amount of data required for most effects-based models includes one entire year of measurements with weekly sampling. Rarely, however, will one year of data be adequate. We recommend three to five years of growing season data to account for annual variability. Table 5 lists sources of nutrient and other water quality data that can be used to develop nutrient criteria. Additional data and information might be available from State environmental agencies, universities, and county or local government organizations.

Table 5. Data Sources Useful in Developing Nutrient Criteria.		
Organization	**Description**	**Website**
U.S. EPA	Nutrient Criteria Database	http://www.epa.gov/waterscience/criteria/nutrient/database/index.html
U.S. EPA	STORET - data storage and retrieval system	http://epa.gov/storet/
USGS[1]	National Water Information System – NWIS	http://water.usgs.gov/nwis
USGS/ U.S. EPA	National Hydrography Dataset	http://nhd.usgs.gov/
U.S. EPA	Watershed Information Network – WIN	http://epa.gov/win/
U.S. EPA	Surf Your Watershed	http://epa.gov/surf/
[1]USGS = U.S. Geological Survey		

In some parts of the United States, nutrient data are available in a readily useable format. Examples include Iowa (Jones and Bachmann 1978), Texas (Ground and Groeger 1994), Minnesota (Heiskary and Walker 1988), Missouri (Jones and Knowlton 1993), Colorado (Morris and Lewis 1988), and Florida (Canfield and Hoyer 1988). Compilations of lake and reservoir data are available for some regions (e.g., Reckhow 1988). In many regions, however, considerable water quality information is available only for a small number of economically important water bodies, and data for the remaining systems are scant. Thus, characterizing water quality and levels of use support from existing data could prove difficult.

6.4 Step 4: Evaluate Data Adequacy

The determination of data adequacy is a difficult issue. The amount and type of data required for effective criteria development are dependent upon the type of water body, the current condition of the water body with respect to nutrient concentrations, designated uses potentially affected by nutrients, sources of nutrients in the watershed that may be impacting designated uses in the particular water body under consideration, and anthropogenic growth and development issues influencing the nutrient concentrations and designated uses in the water body.

From a statistical perspective, data are adequate if they are representative of the nutrient concentrations within the water body for average or typical climatic conditions. Nutrient criteria should not be developed using data reflective of unusual hydrologic and physical conditions of the water body. For example, years of unusually high rainfall may result in larger than normal non-point source runoff of pesticides into the water body of interest. From this perspective, a key issue underlying data adequacy is determining average or standard conditions. The best way of attacking this problem is to gather long-term records of nutrient and response variable concentrations. Examination of these records using time-series plots may provide investigators insights into the typical patterns found in the water body. Box-and-whisker plots of consecutive seasonal or yearly data can provide a visual determination of patterns and trends. Current year data may not be representative of the water body. Therefore, the newest information may not be the best data for creating nutrient criteria. Investigators should carefully critique the amount and quality of data from the perspective of watershed protection.

Working groups examining the data within the context of watershed goals and anthropogenic growth can be used to create a conceptual model of the nutrient issues of concern. Data, both current and historical, need to be critically examined with respect to the conceptual model. For example, current data from water bodies in rural watersheds with decreasing agricultural growth may be more representative of future water quality conditions than historical survey efforts.

For many water bodies, available data may be inadequate for developing defensible nutrient criteria. Typically, measurements of TN, TP, water clarity, and basic water chemistry (conductivity, pH, DO, etc.) data will be available. However, data for Chl *a* and measures of use support will be available for a relatively few water bodies. In addition, the response variables (e.g., Chl *a*, DO, pH), predictor variables (N, P, water chemistry) and measures of use support (aquatic life, recreation, and water supply) must be closely matched in both space and time.

Therefore, for many water bodies, new data may need to be collected. The U.S. EPA (2000a, 2000b, 2001) provides recommended guidance on sampling plan designs for nutrient studies in lakes and reservoirs, rivers and streams, and estuaries.

6.5 Step 5: Classify Water Bodies

The first step in the classification process is to classify the water bodies in each State's Level III and IV ecoregions into the following areas:

- estuaries and coastal waters,
- natural lakes,
- man-made reservoirs and impoundments, or
- rivers and streams.

Individual water bodies may be further divided into subsegments, if water quality within that water body varies significantly, for example, among arms of an impoundment or estuary, or longitudinally in streams.

Within each class, water bodies can be classified as reference or non-reference, although VA WRRC (2004) recommends against classifying waters as reference and non-reference for nutrient criteria development. The VA WRRC (2004) suggests that reference and non-reference water bodies are not directly comparable because of large differences in many important watershed characteristics. In addition, classification as reference or non-reference is not done with respect to an evaluation of attainment of designated uses; consequently, classification as reference or non-reference is not necessary for nutrient criteria development. Depending on the numbers of water bodies in each of these classes and the variability in characteristics within each class, it may be useful to further sub-classify the water bodies based on physical, chemical, hydrological, geological, geographical, limnological, and/or biological characteristics. Designated uses and sub-classifications of uses may also be used as a basis of sub-classification. For example, all lakes with the same aquatic life designation within an ecoregion (i.e., coldwater, cool water, warmwater) should be grouped together. Table 2 lists characteristics that could be used to sub-classify water bodies. The U.S. EPA nutrient criteria guidance manuals (U.S. EPA 2000a, 2000b, 2001) provide guidance on using these variables to classify river and streams, lakes and reservoirs, and estuaries and coastal waters, respectively. These should be referred to for more information on water body classification.

6.6 Step 6: Evaluate Chl *a*, P, and N vs. Level of Use Support

An important step in the building of effects-based models is to evaluate the magnitude of the response variable for specific designated uses, e.g., fish species catch per unit effort (CPUE), various metrics for aquatic communities, clarity, taste, odor, treatment costs, dissolved oxygen concentration, pH, etc. For example, examination of Chl *a* concentrations against fish species CPUE can be accomplished graphically or by using ordinary least squares (OLS) models. Similarly, determining the mean or median Chl *a* concentration associated with changes in water clarity, taste and order can be accomplished providing the data exist over time periods capturing the variability in the measurements. However, in many cases the relationships are not particularly strong due to large variability in both the response and predictor variables.

An alternative and particularly useful model for this kind of application is the multinomial model. In particular, this type of model has a higher chance of finding relationships by overcoming the statistical issues associated with highly variable data. And, the models provide a direct link between the level of use support and environmental measurements.

For example, within classes of lakes, data sets containing measurements from multiple lakes can be developed (i.e., a cross-sectional data base). Each observation in the data set would represent a sampling date for a specific lake with corresponding measurements of Chl *a*, N, or P as well as results from the user perception survey. In Virginia impoundments, a project rating the recreational fishery on a scale of 1 to 5 is currently underway (described above, see VA WRRC 2004) with corresponding measurements of key nutrients. The measurements of Chl *a*, N, or P in each of the corresponding lakes results in a data set appropriate for fitting multinomial models. Here, the rating (1 to 5) is modeled as a function of either Chl *a*, N, or P. For individual water bodies, multiple measurements over time would be required. We suggest fitting all three models, if possible.

Multinomial models apply to data sets where observations fall into one of k categories (k>2). Binary models, like logistic functions, are special cases where k = 2. Multinomial models are general linear models (GLM) with specified link functions. In our case, the model can be written as:

$$g(P_{i\,r}) = \mu_r + \beta \text{ Chl } a$$

where,

g = a generalized link function like the logit or probit

i = the number of observations in class r

r = a category, r = 1,.., k total categories (in the above example k = 5)

μ = 1,...,k - 1 intercept terms that depend only on the categories

β = generalized slope term common to each of the k categories

This same approach could be developed for other designated uses. For example, the recreational use of a water body could be rated on a scale from 1 to 5 based on user perception surveys or expert elicitation (see Tables 4 and 5 and Appendix 4). The same approach would work for water treatment costs to evaluate the public water supply use. Here, the ratings would reflect the relative cost of water treatment as a function of Chl *a*, N or P. The resulting cross-sectional data base should include enough observations to capture the range of possible ratings (e.g., 1 to 5) and the variability of the predictor variables in the lake population for which the criteria will be developed.

For example, Figures 2-4 (from Jensen et al. 2004) present hypothetical outputs that could be derived from the multinomial model (described below). One model is developed for each of the designated use categories using the associated scaled endpoints. The independent level of use models are comparable because both the x-axis (e.g., Chl *a*) and the y-axis (level of scaled response) have been normalized to comparative units. Graphics where the x-axis represents N or P could also be developed from models using N or P as predictor variables. The shapes of the curves vary, but the response variable is the same for all models as illustrated in the hypothetical plots. Therefore, the curves could be placed on the same graphic without loss of continuity or inference (Figure 5).

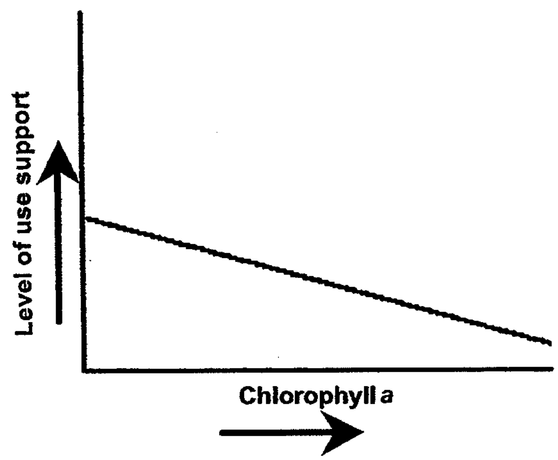

Figure 2. Theoretical Relation Between Chlorophyll *a* and Level of Use Support for Recreation

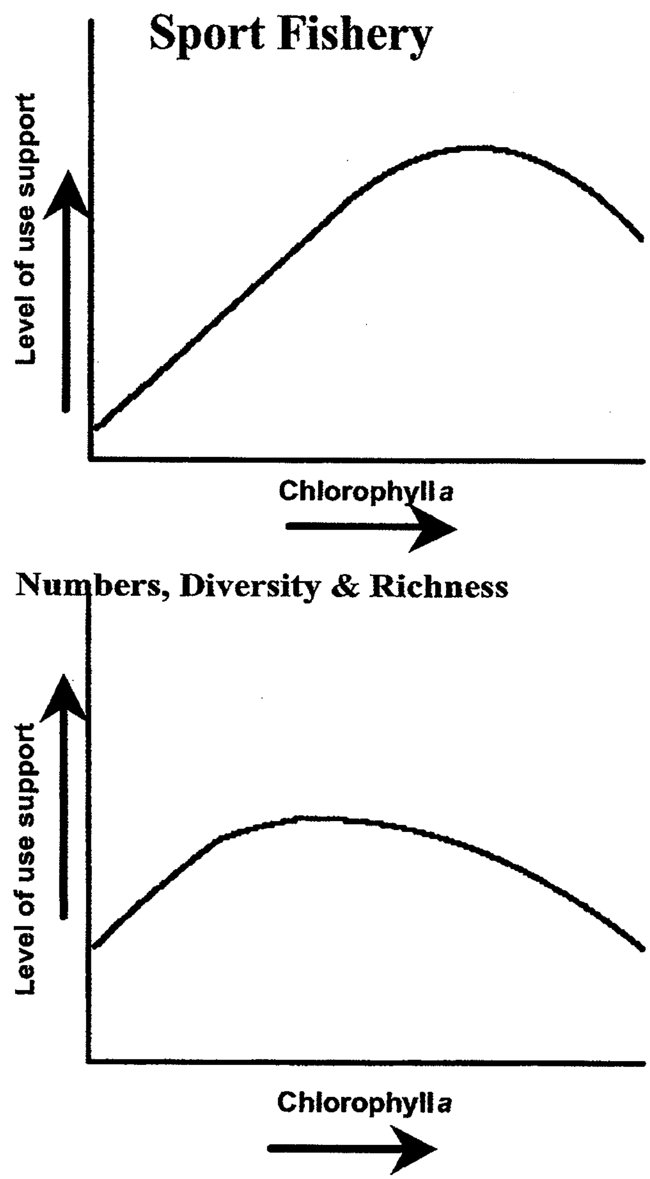

Figure 3. Theoretical Relation Between Chlorophyll *a* and Level of Aquatic Life Support, Including Sport Fishery and Aquatic Biota Numbers, Diversity and Species Richness.

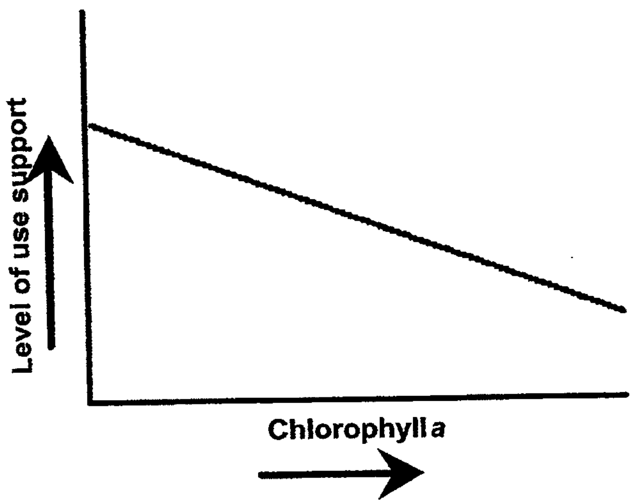

Figure 4. Theoretical Relation Between Chlorophyll *a* and Level of Water Supply Use Support

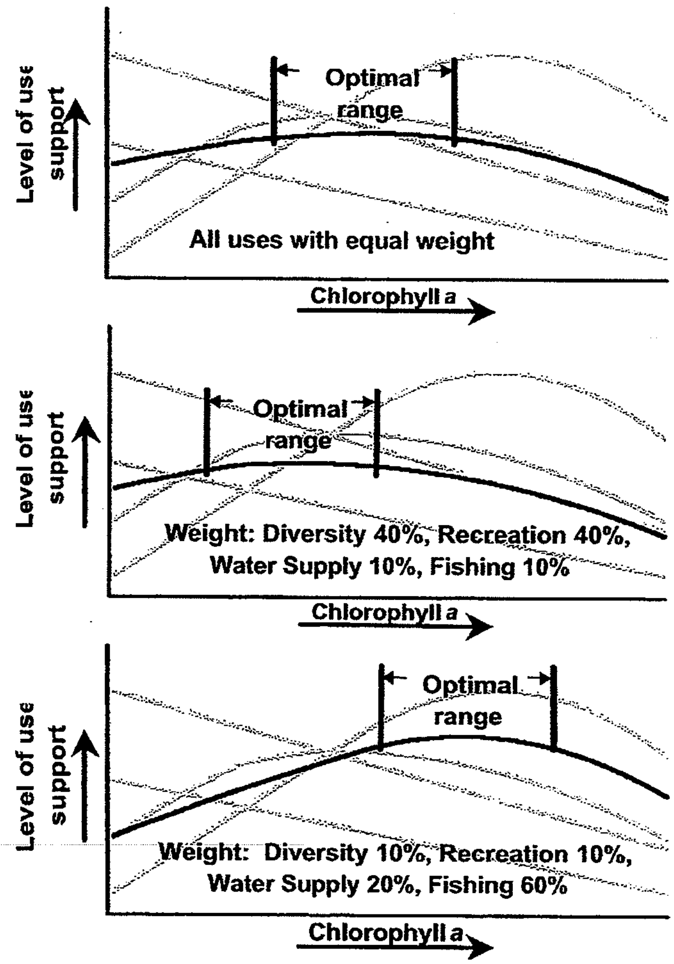

Figure 5. Theoretical Relationship Between Overall Level Of Use Support and Chl *a* (taken from Jensen et al. 2004).