus distribution in different lakes of Puerto Rico. Water stations' descriptions correspond to those from Table 2.

hand, Lakes Loíza, La Plata, Dos Bocas and Cidra denote certain degrees of contamination, with Loíza and La Plata the most severely impacted. A similar situation is observed with chlorophyll *a* (Figure 3). However, on the basis of the chlorophyll-total P relation exhibited by most lakes (Carlson, 1977), the levels of chlorophyll a in Lake Loíza are lower than would be expected if phosphorus were the limiting factor for biomass growth. It appears that the high turbidity of this lake, as well as low N/P ratios may be limiting algae growth (data not shown). It is important to note the great improvement in water quality exhibited by Lake Carite in the last five years.

In addition to estimating the numeric criteria for different nutritional parameters, I evaluated the trophic status of the different lakes with the purpose of identifying eutrophic conditions. Eutrophication of most fresh waters is dependent upon supplies of nitrogen and phosphorus. Efforts to control nutrient loadings to surface waters focus primarily on phosphorus since evidence from limnological studies suggests that phosphorus is the limiting nutrient for algal growth in rivers and lakes (Carlson, 1977). During the past three decades scientists have developed a quantitative framework that allows the prediction of algal biomass response to nutrient loading and water column nutrient concentrations in lakes and reservoirs (Dodds et al., 1997).

I followed the approach established by Carlson (1977), who developed a quantitative tool that correlated algae biomass growth with the depth of light penetration in lakes as

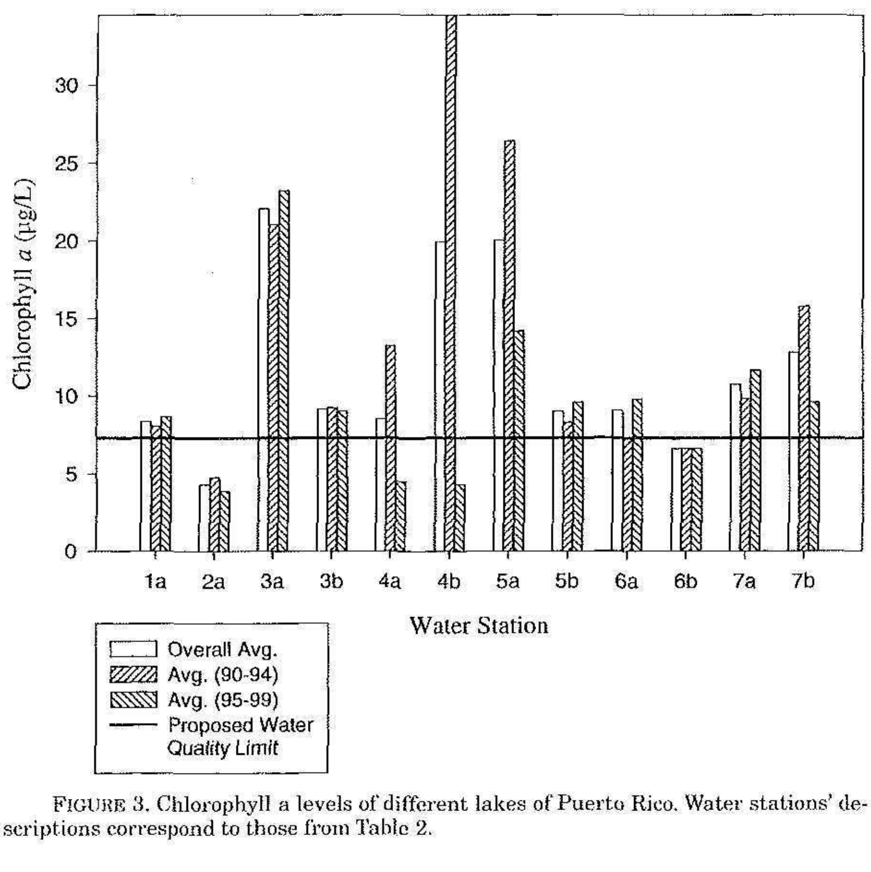

FIGURE 3. Chlorophyll a levels of different lakes of Puerto Rico. Water stations' descriptions correspond to those from Table 2.

an index of their trophic status. An initial estimate revealed that, contrary to what Carlson observed, Secchi depth was not a good indicator of biomass growth in Puerto Rico. This result is probably due to the high sedimentation prevailing in most of our lakes (data not shown). However, the relationship between total P and chlorophyll *a* in our lakes was similar to that found by Carlson (Figure 4). On the basis of that finding, we decided to use the range of chlorophyll *a* values considered to be indicative of lake eutrophication by most scientists (14 to 25 µg/L chlorophyll a) to calculate the corresponding concentration of total P in Puerto Rico. The result, 37 to 63 µg TP/L represents an estimate of the total P concentration that may promote lake eutrophication in Puerto Rico.

An evaluation of the trophic status of our lakes indicates Lakes Loíza and La Plata are the most likely to exhibit symptoms of eutrophication (Figure 5). Chlorophyll a results suggest that Lake Dos Bocas is also in danger of becoming eutrophic (data not shown).

The results indicate the need to monitor more intensively (increase frequency of sampling and number of stations) the chemistry of our lakes. It is important that studies be conducted to gain more insight into the factors controlling the relation between the nutrient status of our lakes and biomass growth. Specifically, there is need to evaluate the impact of turbidity, contaminant source, and water retention time.

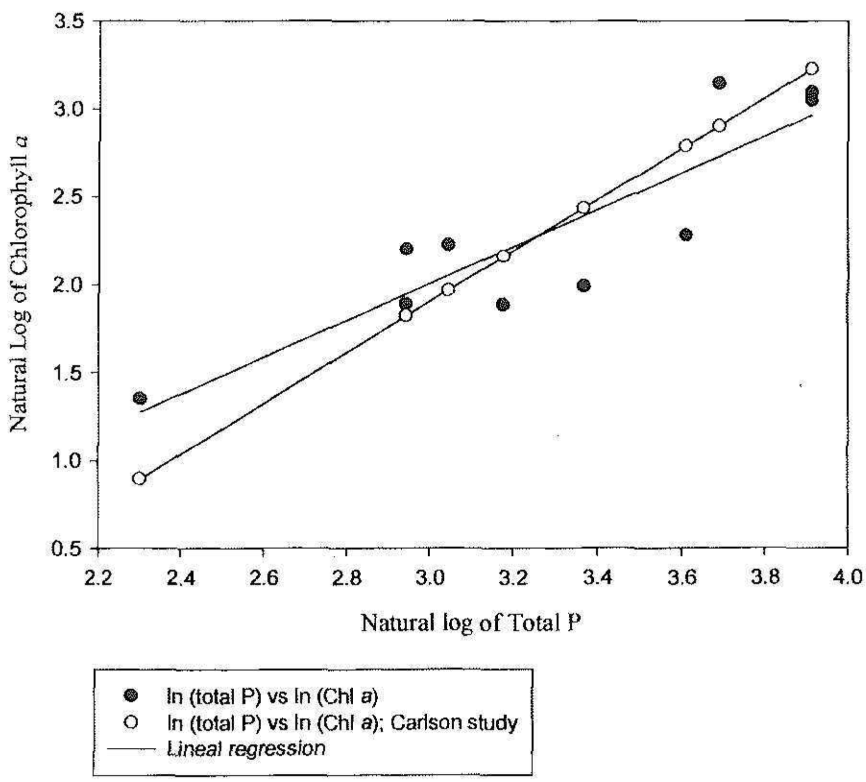

FIGURE 4. Comparison of the relation between chlorophyll a and total P levels in lakes for Carlson's study and different lakes of Puerto Rico. The Puerto Rico data exclude highly contaminated lakes (e.g., Loíza).

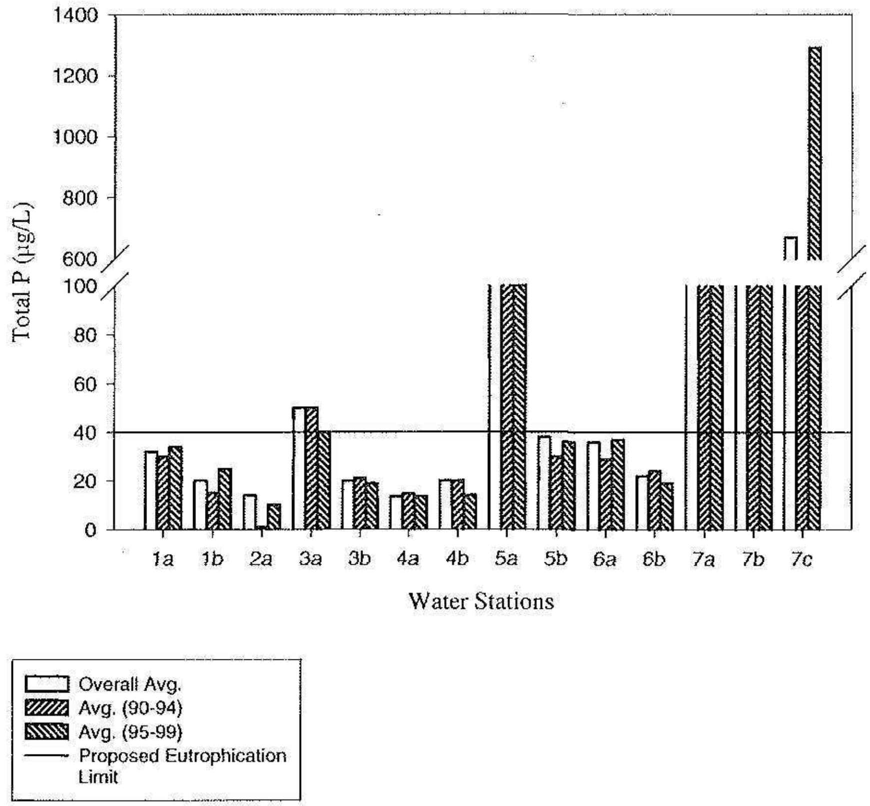

FIGURE 5. Relation between level of phosphorus and a proposed estimate of eutrophication for different lakes of Puerto Rico. Water stations' descriptions correspond to those from Table 2.

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