Environ. Sci. Technol. **2008,** *42,* 6772–6773

Response to Comment on "Estimating Ecological Thresholds for Phosphorus in the Everglades"

We thank Gaiser et al. for their comments (*1*) on our article (*2*). We support their contention that excess phosphorus has caused serious ecological effects and that caution must be taken when setting water quality standards to provide the best protection for an ecosystem. However, we disagree with their interpretation that our approach fails to protect wetlands because it bases thresholds on averages and with their view that "any" increase above ambient background concentrations causes an ecological imbalance.

They also make incorrect assumptions about our database and Bayesian data analysis, and they mistakenly suggest that we proposed "a protective water quality standard". First, we proposed no P standard or criterion because that has already been set by Florida and approved by the Environmental Protection Agency (EPA). Rather we presented a comprehensive, robust TP threshold across trophic levels, which we contend maintains a balanced ecosystem. This is a new approach which we believe deserves to be tested and considered at other sites. Second, we did not base our work only on our 6 year P dosing study. We state in the paper (ref *2*, p 8090), "To test if our mesocosm results were representative...we completed TP change point analyses...along a 10 km gradient...and found that the average of all five metrics in the dosing channels was slightly lower (14.4 μg L^{-1}) than found along the gradient (15.5 μg L^{-1})" as were the median change points among dates. Thus, we validated our research on the same nutrient gradient that Florida scientists studied to develop their standard. Gaiser et al. next suggest that "if the system is already biologically saturated in P...TP would remain in the water, increasing the probability of finding an increasing higher water TP threshold over time." This is not supported by our data, as shown in Figure 3 (*2*) where the highest thresholds for *U. purpurea* were in the beginning years and the lowest in years 3 and 4.

They also claim that the result of "calculating the change point annually for each attribute and averaging among years...was to inflate the derived threshold range." They apparently misinterpreted our methodology to be one where long-term nutrient data were simply averaged to yield the statistical threshold range. The approach used was designed to summarize the temporal range of variability in both total phosphorus (TP) and biological responses to more faithfully represent natural variability in the TP threshold. Because nutrient criteria are based on summary statistics of measurements from various sites over time, estimating a range and mean of threshold TP values over time is entirely consistent with the manner in which nutrient criteria are evaluated and enforced. Moreover, ignoring temporal variability is risky because the temporal dynamics are critical for maintaining the structure and function of natural ecosystems.

Specifically our approach estimates the distribution of change points representing multiple metrics in the ecosystem. This is important because no matter how many metrics we use, we cannot guarantee that all important features of the ecosystem are included. Using a statistical distribution allows a rigorous account of the between-group variation and hence proper treatment of the uncertainty associated with any analysis. In other words, this distribution is to capture all possible change points representing the between-group (ecological groups) variation. Because the estimated change point is a mean parameter, we assume that this distribution of mean change points is a normal distribution with its mean estimated as the sample mean of the estimated change points and the standard deviation is estimated by the sample standard deviation of the estimated change points. Our threshold is the lower boundry of the 95% interval (mean minus 2 times standard deviation). This approach is consistent with the hierarchical modeling approach advocated by many leading statisticians and is similar to the species sensitivity distribution approach for deriving water quality standards proposed by U.S. EPA (*3, 4*).

The current U.S. EPA and Florida P criterion for the Everglades indicates that all measured sites must meet a five-year geometric mean criterion of less than or equal to 10 μg L^{-1} P in 3 of 5 years, have annual concentrations less than or equal to 11 μg L^{-1} P across all stations, and have concentrations less than or equal to 15 μg L^{-1} P annually at all individual stations (*5*). Our *threshold zone* of 12−15 μg L^{-1} for TP falls within this current range of values and takes into account the natural, seasonal, and annual variations within the Everglades. Importantly, we also suggested that while "...a TP concentration of 15 μg L^{-1} TP is a reasonable estimate of a TP concentration that will maintain a balance in the flora and fauna at the *northern edge* of the Everglades some species, especially in the interior of the southern Everglades and ENP, may require a value closer to the 10 μg L^{-1} TP criterion." Thus, our analysis highlights the importance of understanding the natural decreasing TP nutrient gradient that existed historically from the northern exterior of the Everglades inward (*6*).

Gaiser et al. do raise an important point that should be considered regarding the 10 μg L^{-1} TP criterion. U.S. EPA guidance suggests that numerical criteria can be interpreted to represent the 90th percentile of samples from the waterbody (*7*); thus, if 10% of samples exceed a criterion then the waterbody may be determined to be not fully supporting the applicable standards. To test this we examined Florida FDEP data from their interior reference water quality sites used to develop the criterion and the criteria would not be met because more than 10% of the monitored concentrations were greater than 10 μg. L^{-1} (*8*). The 90% criterion is only met with reference data when the standard is set at 14 μg. L^{-1} TP.

Finally, their assertions that our method is a "risky approach to water quality assessment and management that decreases the chance of detecting P-elicited changes before the ecosystem has transitioned to an irretrievable state" shows a lack of understanding of Bayesian threshold analyses, our use of multiple trophic levels, and our suggestion for more stringent standards for interior areas of the Everglades.

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Published on Web 08/15/2008

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ES801411R