This paper rather elegantly shows that, to a first approximation, spiraling length scales directly with river length while nutrient uptake measured as a mass transfer coefficient ("$v_f$") varies relatively little throughout a basin. Individual nutrients--ammonium, nitrate, and dissolved reactive phosphorus (SRP)—each vary from this template in their own way. The analysis is framed in a theoretical context, tying in Hack's law and the power law relationships of channel geometry. I believe this is an important paper that has both theoretical significance as well as practical utility.

I would like to see substantial revision. Most of my comments below are relatively minor and easily addressed. One that is noteworthy is that I think the interpretation of Alexander (2000) is incorrect—that their results (especially as updated in a 2008 paper)—are actually consistent with the result of this paper. My major issue, fully elaborated below, is that your inferences about the nutrient uptake of large rivers, relative to small streams, are not clear and, worse, are not justified. I think you can easily clarify them and I suggest an extension of your analysis that would provide the needed justification.

I have a concern about using the word "remove," because it obscures the notion of cycling and conveys the often wrong impression that nutrient once "removed" upstream does not reappear downstream. The spiraling literature hosts some confusion over this issue. I admit that the expression "to take up" has its weaknesses, especially in that it appears to exclude physical sorption. "Transfer" is also awkward. I suggest minimizing the use of "remove", especially where it is potentially misleading. It is good that the first two invocations of "remove" are followed by "from the water column," which constrains the interpretation. I also suggest that, early on, you add a clarification such as: "Nutrient uptake does not directly imply a reduction in downstream transport because of compensating nutrient regeneration. Uptake may reduce downstream transport temporarily during periods of benthic biomass accumulation, or on an ongoing basis through conversion to another dissolved form or to a particulate form, or in the case of denitrification by transferring nitrogen to the atmosphere."

6673:2 remove period after "network"

6673:10 I suggest (request) changing the sentence to read:
Uptake length is estimated from the inverse of a first-order uptake rate of nutrients experimentally added to the water column of a stream, either as a tracer (Newbold et al., 1981), as a small increment to ambient concentration (Stream Solute Workshop, 1990)."

6673:21 I suggest removing "removing" by rewriting the sentence as: "The role of small streams in taking up dissolved nutrients has been well studied, with > 970 measurements of uptake length (Ensign and Doyle, 2006; Tank et al., 2008)."

6673:25 "initial evaluation of the degree to which large streams and rivers may regulate downstream transport of nutrients." I find this problematic because it evokes the "removal" confusion, but if a clarifying caveat, such as I suggest above, has been presented prior to this, I have no fundamental objection.

6674:3 "Although there are much [many?] data"

6675:9 I suggest introducing the exponent, *a*, here: "…prediction of $S_W \propto (Q/W)^a$ where *a*=1." Then also, in Table 1, identify the "slope" as the exponent, *a*.

6676:18 Clarify the citation to Vannote et al., perhaps by inserting, after "river," , "i.e., along the river continuum". As it stands, the uninitiated reader would have no idea why Vannote is being cited here.

6676:20 Why say "we predict"--isn't this what was just found? How about, "Based on the preceding analysis, nutrient uptake length (SW) will scale.. "

6678:10-11 It would be helpful to report the standard deviations for Hack's constant, *h,* and for *c*, as you did for *b*.

6679:12 "SRP, thus" Run-on sentence (comma splice). Use semicolon or two sentences.

6679:23- 6680:5. This paragraph is poorly written. Rewrite to resolve the following issues.
1. Topic sentence is not topic and is redundant on third sentence.
2. Rationale for Table 1 reference is unclear.
3. Second sentence is missing articles, "the", and "a"
4. m is given as 0.79 once, then again as 0.8

6680:11 Insert "length" after NH4.

6680:11-12. Define the distinction between isometric and allometric. E.g., insert ("i.e., *a*=1)" after "isometrically." The second part of the sentence is stated imprecisely and could be written, "while uptake lengths for NO3 and SRP scaled allometrically (a>1), indicating a declining demand ($v_f$) with increasing Q/w.

6682:21 insert "(0.79-1.06)" after "1".

6682:21-25 These lines refer to variation in $v_f$ with stream size and so belong in the previous section. The sentence about Ensign and Doyle (2006) begins with a statement about length, and is therefore appropriate to the section, but ends with a statement about uptake in large rivers, which belongs in the previous section.

6682:22 I suggest changing "remove" to "take up".

6683:1-4. The paragraph started (previous page) by implying that the relation between $S_W$ and *L* is isometric (near 1), but in this sentence (line 2) it is allometric, while in the next sentence (line 6) we learn that for two of the nutrients it is isometric. You need to sort this out. It probably should be explicitly explained that the geomorphic parameters, *b*, *h*, and *c* combine to suggest an allometric scaling, which carries through to an allometric $S_W$ -*L* scaling for ammonium because its scaling with *Q/W* is isometric, but combines with a compensatory allometry in $S_W$ -(*Q/W*) for nitrate and SRP, to produce the isometry in $S_W$ -*L* for these nutrients..

6683: 34 "$S_W$ increases more slowly than does distance" lacks the necessary precision, because it could be true even under isometry. You might say "increases less than proportionately".

6683:5 I suggest changing "remove" to "take up".

6683:4-6 "This finding [$m$<1] suggests that large streams and rivers may remove as much or more nutrients than the well-studied small streams." Perhaps it does "suggest" this, but it is not clear what is being suggested. On an areal basis (and assuming uniform concentration) the river takes up more ammonium, and about the same nitrate and SRP as the stream, but this is based on the $v_f$ and not the length scaling. On a per unit length basis, the river takes up more, but this is just because the river is wider. On a per unit length basis relative to downstream flux, the river takes up much less, because $S_W$ is longer. I think what you are trying to say is that a river takes up the same or more, relative to flux, *over the length of the river.* But you can't really say this without saying something about how rivers are longer than streams. What's missing is some way of scaling river length, specifically that length scales logarithmically. This concept is captured by stream order and Horton's law of stream segment lengths. I suggest the following approach: Ensign and Doyle (2006), as you noted, showed that each order cycles nutrients about the same number of times, but they showed this using empirically derived order-specific $S_W$ . What you want is Ensign and Doyle's result, but from a theoretical basis, tied to your allometry of $S_W$. Here is how you might do it:

Ensign and Doyle (2006) calculated the number of cycles, $\rho_i$ in a stream order, $i$, as:

$$\rho_i = \ell_i / S_{Wi} \qquad (1)$$

where $\ell_i$ is the mean channel length of streams of order $i$, and $S_{Wi}$ is the respective uptake length. However, Equation (1) is an approximation because $S_W$ increases with stream length within the reach. For isometrically increasing $S_W$, we can represent the incremental contribution to the number of cycles within a reach at stream distance, $L$, from the source, as

$$d\rho = \frac{dL}{S_W(L)} = \frac{dL}{\alpha L} \qquad (2)$$

where $\alpha = S_W(L)/L$, and is constant due to the isometry. The number of cycles in stream order $i$ can then be expressed more precisely as:

$$\rho_i = \int_{L_{i-1}}^{L_i} d\rho = \frac{1}{\alpha}\int_{L_{i-1}}^{L_i} \frac{dL}{L} = \frac{1}{\alpha}\ln\left(\frac{L_i}{L_{i-1}}\right) \qquad (3)$$

where $L_i$ is the average length of streams of order $i$, using Horton's definition of stream order, i.e., measured from the source. The ratio $L_i/L_{i-1}$ is Horton's (1945) length ratio, which he showed to be uniform across stream order. Therefore, Eq. (3) shows that, for isometric scaling of uptake length, a nutrient cycles the same number of times in each order, as Ensign and Doyle (2006) empirically observed. Note that although the length ratio is expressed using Horton stream orders, i.e, using full mainstem lengths (as did Horton originally), the result applies to a Strahler-order segment, i.e., measured from the confluence of two lower (Strahler) order segments. Measured across a drainage, the two systems yield nearly identical length ratios (Scheidegger 1968).

The result from Equation (3) allows you to state meaningfully that a large river takes up as much (or more, in the case of ammonium) nutrient than a small stream, relative to its upstream inputs.

6683:13-23.
Alexander et al. (2000) did not actually demonstrate that "most .. in small streams." They showed that a small percentage (<40% ) of the N originating in small streams makes it to the Gulf while a large percentage ("some more than 90%) of N originating in or near large rivers reaches the Gulf. Alexander et

al. (2008) updated the analysis, finding (p. 826) the small streams delivered more (a median of 57%) than reported in the 2000 paper. But the main point is that nitrogen originating in small streams was removed not necessarily in the small streams themselves, but throughout the network as it flowed to Gulf. Alexander et al.'s (2000, 2008) results are, in fact, consistent with a constant removal per stream order. Suppose the removal rate was 7% per order. The Mississippi River is about order 11 (one order higher than represented by Table 5-2 of Leopold et al 1964 because their first-order was probably second order). Consider the minority of first-order streams that run through the entire hierarchy of first-to-11th order. Of the nutrient input to a first order stream that then passes through the full hierarchy of 11 orders, 45% would reach the Gulf. For a pathway that skips three of these orders, the delivery would be 75%. Many of the distal watersheds shown in Fig. 3A of Alexander (2008), except for the arid northwest fall into this delivery range. Alexander (2008, p. 825) stated, "The largest percentages (>90%) occur in the largest mainstem rivers and their tributaries." These would be nutrients that pass through only 1 or 2 orders. At our assumed loss rate 7% per order, the delivery of a nutrient passing through two full orders would be 87%. Thus, the assumption of a constant per-order loss rate is consistent with the results reported by Alexander and their results do not show that most nutrient uptake occurs in small streams.

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6683:14 Alexander et al. (2000) used a first-order loss rate, not a $v_f$. The loss rates the reported did decrease greatly with stream size, but the decrease was consistent with a spatially uniform $v_f$ as they showed in the 2008 paper.

Alexander, R.B., R.A. Smith, G.E. Schwarz, E.W. Boyer, J.V. Nolan and J.W. Brakebill, 2008. Differences in Phosphorus and Nitrogen Delivery to the Gulf of Mexico from the Mississippi River Basin. Environmental Science & Technology 42:822-830. DOI: 10.1021/es0716103.

Horton, R.E., 1945. Erosional Development of Streams and Their Drainage Basins: Hydrophysical Approach to Quantitative Morphology. Geological Society of America Bulletin 56:275-370.

Scheidegger, A.E., 1968. Horton's Laws of Stream Lengths and Drainage Areas. Water Resources Research 4:1015-1021. DOI: 10.1029/WR004i005p01015.