Periphyton Biomass per Unit Area

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The representation of periphyton biomass for an entire reach by AQUATOX and the conversion of the USGS periphyton samples from pebbles in the Lower Boise River are consistent with the established procedures for determining periphyton biomass in the field (Stevenson and Bahls 1999).

The periphyton data were normalized to total unit area by multiplying by the percent substrate greater than sand-sized at a given site based on available pebble-count data. The pebble-count information for each site was provided by Dorene MacCoy. Conversion of the observed data enables comparison with model results given for an entire reach. First we will consider the approach taken by the model in representing a stream reach with riffle, run, and pool; then we will document the corresponding accepted sampling protocol.

Modeling Approach in AQUATOX

Park, R. A. and J. S. Clough. 2012. AQUATOX (Release 3.1) Volume 2: Technical Documentation. U.S. Environmental Protection Agency, Washington D.C.

Habitat Disaggregation

Riverine environments are seldom homogeneous. Organisms often exhibit definite preferences for habitats. Therefore, when modeling streams or rivers, animal and plant habitats are broken down into three categories: "riffle," "run," and "pool." The combination of these three habitat categories make up 100% of the available habitat within a riverine simulation. The preferred percentage of each organism that resides within these three habitat types can be set within the animal or plant data. Within the *site* data, the percentage of the river that is composed of each of these three habitat categories also can be set. It should be noted that the habitat percentages are considered constant over time, and thus would not capture significant changes in channel morphology and habitat distribution due to major flooding events.

These habitats affect the simulations in two ways: as limitations on photosynthesis and consumption and as weighting factors for water velocity (see 3.2 Velocity). Each animal and plant is exposed to a weighted average water velocity depending on its location within the three habitats. This weighted velocity affects all velocity-mediated processes including entrainment of invertebrates and fish, breakage of macrophytes and scour of periphyton. The reaeration of the system also is affected by the habitat-weighted velocities.

Limitations on photosynthesis and consumption are calculated depending on a species' preferences for habitats and the available habitats within the water body. If the species preference for a particular habitat is equal to zero then the portion of the water body that contains that particular habitat limits the amount of consumption or photosynthesis accordingly.

$$HabitatLimit = \sum_{Preference_{habitat}>0} \left(\frac{Percent_{habitat}}{100} \right) \quad \textbf{(13)}$$

where:

$HabitatLimit_{Species}$ = fraction of site available to organism (unitless), used to limit ingestion, see **(91)**, and photosynthesis, see **(35)**, **(85)**;

$Preference_{habitat}$ = preference of animal or plant for the habitat in question (percentage); and

$Percent_{habitat}$ = percentage of site composed of the habitat in question (percentage).

It is important to note that the initial condition for an animal that is entered in g/m^2 is an indication of the total mass of the animal over the total surface area of the river. Because of this, density data for various benthic organisms, which is generally collected in a specific habitat type, cannot be used as input to AQUATOX until these values have been converted to represent the entire surface area. This is especially true in modeling habitats; for example, an animal could have a high density within riffles, but riffles might only constitute a small portion of the entire system.

Photosynthesis is modeled as a maximum observed rate multiplied by reduction factors for the effects of toxicants, habitat, and suboptimal light, temperature, current, and nutrients:

$$Photosynthesis = PMax \cdot PProdLimit \cdot Biomass \cdot HabitatLimit \cdot SaltEffect \quad \textbf{(35)}$$

The limitation of primary production in phytoplankton is:

$$PProdLimit = LtLimit \cdot NutrLimit \cdot TCorr \cdot FracPhoto \quad \textbf{(36)}$$

Periphyton have an additional limitation based on available substrate, which includes the littoral bottom and the available surfaces of macrophytes. The macrophyte surface area conversion is based on the observation of 24 m^2 periphyton/m^2 bottom (Wetzel, 1996) and assumes that the observation was made with 200 g/m^3 macrophytes.

$$PProdLimit = LtLimit \cdot NutrLimit \cdot VLimit \cdot TCorr \cdot FracPhoto \cdot (FracLittoral + SurfAreaConv \cdot Biomass_{Macrophytes}) \quad \textbf{(37)}$$

where:

Pmax	=	maximum photosynthetic rate (1/d);
LtLimit	=	light limitation (unitless), see **(38)**;
NutrLimit	=	nutrient limitation (unitless), see **(55)**;
Vlimit	=	current limitation for periphyton (unitless), see **(56)**;
TCorr	=	limitation due to suboptimal temperature (unitless), see **(59)**;
HabitatLimit	=	in streams, habitat limitation based on plant habitat preferences (unitless), see **(13)**.
SaltEffect	=	effect of salinity on photosynthesis (unitless);

Sampling Protocol

Stevenson, R. J. and L. L. Bahls. 1999. 6 Periphyton Protocols. Pages 6-1 to 6-23 *in* M. T. Barbour, J. Gerritsen, B. D. Snyder, and J. B. Stribling, editors. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. U.S. Environmental Protection Agency; Office of Water, Washington, D.C.

6.1.5 Determining Periphyton Biomass

Measurement of periphyton biomass is common in many studies and may be especially important in studies that address nutrient enrichment or toxicity. In many cases, however, sampling benthic algae misses peak biomass, which may best indicate nutrient problems and potential for nuisance algal growths (Biggs 1996, Stevenson 1996).

Biomass measurements can be made with samples collected from natural or artificial substrates. To quantify algal biomass (chl *a*, ash-free dry mass, cell density, biovolume cm^{-2}), the area of the substrate sampled must be determined. Two national stream assessment programs sample and assess area-specific cell density and biovolume (USGS-NAWQA, Porter et al. 1993; and EMAP, Klemm and Lazorchak 1994). These programs estimate algal biomass in habitats and reaches by collecting composite samples separately from riffle and pool habitats.

6.1.1.1 Multihabitat Sampling

The following procedures for multihabitat sampling of algae have been adapted from the Kentucky and Montana protocols (Kentucky DEP 1993, Bahls 1993). These procedures are recommended when subsequent laboratory assessments of species composition of algal assemblages will be performed.

3. Collect algae from all available substrates and habitats. The objective is to collect a single composite sample that is representative of the periphyton assemblage present in the reach. Sample all substrates (Table 6-1) and habitats (riffles, runs, shallow pools, nearshore areas) roughly in proportion to their areal coverage in the reach. Within a stream reach, light, depth, substrate, and current velocity can affect species composition of periphyton assemblages. Changes in species composition of algae among habitats are often evident as changes in color and texture of the periphyton. Small amounts (about 5 mL or less) of subsample from each habitat are usually sufficient. Pick specimens of macroalgae by hand in proportion to their relative abundance in the reach. Combine all samples into a common container.

6.1.1.2 Single Habitat Sampling

Variability due to differences in habitat between streams may be reduced by collecting periphyton from a single substrate/habitat combination that characterizes the study reach (Rosen 1995). For comparability of results, the same substrate/habitat combination should be sampled in all reference and test streams. Single habitat sampling should be used when biomass of periphyton will be assessed.

1. Define the sampling reach. The area sampled for single habitat sampling can be smaller than the area used for multihabitat sampling. Valuable results have been achieved in past projects by sampling just one riffle or pool.

2. Before sampling, complete the physical/chemical field sheet (see Chapter 5; Appendix A-1, Form 1) and the periphyton field data sheet

(Appendix A-2, Form 1). Complete habitat assessments as in multihabitat sampling so that the relative importance of the habitats sampled can be characterized.

3. The recommended substrate/habitat combination is cobble obtained from riffles and runs with current velocities of 10-50 cm/sec. Samples from this habitat are often easier to analyze than from slow current habitats because they contain less silt. These habitats are common in many streams. In low gradient streams where riffles are rare, algae on snags or in depositional habitats can be collected. Shifting sand is not recommended as a targeted substrate because the species composition on sand is limited due to the small size and unstable nature of the substratum. Phytoplankton should be considered as an alternative to periphyton in large, low gradient streams.

4. Collect several subsamples from the same substrate/habitat combination and composite them into a single container. Three or more subsamples should be collected from each reach or study stream.

5. The area sampled should always be determined if biomass (e.g., chlorophyll) per unit area is to be measured.