Correspondence

Comment on “In-Stream Nitrogen Attenuation: Model-Aggregation Effects and Implications for Coastal Nitrogen Impacts”

We fully support the evaluation of modeling tools, such as that by Darracq and Destouni (*1*), to advance understanding of the sources and fate of nitrogen in terrestrial and aquatic ecosystems. Such understanding is important to manage the inland nutrient sources that contribute to coastal eutrophication problems. We are deeply concerned, however, that Darracq and Destouni’s evaluation (*1*) of watershed models demonstrates a fundamental misunderstanding, both conceptually and practically, of the SPARROW model (Spatially Referenced Regression on Watershed attributes; *2, 3*). SPARROW is a mass-balance, nonlinear watershed model with statistically estimated parameters that describe contaminant sources and terrestrial and aquatic transport, including in-stream first-order decay.

Darracq and Destouni (*1*) commit major factual errors that render invalid several conclusions of their study. They argue that the observed inverse relation between the first-order rate of in-stream nutrient loss and channel size (i.e., as measured by stream depth or flow), estimated by SPARROW (*2, 3*), is an “artifact” of the “spatial aggregation” used in the model. A fundamental problem is that the authors’ claim relies on their faulty assumptions about how water velocity is computed in the model, and how water velocity actually varies longitudinally in streams. It is well established from hydraulic investigations of U.S. streams (*4, 5*) that mean water velocity at a site increases (and water travel time per unit channel length, or reciprocal velocity, decreases) with increases in the mean water flow and depth of streams; mean flow, depth, and water velocity all tend to increase in a downstream direction in nonarid areas. These intrinsic hydraulic properties are reflected in the stream network data used to calibrate the SPARROW model (*2, 3*). By contrast, the authors’ model simulations using a purported SPARROW methodology for streams in the Swedish Norrstrom basin do not reflect these fundamental hydraulic relations. They mistakenly apply an equation (*1*, p 3718) that calculates the mean water travel time (T, units = days) along all streamflow paths from the headwaters to the outlet of a drainage basin [$T = 0.5(-0.0065 + 0.2642A^{0.3})$, where A is the total area above the watershed outlet; *3*] to the *incremental* drainage area associated with the individual reach segments of stream channels. This equation cannot be used to calculate the mean water velocity (or reciprocal velocity) along individual reach segments as required by the SPARROW model. We did not, as the authors suggest, use this equation to calibrate the SPARROW model (*2, 3*); we used the equation only to graph first-order nitrogen loss rates for German river basins (*3*; see Figure 2). These mistaken assumptions about water velocity invalidate all of the simulation results that the authors attribute to the SPARROW model. These results include the in-stream loss rates attributed to SPARROW in Figure 4 of Darracq and Destouni (*1*), which were back-calculated from erroneous water time-of-travel values. This also includes the simulations of nitrogen delivery to the coast attributed to SPARROW in Figure 5b of Darracq and Destouni (*1*), which are based on the erroneous loss rates.

The authors (*1*) further discuss SPARROW “artifacts”, drawing on results from a previous study (*6*) in which similar erroneous assumptions were made about the calculation of water velocity in SPARROW. Through misapplication of the same equation, Lindgren and Destouni (6) incorrectly assumed that mean water velocity declines (and reciprocal velocity increases) with increases in mean streamflow and depth in the SPARROW model. Thus, they concluded that the model calibration systematically underestimates in-stream loss rates by a disproportionately larger amount with increasing stream size to compensate for the assumed decrease in water velocity with increasing stream depth. Because mean water velocity actually increases with increasing mean stream depth in the model, one would expect SPARROW-based estimates of the first-order loss rate to increase with increasing stream depth, if the “artifact” theory of Lindgren and Destouni (*6*) were correct. This pattern is the opposite of what we have repeatedly observed in our model applications in the United States (*3*) and New Zealand, and is also the opposite of the observations from other studies (*7*).

There are further problems in Darracq and Destouni (*1*) regarding what is meant by “spatial aggregation,” a term that is not defined. From their model simulations, the term appears to reflect the spatial averaging of model inputs and loss rates over “subcatchment” areas, another term that is not defined. We are concerned that this spatial averaging greatly misrepresents the SPARROW methodology. The authors’ misunderstanding seems to center on how the model represents the losses of nonpoint-source pollutants that enter individual stream reaches. Our assumption that nonpoint-source pollutants, once entering a stream segment from the land, travel on average one-half the length of the stream segment is a conventional approximation of the behavior of pollutants entering at random locations along a segment, and therefore, not likely to introduce a significant bias. More importantly, the authors ignore the fact that the effects of this approximation are greatly diminished because pollutants entering a given reach undergo decay along the entire length of all downstream reaches that connect with the monitoring sites used to estimate in-stream decay in SPARROW calibrations.

We also find inconsistencies in the simulation results in Figure 4 (*1*). The authors report that SPARROW *overestimates* loss rates in small Norrstrom streams with depths <0.15 m—a finding that clearly contradicts Lindgren and Destouni’s (*6*) theory that SPARROW loss rates would be expected to *underestimate* the “actual” loss rate. Also unexplained is that the overestimates of the loss rate occur exclusively in the smallest streams (<0.15 m; streams smaller than any used in previous SPARROW calibrations), which would be the least affected by “spatial aggregation” or “spatial averaging” effects because of their small drainage areas. Oddly, an unexplained, precipitous drop occurs in the loss rate at a depth of 0.15 m; notably, the estimation bias is of little consequence in all streams with greater depths.

The SPARROW model is a valuable tool for advancing understanding of the factors that influence the sources and delivery of nitrogen to inland and coastal waters. We contend that our previous finding—the in-stream first-order nitrogen loss rate declines with increases in stream size—is valid and extends across a wide range of stream sizes. This is consistent with widely held scientific beliefs (*7, 8*), and reflects the intrinsic response of first-order reaction rates to increases in water volume per unit of streambed surface area that accompany increases in water depth and streamflow (*7, 8*).

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