21 July 2009 Preliminary Review Comments from CASAC NO_x & SO_x Secondary NAAQS Review Panel on EPA's *Risk and Exposure Assessment for Review of the Secondary National Ambient Air Quality Standards for Oxides of Nitrogen and Oxides of Sulfur: Second Draft (June 2009)*

Comments Received:

Dr. Paul J. Hanson **2**
Dr. Donna Kenski **8**
Dr. Myron J. Mitchell **13**
Dr. Kathleen Weathers **41**

Dr. Paul J. Hanson

Draft Comments on the

Second Draft: Risk and Exposure Assessment (REA) for Review of the Secondary National Ambient Air Quality Standards for Oxides of Nitrogen and Oxides of Sulfur

Submitted by– 13 June 2009

General Comments:

I found the second draft REA to be improved over the first draft. The document is largely successful in defining air quality indicators and ecological indicators that might be used in the context of evaluating exposure metrics for both aquatic and terrestrial in the context of acidification and nutrient enrichment for exposures to SO_x and both oxidizes and reduces forms of nitrogen.

In some cases data and justification are provided for the levels of the ecological indicators that might be considered in evaluating ecological responses, but for the most part levels, averaging times, and forms are not discussed.

While the document makes clear statements about the nature of exposures to US land surfaces and target case study ecosystems, it provides very little (if any) useful characterization of the welfare risks involved in allowing current pollutant levels to continue.

The following specific comments and minor editorial suggestions are provided for discussion and consideration by EPA staff.

Front Matter – Key Terms

Page xxi: Add a definition for ASSETS

Page xxii: The definition listed for Determined Future Outlook doesn't stand on its own. You might also reference page numbers in the body of the text for all of the definitions related to ASSETS.

Page xxiii: Prior comments on the definition of ecological dose were not addressed. Why is this definition limited to microbes?

Page xxvi: The definition of a semi-arid region was not changed from the first draft. The rainfall amounts overlap with those for Arid Regions, which seems inappropriate.

Executive Summary:

Page ES-2 Line 12: Change "These effects include" to 'When fully developed acidification effects include…'

Page ES-2 Line 22: Change to " a well-documented phenomenon indicating…"

Page ES-3 Line 6: Change "the" to 'that'.

Table ES-7 under Terrestrial acidification: "Tree Health" is used as an undefined and unclear term. Use other words or phrases to describe what is really intended (e.g., changes in growth?).

Figure ES-3 and elsewhere throughout the REA: Although some process was conducted to limit the number of case studies for inclusion within the REA that process is not well described. Why were these case studies chosen from an original longer list of possibilities? Should these be characterized as worst-case scenarios? Should the reader assume that these are the only areas of the US for concern with respect to acidification or nutrient enrichment?

Figure ES-4 and elsewhere throughout the REA: "Change in ecosystem structure and process" is used to describe an ecological benefit/Welfare effect. How do (or can) we distinguish changes occurring through natural processes from changes from the effects of acidification and nutrient enrichment? The document should include some discussion about ecological changes in the context of 'background temporal changes" vs. those driven by pollutant exposure.

Pages ES-11 to ES-14 are quite good, but I noted one issue. The term NOy is used in the caption for figure ES-5, but it hasn't been used much in the text. Is it intended to be a placeholder for total reactive forms of N?

Page ES-17 Line 18: In this paragraph sugar maple and red spruce are characterized as being the "most sensitive" to acidification with the implication that all other tree species are less sensitive. Is this really true? Perhaps, other tree species simply haven't been evaluated in enough detail to appropriately characterize their sensitivity. Please reword the beginning of the paragraph to indicate that these species are being highlighted because sufficient data are available to evaluate their response to acidification.

Table ES-2: Does the concept of a policy relevant background Bc/Al ratio belong in this discussion?

Page ES-18 Lines 4 through 16: These paragraphs provide a description of valued characteristics of northeastern forests, but they **do not** provide an indication of fraction of these welfare metrics that are at risk under acidification**.**

General comment: The previous statement is a recurring theme throughout the REA (especially in Chapters 4, 5, and 6). Ecological benefits or measurable welfare metrics are listed for key ecosystems or case study areas with the presumption that all are subject to loss or failure with acidification or nutrient enrichment. In most cases the text (and presumably the available

data) do not provide sufficient information to fully characterize what fraction of a measurable ecological endpoint is likely to be subject to loss under pollutant exposure. I don't believe that it is appropriate for the reader to conclude that 100 percent of a given welfare metric is likely to be lost.

Page ES-21 Line 7: Don't use the term ecological health without an adequate definition.

Page ES-21 Line 12: Can you provide the deposition rate needed to drive mortality? Is it a higher level of deposition or might it alternatively be simply long term cumulative exposure to a lower deposition level?

Page ES-21 Lines 20 and 21: Please provide a range to clarify what is meant by a low C: N ratio.

Page ES-22 Lines 19 to 21: Surface area increases of root systems driven by mycorrhizae are most often associated with the morphological changes driven by ectomycorrhizae, but the authors are using AM as the example. Are they referring to fungal filament exploitation beyond the root systems of plants?

ES-23 Line 13: Are fishing and hunting really a big land use activity for the California Coastal Sage area?

Chapter 1:

Page 1-12 Line 19: Remove the word "not". It appears to generate a double negative that changes the sentence meaning.

Page 1-13: I suggest modifying the sentence by adding the underlined text as follows: "Both are essential <u>elements for vegetation growth and development</u>, and..

Page 1-14: Should "main source" be changed to 'main anthropogenic source'?

Page 1-17: These are all good policy relevant questions. Unfortunately, a number are not addressed within the REA.

Chapter 2:

Page 2-1: This section starts out with a great point – "response to pollutant exposures can vary greatly between ecosystems". Unfortunately, the REA doesn't fully address how to handle extrapolation of responses in case study areas to the balance of the US.

Page 2-1 Line 19: I would remove the word "and" in this line.

Figure 2.4-1: Please add more explanations to the figure caption. What do the arrow widths

imply?

General Comment: How do we distinguish ecological effects of acidification and nutrient enrichment from other co-occurring and likely highly correlated pollutant exposures (e.g., ozone)? This issue should be fully vetted in the document.

Chapter 3:

Page 3-2 Line 18: Add the phrase 'other forms of reactive N' after NOx.

Figure 3.2-1: Increase the font size.

Figure 3.2-4: Increase the font size.

Figure 3.2-6: The figure caption uses NOy, but the related text on the previous page (3-11) exclusively discusses NOx. The authors should be consistent and define and use NOy appropriately or not at all.

Figure 3.2-10: The color scale in this figure was inappropriately changed from the scales used in the two prior figures. This isn't a big deal, but by changing the color scale a direct visual comparison isn't really possible.

Section 3.2.5: Should the concept of policy relevant background loadings or deposition levels be introduced and used?

Chapter 4:

Section 4.3.1.2

This section is a good example of how an ecological indicator can be developed for the characterization of a response to acidification. Unfortunately, the other metrics described in the REA are not this clear.

Page 4-43: Is this a true general statement or should it apply only to sugar maple on susceptible sites?

Page 4-47 Lines 9 to 12: This sentence underscores a continuing theme. It is difficult to isolate and estimate the proportion of a given measure of welfare benefit attributable to acidification and nutrient enrichment. See also Page 4-48 lines 4 to 6. Given this reality, how doe we proceed in the development of standards to protect welfare issues without a capacity to judge success or failure in the context of the target pollutants (or combined pollutants).

Chapter 5:

Page 5-1 Lines 6 to 12: This sentence should also appear in the executive summary.

Page 5-6 line 6: Spell out and define NEEA.

Page 5-44 and Section 5.3.1.1: This section is very useful and helpful to the reader. I would sentences to further describe why this discussion is limited to a couple of southern California case studies. Are other ecosystems in the US not impacted? Is there insufficient data to evaluate impacts in other ecosystems? For those that don't live in the region discussed, tell them why or how these results have meaning to broader pollutant exposures across the US.

Page 5-46 Lines 1 to 10: I would remind the reader tat one size doesn't fit all at this point. These data are quite good for lichens, but they may not have quantitative value for evaluating the response for other species or species in other regions of the US.

Section 5.3.1.3:

How is the reader supposed to interpret this information? What fraction of these services is at risk? Much of this information seems tangential.

Page 5-55 line 1: This bullet statement was discussing Eastern United States ecosystems. Do we have semi-arid lands in the eastern US?

Page 5-55 Lines 9 to 19: These statements seem to undermine the discussion. If we don't have the data why are we having the extended discussion?

Figure 5.3-5: A solid connection of this graphic to N deposition isn't made. What fraction of fuel loadings leading to fire danger and frequency can be attributed to pollutant exposure as apposed to natural secondary succession?

Page 5-66 lines 21 and 22: This is a key point.

Page 5-66 line 24: Replace "tree health" with terms that describe what you really mean.

Chapter 6:

Page 6-13 Lines 28 and 29: This statement is written as though it would apply equally to all ecosystems. I'm not convinced that this would be true for all systems at similar time frames.

Page 6-23 Lines 20 to 22: This is an important statement. I'm glad to see it included here.

Chapter 7:

Page 7-10 Line 17: Change "most" to 'known to be'.

Page 7-14 line 27: Add the level of deposition needed to drive mortality.

Page 7-15 lines 17 to 26: Why the focus on these specific metrics for CSS and MCF? Are we to

conclude that these are the metrics that are the best fit for all US ecosystems? Where is the discussion about the metrics needed for the development of a US national standard? Is a standard likely to be based on most sensitive systems in the west and then applied to all ecosystems?

Page 7-18 Lines 9 to 30: What is the point of this information? How is it be used? What fraction of each of these welfare metrics are at risk under terrestrial acidification?

Page 7-19 lines 1 to 3: Add some specifics.

Page 7-19 line 29: Should oconic be iconic?

Page 7-22 lines 28 to 30: Again. This is a very key conclusion. How do we use this conclusion in the extrapolation of case study data?

Dr. Donna Kenski

Premeeting comments, NOx/SOx Secondary REA (2nd Draft)
Lake Michigan Air Directors Consortium
July 20, 2009

General Comments: Overall, the 2nd draft REA provides, through its case studies, a comprehensive summary of acidification and nutrient enrichment effects of sulfur and nitrogen deposition in sensitive ecosystems. I am generally satisfied that the data presented here sufficiently demonstrate the environmental damage done at current atmospheric concentrations of NOx, SOx and NHx and that it constitutes enough evidence on which to base a standard. What's still lacking is a clear discussion of the specific route to formulating a standard. The Executive Summary lays out a very general outline, which is repeated in various fashions in Chapters 1, 2, and 7, but there is still no concrete, detailed example of how a standard might be structured, despite having all the necessary information collected here. The committee raised a number of questions related to this in the last review, and it would have been good to see those addressed here, rather than waiting for a separate policy assessment. For example, how will varying degrees of geographic susceptibility and variability be incorporated (i.e., ANC might be the most logical indicator for the eastern US, but would it protect CSS and MCF communities?) Is EPA contemplating a standard based on just one of the ecological indicators (ANC seems like the logical choice) or will it be combined with other indicators? What kind of overlap might there be if multiple indicators are selected and how do we determine which is controlling? Is there any accommodation for uncertainty in the estimation of concentrations, deposition, ecological effects, and indicators? Because linking all of these modeled values will incorporate so many different estimates of variability and uncertainty, it is very difficult to imagine their cumulative effect on a standard. Given that EPA is proposing a brand new approach to an ambient air quality standard, the sooner these issues are dealt with and reviewed the better.

I like the stylized graphic of Fig. ES-2 that is used on the introduction pages to each chapter. The use of boldface for figure and table references in the text was a big help to readers hunting for those. Also I thought the use of the call-out boxes was very effective. Throughout the document, but especially in Chapter 3, the figures were well done – no extraneous information, thoughtful and consistent use of color. Very nice.

One point that needs to be made more strongly throughout the document, whenever the various ecosystem services are being described, quantified, or otherwise valued, is that they are only a small subset of the sum total of services we derive from these resources.

Exec. Summary: The last statement of the conclusions to the ES was disappointingly weak ("…effects due to aquatic and terrestrial acidification *may be* the most useful…"). The REA was quite convincing that the aquatic nitrogen enrichment effect was not going to be a suitable basis for a standard, and also that aquatic and terrestrial acidification were the effects we have the best

science for and the most developed quantitative relationships on which to base a standard. The ES could be a bit more forthright about its findings.

Chapter 1: I like the list of policy relevant questions at the end of Chapter 1, but I expected to see answers to the questions when we got to the final synthesis and integration in Chapter 7. A conclusions section framed in such a way would be ultimately more useful than the current structure of Chapter 7.

Chapter 2: Good overview.

Chapter 3 (and Appendix 1): Great graphics, except for the unnecessary 3d pie charts. Conclusion 6 on p. 3-79 that the season (in the East) with the most TN deposition corresponds to the season with the most S deposition is difficult to confirm because the N and S data aren't shown together. Could a plot or two be added to demonstrate that this is indeed the case? The CMAQ comparison with measurements was well done and did provide some reassurance that CMAQ was adequate for this assessment, although the model performance assessment in Appendix 1 wasn't exactly what I was expecting. Making the assessments on an annual or monthly domain-wide basis isn't the typical way of evaluating CMAQ, and looking at those long term averages tends to make performance look much better than on a shorter term basis. If the logic was to look at long term averages because the case studies are only looking at long term averages, the text should be clear about it, although I'm not sure that's a sufficient reason. EPA has plenty of model performance guidelines, so its surprising that these results weren't presented in light of those guidelines. Also, I'm not convinced that because these results fell within the range of other studies, that constitutes acceptable performance (as discussed much too briefly on pp. 1-4 and 1-5). The performance is not particularly good for many of the components and it deserves a more thoughtful discussion of what is really acceptable for this particular application. That said, I think this is a much better approach than the previous draft's RSM approach.

Chapter 4: This chapter's finding that aquatic acidification in both case study areas was driven primarily by sulfate was not brought out in any of the conclusions or summary statements, although it seems like it could potentially be significant information in the standard setting process. No examples were given of nitrate-driven aquatic acidification; it would be useful to explore where these might be, if they exist. The section (4.2) that looked at recovery potential should have examined at least one or two scenarios with reduced emissions, since maintaining emissions at current levels for the next 10 or 40 years is not realistic. It could have been tied in with the emissions reductions analysis in Chapter 3. Also, the chapter could use a brief discussion of the averaging time for ANC. It uses mostly annual average values, although frequent mention of episodic pulses of acidity are made. Do seasonal patterns in deposition have any impact on ANC? This isn't my area of expertise, coming from the ambient air world of hourly measurements, but it was a little startling to see that much of the lake data is based on one measurement a year. So a brief explanation of ANC behavior over time might be helpful. With respect to uncertainty, the specific discussions about uncertainty in the various models employed was generally adequate (note comments above about CMAQ though). The discussion on uncertainty in the aquatic nutrient enrichment was especially well done (Sec. 5.2.8).

However, a broader discussion that pulls together uncertainty from MAGIC, along with uncertainty from CMAQ, and uncertainty in the effects of ANC on sensitive biota, etc., needs to take place somewhere. Chapter 7 takes a broader look but still doesn't discuss the cumulative, quantitative impact of these various sources of uncertainty on a standard. Perhaps this is more appropriately left for the policy analysis.

The 2nd charge question for this chapter asks if we agree with focusing on aquatic acidification for a basis of the standard. I do agree; the quantity and quality of data available for aquatic acidification really make it the only logical choice, relative to the other effects examined in the REA. The nutrient enrichment studies were just too qualitative to think about basing a standard on them.

Specific comments (page, line number)
ES-10, 10-11: MM is not an SI unit, nor is it a standard abbreviation in the air quality community. Scientific notation would be better. Or at least include it in the table of abbreviations.

ES-10, 18: fix subject-verb agreement

ES-15, 11: missing a closing parentheses for the phrase that starts "(especially…"

ES-16, 27, 36, and others throughout document: should be "sensitive *to* or at risk *from* acidifying deposition" . The phrase "at risk to acidifying deposition" is jarring.

ES-16, 31; ANC level ~~of~~ above

ES-18, 1: Bc/Al level ~~of~~ above

1-12, 17-19 : Is this sentence correct? Or do you mean there is little new evidence that S and N oxides are high enough to be phytotoxic (delete *not*?)

1-17, bullet 2: this bullet is awkwardly phrased – reword

2-2, 5: It is not clear what the role of these supplemental study areas is. Little Rock Lake, for example, is not summarized in Table 2.1-1 or Fig. 2.1-1, and it's not even mentioned again except a passing reference to it in Chapter 6. It hardly seems to merit mention here. Rocky Mountain alpine lakes are discussed in Chap 5.

2-7, 17: public

3-2, 9 and 18: the subscript x should be NHx

3-4, 1-4: MM is not an SI unit, nor is it a standard abbreviation in the air quality community. Scientific notation would be better. Or at least include it in the table of abbreviations.

3-11, 27: Figure 3.2-6 says it shows NOy, not NOx – which is correct?

3-28: Table 3.3-1 says the Neuse River has 14 kg N/ha/yr in 2002, but the figure 3.3-1a says it has 15; shouldn't these be the same?

3-30, 1: contains should be contain

3-82, 5 and 8: seems to be missing NH before the orphaned subscripts

3-90, 14: …are based *on* the application of

3-91,24: …the formation *of* sulfate and nitrate…

3-93, 5: similarities *and* differences

4-6, 11-14: edit this final sentence

4-11, 15: delete sulfate

4-23, Fig. 4.2-13 misspells exceedances in each of the 4 titles

4.34, 10-13: This first sentence is too long and convoluted.

4-37, 10: Shouldn't Q be in m3/yr?

4-40, 23: levels -> level

4-41, 3-12: This explanation of the MAGIC calibration procedure is pretty fuzzy. At least refer the reader to Attachment A of Appendix 4 for additional information.

4-45, 6-8: Delete these lines

5-16, Fig. 5.2-3: this figure was pretty confusing – too much information is presented, and it's hard to read besides.

5-47, Fig 5.3-2: the 7th bullet on Minnesota grasslands doesn't list any ecological effect. Farther down the list, Bytnerowicz is misspelled

7-12, 4: res -> red

7-16, Fig. 7.1-3: the 7th bullet on Minnesota grasslands doesn't list any ecological effect. Farther down the list, Bytnerowicz is misspelled

7-17, 19: res -> red

7-19, 29: oconic -> iconic

7-21, 12-16: fix run on sentence

Dr. Myron J. Mitchell

General Comments and Responses to the Charge to the CASAC NO_x/SO_x Secondary Review Panel Draft: July 21, 2009

Comments are provided in *italics*

Charge to the CASAC NOx/Sox Secondary Review Panel

Within each of the main sections of the second daft Risk and Exposure Assessment document, we ask the panel to address the following questions, taking into consideration the changes and additions since the first draft Risk and Exposure Assessment:

Executive Summary:

1. In response to the Panel's review of the first draft Risk and Exposure Assessment, we have included an executive summary of this document. Does the Executive Summary adequately summarize and characterize the key issues driving this review as well as the important findings of the analyses? Does the Panel have any suggestions for clarification or refinement of the Executive Summary?

The Executive Summary does a good job of providing a summary of the document. The summary, however, needs attention to detail, clarity and consistency. For example, there needs to be more consistency in the use of the past and present tense. If the focus is on the summary of findings, the past tense is appropriate. However, if emphasis is on the current conditions, the present tense should be used. There is some redundancy in the document such as the mentioning at various locations of the importance of looking at the effects of total reactive nitrogen versus NO_x. I know that there has been considerable discussion of the importance of using total reactive nitrogen in these analyses, but some of this usage and other areas of duplication should be reduced. A clearer transition and better linkage between Section 2.0 (OVERVIEW OF RISK AND EXPOSURE ASSESSMENT) and previous text need to be provided.

In my detailed comments, I have provided a number of editorial corrections and suggestions. There should be consistency of whether or not to use direct references in the executive summary. I would suggest, unless there is a very compelling reason, that direct literature references should not be part of the Executive Summary.

There were no specific questions directed at Chapter 2, but the comments provided for the Executive Summary are relevant to this chapter. Much of the contents of this chapter is based upon further elaboration and justification of the use of ecosystem services in this assessment.

The entire document could be improved by attention to repetition both within and between chapters. A more succinct narrative would provide a more focused presentation of the important issues.

Air Quality Analyses (Chapter 3):

1. This chapter describes an approach for characterizing the spatial and temporal patterns of nitrogen and sulfur deposition in the case study locations including both oxidized and reduced nitrogen, and both wet and dry deposition of oxidized nitrogen, reduced nitrogen, and sulfur. Are the uncertainties associated with these analyses appropriately identified and described?

The Chapter does a good job of describing the spatial and temporal patterns of nitrogen and sulfur deposition including the areas of the case studies. The report needs to further emphasize the inherent limitations associated with estimates of dry deposition. In the chapter it is sometimes indicated that "measured deposition" is provided. Although good measurements of wet deposition can be provided, there is considerable uncertainty in the dry deposition estimates and the importance of this uncertainty should be emphasized in this chapter.

2. In response to CASAC's recommendation, the RSM analysis presented in the first draft Risk and Exposure Assessment was replaced by an analysis of results from a new series of CMAQ simulations designed to explore the relative contributions of NOx and NH3 emissions to total, reduced and oxidized nitrogen deposition and the relative contribution of SO2 emissions to sulfur deposition. Does this approach enable us to adequately examine the contribution of NOx to total nitrogen deposition?

The relative role of NO_x and NH_3 simulations is better developed in the current document.

3. The CMAQ application and model performance evaluation is presented in Appendix 1, as recommended by the Panel. Is this analysis sufficient to support the use of the model in this review?

There is more information provided on the CMAQ application and model performance. The comparisons of the model with other independent measures (e.g., CMAQ wet deposition versus NADP/NTN wet deposition estimates) provide important information with respect to the estimates of deposition. Some further comparisons with other deposition measurements would strengthen the report. These results need to be used in showing potential uses and limitations of the model predictions both with respect to regions and temporal changes.

Case Study Analyses (Chapters 4 & 5)

Questions related to the individual case study analyses are presented below. Overarching questions across all the case studies include:

1. Are uncertainties appropriately characterized across the case studies? Is there adequate information to allow us to weigh the relative strengths of each case study to inform the standard setting process?
There is sufficient information related to understanding some of the variation associated with each case study. However, it is difficult to translate this uncertainty to developing standards that can be used that include larger regions. Some of this uncertainty is related to the case studies not representing the full spectrum of effects associated with the deposition of nitrogen and sulfur.

2. In using the Risk and Exposure Assessment to inform the policy assessment, we plan to focus on aquatic acidification as the basis for an alternative multi-pollutant secondary standard as this is the area where we have the most confidence in our ability to characterize adverse effects. Does the Panel agree with this approach?

The focus on aquatic acidification is reasonable based upon the current information related to both acidification and nutrient enrichment. However, recent findings are suggesting that the recovery of soils from acidification may take an extended period and over the long-term this will also affect the rate of recovery of aquatic ecosystems.

Acidification:

1. Section 4.2 and Appendix 4 describe the analyses used to evaluate the effect of aquatic acidification. The analysis evaluates the ANC in selected lakes and streams in the Adirondacks and Shenandoah relative to three potential ANC cutoff levels (20, 50, and 100 ueq/L) to determine the impact of current levels of deposition in these areas as well as a larger assessment area. Is this data adequate to establish critical loads of deposition for the case study area?

2. The ecological effect function for aquatic acidification (section 4.2.7) attempts to characterize the relationship between deposition and ANC. In order to estimate the amount of NOx and Sox deposition that will maintain an ANC level above a given limit requires the knowledge of the average catchment flux of base cation from weathering of soils and bedrock (i.e., preindustrial cation flux (BC0)). How might we generalize from location specific inputs (F-factor approach) to using this approach on a broader scale - watershed, regionally, or some other way - to generalize beyond individual locations? What other methods should be examined for estimating catchment weathering rates nationwide for surface acidity?

This section now does a better job of describing the importance of mobile anions with respect to soil acidification and resultant effects on the depletion of nutrient cations. Many of the figures in this section need to be redone so that legends, axis values, etc. are easier to read.

This section relies substantially on MAGIC model simulations to show various spatial and temporal trends. It needs to be made clear which version of MAGIC is being used in these calculations since there are major differences with respect to the ability of the model to predict nitrogen watershed chemistry.

In this chapter the term "acidifying deposition" is used. I assume this is done to account for the role of ammonium inputs that can be nitrified resulting in acidification. However, this is not common terminology in the public policy and scientific literature and it may be preferable to use the more standard term "acidic deposition" throughout the document to avoid confusion.

Within the chapter the term "natural acidity" is used (e.g., pages 4-34 through 4-35). In some of the discussion related to ecological effects of acidification it is not clear what are the consequences associated with some of the assumptions such as the soils not being a sink for sulfur. We know that some soils are strong sulfur sinks and also there is considerable information that there is a net loss of sulfur from soils (e.g., soils as sulfur sources) (e.g., page 4-37).

In the section on uncertainty and variability (4.2.8) a variety of approaches are provided and these appear mostly to be associated with variation in parameter estimates and how this affects model output. Some discussion on the implicit limitations of the model used (e.g., processes not covered, appropriateness of scale both spatially and temporally, etc.) would help place this section in a broader context of the validity of the model results and any possible major limitations.

The section on ecosystem services is a good summary of helpful information related to ecosystem services and acidification issues (4.3.1.3). It is useful that the report explicitly states the problems of estimating directly how ecosystem services are affected by terrestrial and aquatic acidification.

3. Section 4.3 and Appendix 5 describe the analyses used to evaluate the effect of terrestrial acidification. This analysis uses the Simple Mass Balance Model to determine the impact of current deposition levels on Bc/Al levels relation to three potential Bc/Al cutoff levels (0.6, 1.2, and 10.0) for sugar maple in the Kane Experimental Forest and red spruce in the Hubbard Brook Experimental Forest and a larger assessment area based on the FIA database for 17 states. Is this approach adequate to develop critical loads of deposition for the broader terrestrial acidification case study area? Is the regression analysis between Bc/Al rations and tree health sufficiently described and are uncertainties adequately characterized?

In the sections looking at critical load calculations, there is considerable emphasis on the CMAQ model and its application and other issues related to deposition. I am not sure that there is sufficient balance between these issues and the other issues related to the within system elemental cycles including those processes affecting acidification.

The extrapolation of the critical load calculations for sugar maple and red spruce to other regions (e.g., different states) beyond those of the case studies helped place these results in a broader geographical context. There are some potential issues in looking at these results on state by state basis since these boundaries do not reflect the important characteristics that affect critical loads, but having this information on a state by state basis might be of more interest to

policy makers. It is a surprising result that such a high percentage of sites have been compromised with the acidifying total nitrogen and sulfur deposition in 2002 (page 4-62). In this section there is some use of the use of average critical loads related to three levels of projection. It is not clear if this "average" is meaningful in the context of how critical loads may be applied since the critical load is dependent on specific edaphic features of an area. Does the average take into account how the spatial distribution of edaphic features? Does this "average" apply to specific case study areas or to larger regions? The discussion and analyses that show how specific factors such as parent soil properties affect critical loads calculation is most important.

Nutrient Enrichment:

1. Section 5.2 and Appendix 6 describe the analyses used to evaluate the effect of aquatic nutrient enrichment. The analysis uses the SPARROW model on one stream reach (Potomac River and Neuse River) to determine the impact of atmospheric total nitrogen deposition on the eutrophication index for the estuary. Does the Panel think that the model is adequately described and appropriately applied?

In discussing nutrient enrichment it would be helpful to provide some background on nitrogen being a limiting nutrient in freshwater aquatic systems. Recent evidence suggests that nitrogen limitation is more common than once thought for freshwater systems. Historically, the importance of phosphorus limitation has been emphasized, but more recent work has suggested that nitrogen limitation was less noted due to it being at relatively high levels in many freshwater systems. A major challenge in developing protocols for returning systems to a level of lower nutrient enrichment is defining what attributes and their specific values that are the goals in the restoration of ecosystem type and function. The presentation of areas related to sensitivity to nitrogen loading needs some further clarification on the importance of those areas in the west (e.g., Rocky Mountains of Colorado) that are impacted by relatively low levels of atmospheric nitrogen inputs. Such areas have very different attributes and issues compared to the estuaries that are affected by relatively high levels of anthropogenic nitrogen.

The discussion of the case studies related to the Potomac River/Potomac Estuary Case Study Area and Neuse River/Neuse River Estuary Case Study Area including the application of the SPARROW model is adequate. The broader extrapolation of these results is also helpful. Some of the details provided in this chapter should possibly put into the appendices. The discussion of the uncertainty estimates provides important information on the application of the model simulations. A summary of which of these components is most important with respect to policy recommendations would help clarify what are the most important issues that could affect the interpretation of these results.

2. Section 5.3 and Appendix 7 describe the analyses used to evaluate the effect of terrestrial nutrient enrichment. This qualitative analysis describes the impacts due to nitrogen deposition on the Coastal Sage Scrub community in California and in mixed conifer forests in the San Bernardino and Sierra Nevada Mountains and larger areas where possible. In addition, the effects of nitrogen deposition in the Rocky Mountain National Park supplemental case study location are summarized. How would the Panel apply the threshold values presented in this case study to allow for a broader geographic application that accounts for regional variability? Have the associated uncertainties been adequately characterized?

The emphasis on the California coastal sage scrub (CSS) and San Bernardino Mountains mixed conifer forest (MCF) systems seems appropriate due to their importance with respect to population centers and interactions with nitrogen deposition with other environmental issues including fire susceptibility. Also, other environmental issues such as the potential effects on biodiversity and threatened species is important for these case study areas. The document clearly indicates that although qualitative interactions among these various environmental concerns are well documented there is not good information on the actual quantitative relationships including direct and indirect effects of sulfur and nitrogen deposition. It is noteworthy that the alpine ecosystems of the Rocky Mountains was considered as a case study area, but was not selected. It is suggested that "the ecological benchmarks suggested for alpine ecosystems were comparable to the benchmarks from CSS and MCF ecosystems"(p. 5-57). I am not sure this is true since the alpine systems seem to be especially sensitive to low levels of nitrogen deposition. These is some extensive discussion of the specific issues related to the Eastern Slope of the Rocky Mountains (including Rocky Mountain National Park) in Section 5.3.6.2.

The section on "Uncertainty and Variability" (5.3.8) does a good job of summarizing some of the major issues with a particular focus on the CSS and MCF case studies. On the other hand the "Conclusions" (5.4) section is too short to be very helpful in linking this Chapter with the entire focus of the document.

Additional Effects (Chapter 6):

1. In this chapter, we have presented results from some qualitative analyses for additional effects including visibility, climate and materials, the interactions between sulfur and methylmercury production, nitrous oxide effects on climate, nitrogen addition effects on primary productivity and biogenic greenhouse gas fluxes, and phytotoxic effects on plants. Are these effects sufficiently addressed in light of the focus of this review on the other targeted effects and in terms of the available data to analyze them?

The section on methyl mercury formation and relationships to sulfur are generally adequate and well done. Some of the wording needs to be changed so that it is clear that this process can occur in areas beyond just surface waters.

The other sections including 6.3 NITROUS OXIDE, 6.4 NITROGEN ADDITION EFFECTS ON PRIMARY PRODUCTIVITY AND BIOGENIC GREENHOUSE GAS FLUXES (including subsections: 6.4.1 Effects on Primary Productivity and Carbon Budgeting; 6.4.2 Biogenic Emissions of Nitrous Oxide; 6.4.3 Methane Emissions and Uptake; 6.4.4 Emission Factors; 6.4.5 Uncertainty), 6.5 DIRECT PHYTOTOXIC EFFECTS OF GASEOUS SO_X AND NO_X [including subsections: 6.5.1 SO_2; 6.5.2 NO, NO_2 and Peroxyacetyl Nitrate (PAN),6.5.3 Nitric Acid (HNO_3)] are adequate in the context of the needs of the current report.

Synthesis of Case Studies (Chapter 7):

1. Here, the case study analyses are integrated and synthesized within the conceptual framework of ecosystem services as shown in Figure 7-2. Where possible, we have quantified select ecosystem services associated with the ecological effects targeted in this review. This chapter discusses adversity by characterizing the degree to which ecological effects are occurring under given levels of deposition to inform the discussion of adversity in the policy assessment and standard setting process. To what extent do you think the description of ecosystem services provides a useful framework in the case study analyses for informing standard setting? Does the Panel have suggestions for additional consideration or characterizations for ecosystem services related to the case studies?

The information in Chapter 7 provides a summary of previous information including emphasis on ecosystem services. Much of this information has been previously stated in earlier chapters, but having this summarized information in a single chapter is helpful.

2. Based on the information presented in the current Risk and Exposure Assessment, given adequate time and resources, is there enough information to inform setting separate standards based on the other targeted ecological effects, specifically, terrestrial acidification, aquatic nutrient enrichment, and terrestrial nutrient enrichment? If not, how can our understanding of these ecological effects be enhanced in time to inform the next 5-year review?

There appears to be sufficient information provided in the current "Risk and Exposure Assessment" given additional time and resources to form standards with respect to effects of acidification and nutrient enrichment on terrestrial and aquatic systems. Clearly, however, there is considerable uncertainty on these effects especially with respect to both the current and future deposition of sulfur and nitrogen. Similarly there are complexities associated with interactions with a broad range of factors including land use, climate, effects of invasive species, etc. that result in uncertainties for predicting the effects of sulfur and nitrogen deposition.

Detailed Comments and Responses to the Charge to the CASAC NO_x/SO_x Secondary Review Panel by Myron J. Mitchell
Draft: July 21, 2009

Page	Line(s)	Comment
xxiv	4-5	This statement makes no sense: "Ecosystem Structure: Refers to the species composition, distribution, and interactions with some abiotic attributes of the environment s they vary through space and time".
xxiv	21	Change "*This* indicator may either be the actual criteria air pollutant" to "*An* indicator may either be the actual criteria air pollutant".
xxv	2	Delete "As a result".
xxvii	3	Delete "reduced" twice in this line. Why use the term reduced?
xxvii	3	Give the charge for "NO_2" (nitrite) as "-".
xxviii	7	Change to "other *forms of* precipitation".
ES-2	12-13	Change "slower biomass growth" to "lower rates of production".
ES-2	14	Change "In addition to acidification, NO_x acts" to "In addition to contributing to acidification, NO_x acts".
ES-2	22-23	Change "the ecosystem is receiving more nitrogen than it uses" to "an ecosystem is receiving nitrogen in excess of biotic nutritional needs".
ES-2	23	Delete "also".
ES-2	24	Clarify what "This" refers to. Does this mean nitrogen deposition, primary productivity and/or terrestrial carbon cycling?
ES-2	26	Change to "Lichens".
ES-2	27-28	This statement seems out of place. Does this statement have any relevance to lichens? Clarify what aspects of biodiversity have been reduced in grasslands.
ES-3		Figure ES-1. Within the figure change "Soil Process" to Soil solute generation".

ES-4	9	Change “to determining when the” to “to determining when *and where* the”
ES-5	8	Replace “enrich” with “impact”.
ES-5	8	Clarify what “this” refers to.
ES-5	12	Change “while the Ecological Effect Function (box 6) relates the deposition metric into the” to “while the Ecological Effect Function (box 6) links the deposition metric to the relevant”.
ES-5	19	Change “the degradation of” to “deleterious affecting”.
ES-6	2	Change “Because ecosystems are diverse” to “Because ecosystems differ”.
ES-7		In Table ES-1 the Adirondack Mountains should be referred to as the “Adirondacks” and not the Adirondack”.
ES-8	9	Change “ecosystem services is being used as an umbrella term” to “the term ecosystem services is being used as a broad concept”.
ES-8	10	Change “It is a way to help explain” to “The evaluation of ecosystem services helps to explain”.
ES-9	3-4	Change “some of the ecosystem services likely to be affected are readily identified, while others will remain unidentified” to “ only some of the ecosystem services that are likely to be affected can be readily identified”.
ES-9	4-6	Change “Of those ecosystem services that are identified, some changes can be quantified, whereas others will remain unidentified” to “Of those ecosystem services that are identified, only subset of changes will likely be quantifiable”.
ES-9	6-7	Change “Within those services whose changes are quantified, only a few will likely be monetized, and many will remain unmonetized” to “For those quantifiable services only a few will be subject to monetization”.
ES-9	8	Change “A conceptual model integrating” to “An example of a conceptual model of effects on aquatic ecosystems is used to integrate”.
ES-9	12	Change “can be used to inform a policy judgment” to “can be used to in developing policy”
ES-9	16	Change “inform” to “provide”.

ES-9	18-21	Figure caption needs to be changed to indicate that this is an example focusing on aquatic ecosystems.
ES-11	3	The term "magnitude" can be misleading. The correspondence between the actual amount and relative spatial patterns of measured versus modeled concentrations needs clarification.
ES-12	7	Change "information about meteorology and land use in each grid cell of the domain" to "information about meteorology and land use both of which are critical components in affecting dry deposition".
ES-13	5-7	Change "In the East, high levels of deposition exceeding 18 kg S/ha/yr occur in the immediate vicinity of isolated major sources, as well as in and near areas having a high concentration of SO_2 sources" to "In the East, the highest levels of deposition that exceeding 18 kg S/ha/yr occur in proximity to sources of high SO_2 emission" .
ES-15	13	Change "Acidification can degrade the health of terrestrial and aquatic ecosystems" to "Acidification can have deleterious impacts on terrestrial and aquatic ecosystems".
ES-15	19	Delete "method".
ES-15	28	Delete "the additional".
ES-16	12-13	Change "direct relationship between ANC and fish and phyto-zooplankton diversity and abundance" to "direct relationship between ANC and the diversity and abundance of fish and phyto-zooplankton".
ES-16	13	Change "MAGIC" to "The MAGIC model".
ES-16		Within this page direct citations are provided. This does not seem to be consistent with other portions of the Executive Summary. I would suggest that these should be deleted for consistency. This problem is also found in other parts of the Executive Summary.
ES-17	9	Change "Calcium and Al are strongly" to "Calcium and Al concentrations are strongly".
ES-17	13	See previous comments on the use of citations in the Executive Summary.
ES-17	18	Change "The tree species most sensitive" to "Tree species sensitive"
ES-17	19	Delete "a deciduous tree species".

ES-17 20	Delete “a coniferous tree species”.
ES-17 22	Change “to” to “on”.
ES-17 23	Delete “both”.
ES-18 6	Change “total removal” to “total harvest”.
ES-18 6	Remove “from timberland”.
ES-18 9	Change “roughly” to “approximately”.
ES-18 10	Remove “from timberland”.
ES-18 11-12	Change “spruce forests are home t o the spruce-fir moss spider (endangered), the rock gnome lichen 12 (endangered), and the Virginia northern flying squirrel (delisted, but considered important).” to “spruce forests are important habitats for endangered species including the spruce-fir moss spider, the rock gnome lichen, and the Virginia northern flying squirrel (delisted, but still considered important).
ES-19 1-4	Change “Some organisms may at first respond positively to an initial increase in nutrients, exhibiting an increase in growth due to fertilization effects. However, as the nutrient load continues to rise, the imbalance can have negative effects either in the organism’s response or in the invasion of new organisms that benefit from increased nutrients” to “ Some organisms may at first respond to an increase in nutrients with increased growth. However, as nutrient load continues to rise, the resulting imbalance can have negative effects either directly on the organism or indirectly by the invasion of other species that are better competitors under high nutrient conditions”.
ES-19 12-14	Change “Nitrogen is an essential nutrient for aquatic ecosystem fertility, including lake, marine, and estuarine ecosystems, and is often the limiting nutrient for growth and reproduction in many of these ecosystems” to “Nitrogen is often a limiting nutrient for lake, marine, and estuarine ecosystems”.
ES-19 15	Delete “of a system”.
ES-19 21	Change to “nitrogen *enrichment* now represents”.
ES-19 26	Change “Due to the cascading impacts and effects of nitrogen enrichment” to “Due to the cascading impacts of nitrogen pollutants”.

ES-20 2	Change “estimation” to “estimate”.
ES-20 5	Change “In this assessment” to “In the current assessment”.
ES-20 14	Change “reductions in additional” to “reductions from additional”.
ES-20 15	Change “resident commercial species” to “resident commercial species important for various fisheries”.
ES-20 24-25	See previous statements about citations in the Executive Summary.
ES-20 29	See previous statements about citations in the Executive Summary.
ES-20 29	Change “that was only about” to “of only ~”.
ES-20 31	See previous statements about citations in the Executive Summary.
ES-21 2	Change “only source of nitrogen to these systems” to “the dominant source of nitrogen to these systems”.
ES-21 5-6	Change “;creating increased growth rates in some species over others, which changes competitive interactions among species; and nutrient imbalances” to “. This higher N availability affects the relative interspecific competitive of plant species resulting in changes in species composition and vegetation structure”.
ES-21 13-14	Change “to cause increased litter accumulation in the soils and carbon storage in aboveground biomass” to increased carbon storage in aboveground biomass and litter”.
ES-21 16	Change “can” to “may”.
ES-21 17	Change “by nitrogen limitation can now better compete and alter species dominance” to “by nitrogen limitation are more competitive”.
ES-21 19-20	Change “ the leaching of NO_3^- in soil drainage waters” to “soil NO_3^- leaching”.
ES-21 20	Change “in stream water” to “in surface waters”.
ES-21 22-23	Delete “; however, these measurements are not always widely available”.
ES-21 26	Change “that nitrogen” to “that increased nitrogen inputs”.

ES-21 28-29	Is the description on the "extent of ecosystems" or the extent of the ecosystems impacted by nitrogen deposition?
ES-22 3-6	Delete these lines.
ES-22 19-23	This seems like a rather detailed finding and could be deleted from the Executive Summary.
ES-23 8	Change "could be quite high" to "is quite high".
ES-23 11-13	Change "enrichment potentially include decline in CSS habitat, decline in protection of native species, increase in abundance of nonnative grasses, and increase in wildfires" to "enrichment potentially include declines in CSS habitat the protection of native species, and increases in nonnative grasses and wildfires".
ES-23 16	Change "helps regulate" to helps control".
ES-23 17	Change "upset" to "disrupted".
ES-23 19	Change "could" to "may".
ES-24 1	Change "SO_x deposition on methylmercury production" to "SO_x deposition and resultant change in soil and wetland SO_4^{2-} concentrations in affecting methylmercury production".
ES-24 3	Change "scope of this review" to "scope of the current review".
ES-24 9-10	Change "While there are many uncertainties associated with these analyses, from a scientific perspective there is confidence that known or anticipated adverse ecological effects are occurring" to " Although uncertainties exist, there is strong evidence that known or anticipated adverse ecological effects are occurring".
ES-24 12-13	Change "Of all the case study analyses, there is most confidence in the ecological responses, effects, and benefits associated with aquatic acidification" to "Within the case study analyses, there is most confidence in the ecological responses, effects, and the deleterious impacts associated with acidic deposition".
ES-24 13-14	Change "and there is a fair amount of confidence about those associated with terrestrial acidification" to "Similarly, the importance associated with the impacts of acidic deposition on terrestrial systems is clearly documented".

ES-24	15	Change “benefits” to “deleterious impacts”.
ES-24	18	Delete “However”.
ES-24	20	Change “only” to “dominant”.
ES-24	22	Change “benefits” to “deleterious impacts”.
ES-24	25	Change “terrestrial acidification may be the most useful in terms of developing a secondary” to “terrestrial acidification should be most useful in developing a secondary”.
ES-25		These specific citations should be removed f rom the Executive Summary.
1-2	2	Change “The species of nitrogen and sulfur” to “The chemical species of nitrogen and sulfur’.
1-2	5-7	Change “because NO_x, SO_x, and their associated transformation products are linked from an atmospheric chemistry perspective, as well as from an environmental effects perspective” to “because the atmospheric chemistry and environmental effects of NO_x, SO_x, and their associated transformation products are linked”.
1-2	10	Change “of these two pollutants has been conducted” to “of SO_x and NO_x as well as total reactive N has been conducted”.
1-2	11	Delete “at this time”.
1-2	16	Change “in an ecologically meaningful way” to “that is ecologically meaningful”.
1-3	1	Change “see” to “go to:”.
1-4	13	Why “identical”?
1-4	22	Change “This draft document” to This latter draft document”.
1-5	28	Change “At that time, EPA was aware that SO_x have” to “At that time, EPA was aware that SO_x has”.
1-6	1	Change “specific SO_x concentrations” to “specific atmospheric SO_x concentrations” .
1-8	8	Change “at that time” at the time of the report (1995).

1-8	14	Change “particular relevance to this review” to “particular relevance to the current review”.
1-10	13-21	Should some mention be made of organic forms of N in the atmosphere including DON? It is noteworthy that in Figure 1.3-1 (page 1-11) that organic forms of N are shown
1-11	9-15	Although the figure shows some of the organic atmospheric S forms. There is no mention of these chemical species in the text.
1-12	19	Change “not high enough” to “not sufficiently high”.
1-13	6	Change “Both are essential and sometimes limiting, nutrients needed for growth and productivity” to “Both N and S are essential macronutrients”.
1-13	7	Change “Excess” to However, excess”.
1-13	1	Change from “These effects include slower growth” to “These effects include slower biotic growth”.
1-13	23	Change “Models suggest that” to “Models for the latter study area suggest that”.
1-13	28	Change “acidification effects from acidifying deposition” to “acidification effects from atmospheric deposition”.
1-14	9	Change “that leads” to “that may lead”.
1-14	21	Change “quality in the western United States (U.S. EPA, 2008, Section 3.3" to “quality in the western United States, a region especially sensitive to increased nitrogen atmospheric inputs (U.S. EPA, 2008, Section 3.3"
1-14	23	Change “which leads to eutrophication” to “which may lead to eutrophication”.
1-14	27	Change “in highly eutrophic estuaries” to “in some eutrophic estuaries”.
1-14	30-31	Change “In terrestrial ecosystems, there are multiple chemical indicators for the alteration of the biogeochemical cycling of nitrogen that is caused by total reactive nitrogen deposition” to “In terrestrial ecosystems, there are multiple chemical indicators that the biogeochemical cycling of nitrogen has been altered by the deposition of total reactive nitrogen”.

1-14-15		Change “Nitrate leaching” to “Nitrate leaching from terrestrial ecosystems”.
1-15	2	Change “the onset of leaching” to “the atmospheric deposition threshold for nitrate leaching”.
1-15	7	Change “occurring at 3 kg” to “occurring at atmospheric inputs as low as 3 kg”.
1-15	13	Change “this” to “the current”.
1-15	19	Change “In watersheds where changes in sulfate deposition did not produced an effect” to “In watersheds where changes in sulfate deposition did not result in changes in methylmercury generation”.
1-15	20	Change “meaningful” to “substantial”.
1-16	Figure 1.3-3	See previous comments on Figure ES-1 (Is this figure the same as Figure 1.3-3?)
1-17	18-20	This sentence needs to be reworded.
1-18	15-17	This sentence is confusing. What is meant by “the uncertainties in the estimated reductions”? Is the uncertainty on the amount of atmospheric reduction that will occur or uncertainty on the effects of reductions?
1-19	21	Change “Identifying important chemical species in the atmosphere” to “Identifying important N and S chemical species in the atmosphere”.
1-21	6	Change “All of Figure 1.4-1" to “All of the components of Figure 1.4-1" .
2-6	14-15	Change “to total loadings of in the environment” to “to the combined atmospheric loadings of both elements”.
2-7	7	Change “a broad look into the” to “an overview of”.
2-7	8	Change “services that is one tool that can help link” to “services. The analysis of the effects on ecosystem services will help link “.
2-7	10-11	Change “In this Risk and Exposure Assessment, ecosystem services is used as an umbrella term to aid in describing the impacts of ecological effects on public welfare and to help explain how” to “In this Risk and Exposure Assessment, ecosystem services is used to show the impacts of ecological effects on public welfare and help explain how” .

2-8	3	Change "data were not abundant enough" to data were not sufficient"
2-8	19-20	This sentence seems out of place.
2-15	2	Does the statement "The analysis of ecosystem services for the aquatic acidification focused on recreational fishing" indicating that focus for the current assessment of the general analysis of ecosystem services in aquatic ecosystems. I believe the sentence should be changed to: "The current assessment the analysis of effects on ecosystem services from aquatic acidification focused on recreational fishing".
2-15	24	Change "little data is" to "little data are".
2-16	2	Change "ecosystems are addressed" to "ecosystems were addressed".
3-2	25	Change "species-specific" to chemical species-specific".
3-16	13-24	The term "measured deposition" is used and this needs to be changed to "estimated deposition" since dry deposition are inferred by model calculations and not measured rates. Such nomenclature needs to be changed throughout the document.
3-22	8-16	The title should be changed to "Non-Atmospheric Loadings of Nitrogen and Sulfur". The inclusion of examples associated with the contribution of other sources such as the weathering of sulfur minerals should be considered.
3-17	16	Change "White Face" to "Whiteface".
3-93	23-28	The statement that "Although there are uncertainties in the data, models, and techniques used for this assessment, this analysis relies upon the most applicable measurements and state-of-the-science models. In addition, these data and models are used in a manner that considers their relative strengths and limitations. The inherent uncertainties are not expected to measurably affect the robustness of these conclusions and findings on the characterization of concentrations and deposition" places a very "positive spin" on these model applications, I am not sure that this is entirely justified based upon the level of uncertainties especially with respect to dry deposition estimates of the available models.
4-1	26-27	Change "Under natural conditions (i.e., low atmospheric deposition of nitrogen and sulfur), the limited mobility of anions in the soil controls the rate of base cation leaching" to "Under conditions of low atmospheric

		deposition of nitrogen and sulfur, the naturally produced bicarbonate anion is often the dominant mobile anion with SO_4^{2-} and NO_3^- playing a limited role with respect to cation leaching".
4-1	27-30	Change "However, acidifying deposition of nitrogen and sulfur species can significantly increase the concentration of anions in the soil, leading to an accelerated rate of base cation leaching, particularly the leaching of Ca^{2+} and Mg^{2+} cations" to "Increased atmospheric deposition of sulfur and nitrogen can result in marked increases in SO_4^{2-} and NO_3^- soil fluxes resulting in the concomitant leaching of nutrient (Ca^{2+}, Mg^{2+}) and toxic (Al^{n+} and H^+) cations".
4-2	8	Change to "Criteria for case study selection".
4-2	11	Change "Current conditions for other areas" to "Current conditions for these other areas".
4-2	26	Change "sum of soil and water processes that occur upstream within a watershed, it also reflects the results of watershed-scale terrestrial effects, including nitrogen saturation, forest decline, and soil acidification (Stoddard et al., 2003)." to "sum of terrestrial and aquatic processes that occur upstream within a watershed. Important terrestrial processes include nitrogen saturation, forest decline, and soil acidification (Stoddard et al., 2003)".
4-3	8	Change "certain" to "some".
4-3	10	Change "where strong acids are deposited into the soil" to "where strong mineral acids (e.g., H_2SO_4 and HNO_3) are deposited or generated within the soil.
4-2	13-14	Change "inorganic Al can become mobilized, leading to the leaching of Al into soil waters and surface waters" to "inorganic Al can be mobilized, leading to the leaching of Al from soils to surface waters".
4-2	15	Change "differently" to "differently to acidic deposition".
4-2	15-16	Change "on sensitive species" to "on different ecosystems and species".
4-2	20	Change "migrates" to "leaches".
4-3	23	Change "maintains the balance of electric charge" to "maintains electroneutrality" .

4-4	1	Delete “further”.
4–4	8	I would disagree that episodic acidification is more important than chronic acidification.
4-4	7-8	Change to “ Short-term (i.e., hours or days) episodic changes in water chemistry have perhaps the most significant biological effects” to “Short-term (i.e., hours or days) episodic changes in water chemistry have important biological effects”.
4-4	9	Change “rainstorms or snowmelt” to “precipitation or snowmelt events”
4-4	10	Change “which tends to provide less neutralizing of atmospheric acidity as compared with” to “than tends to provide less acid neutralizing than water passing through”.
4-4	12	Change “storm runoff or snowmelt” to “events”.
4-5	9-10	Change “receptors” to “parameters”.
4-5	13-14	Delete “Although ANC does not relate directly to the health of biota” and start sentence with “The utility”.
4-5	22	Delete “the”.
4-5	24	Change “Low ANC concentrations have” Low ANC has”.
4-5	30	Change “(Figure 4.2-1, a), which” to “(Figure 4.2-1, a) that”.
4-6	3	Change “has been found in studies” to “has been found in various studies”.
4-6	8-9	Change “Below 100 μeq/L, it has been shown that fish fitness and community diversity begin to decline” to “Below 100 μeq/L ANC fish fitness and community diversity begin to decline” .
4-6	11	Delete “decline; however, the overall health of the community remains good”.
4-6	13	Change “that are sensitive to negative effects on biota that are sensitive to acidification” to “that are sensitive to acidification”.
4-7	2	Change “had to have” to “need to have”.
4-7	9	Delete “primarily”.

4-17	17	Change “fishers” to “fisherman”–this may not be a “sex neutral” term, but fishers refers to a type of animal.
4-8	2	Delete “in these states”.
4-8	13-14	Change “services, such as hydrological regime regulation and climate regulation” to “services associated with hydrology and climate”.
4-8	15	Delete “specific”.
4-8	16-17	Change “delicate aquatic food chains” to “ aquatic food webs” .
4-8	19	Delete “it is worth noting that”.
4-8	20-22	Delete “For example, these biological control services may serve as “intermediate” inputs that support the production of “final” recreational fishing and other cultural services”.
4-9	4-5	Change “The regions of the United States with low surface water ANC values are the areas that are sensitive to acidifying deposition” to “The regions of the United States with low surface water ANC values are sensitive to acidifying deposition’.
4-9	6-7	Delete “at their existing ambient concentration levels”.
4-9	14	Change “surface water data” to “analyses of sulfur waters”.
4-9	19	Delete “are estimated to”.
4-9	21-24	Change “In 2002, Stoddard et al. (2003) took another comprehensive look at the level of acidification within all of these regions. Although improvement in ANC occurred, about 8% of lakes in the Adirondack Mountains and 6% to 8% of streams in the northern Appalachian Plateau and Ridge/Blue Ridge region were still acidic at base-flow conditions” to “Stoddard et al. (2003) suggested that although improvement in ANC had occurred ~8% of lakes in the Adirondack Mountains and from 6% to 8% of streams in the northern Appalachian Plateau and Ridge/Blue Ridge region were acidic at base-flow conditions”.
4-10	9-12	Change “After considering this information, the Adirondack Mountains and the Shenandoah Mountains (referred to in this chapter as Adirondack and Shenandoah case study areas, respectively) were selected. The rationale for choosing these two case study areas is described in the

		following subsections" to " Using the rationale described in the following subsections the Adirondack Mountains and Shenandoah Mountains were selected for case study areas".
4-10	16	Change "The case study area" to This area".
4-10-11		Delete ", which all draw water from the preserve".
4-12		For Figure 4.2-3, the axis legends and numbers are too small.
4-13		For Figure 4.2-4, the axis legends and numbers are too small.
4-14	6-7	Delete "because it can no longer be measured".
4-14	7	Change "Likewise, it is also difficult to determine" to "Likewise, it is also difficult to empirically determine".
4-15	9	Change "hydrological" to "biogeochemical"–MAGIC is not a hydrologic model.
4-15	10	Change "quality levels" to "chemistry".
4-15	4-30	The insert on critical loads includes the value of 50 $meq/m^2 \cdot yr$. This value may be confusing in using a load based upon charge versus mass since much of the proceeding discussion including inputs used mass values.
4-17	19	Change "the condition" to "the modeled condition".
4-18	5-8	It is important to mention that although SO_4^{2-} still dominates the relative importance of NO_3^- is increasing substantially. Also, comparing concentrations of SO_4^{2-} and NO_3^- in surface waters can be misleading since there may be substantial losses of NO_3^- due to biotic processes in watersheds.
4-18	13	Were these declines in Al statistically significant?
4-18	14	Change "significant" to "substantial".
4-19	1-5	Reword this sentence it makes not sense.
4-19	7	Change "is" to "was".
4-19	10	Change "are" to "were".

4-21	2-5	Change "Percentage of Adirondack Case Study Area lakes in the five classes of acidification (i.e., Acute, Severe, Elevated, Moderate, Low) for years 2006 and 1860 (preacidification) for 44 lakes modeled using MAGIC. Error bar indicates the 95% confidence interval" to "Percentage of Adirondack Case Study Area lakes in the five classes of acidification (i.e., Acute, Severe, Elevated, Moderate, Low) for years 1860 (preacidification) and 2006 for 44 lakes modeled using MAGIC. Error bar indicates the 95% confidence interval". (Make similar changes in other figure captions including 4.2-19)
4-19	8-11	Change "Sites labeled by red or orange dots have less buffering ability than sites labeled with yellow and green dots, and hence, indicate those lakes that are most sensitive to acidifying deposition, due to a host of environmental factors" to "Sites indicated by red or orange circles have less buffering ability than sites labeled with yellow and green circles, and hence, indicate those lakes that are most sensitive to acidifying deposition".
4-22	2-7	In figure caption change "dots" to "circles". *Make similar changes in all figure captions and text.*
4-23	7-9	Change "In considering the future responses of lakes to current emissions and given the current condition of the lakes, the question becomes whether lakes can recover to healthy systems (i.e., ANC > 50 μeq/L)" to "In considering the future responses of lakes, the question becomes whether lakes can recover to healthy systems (i.e., ANC > 50 μeq/L) under current levels of deposition".
4-24	4-11	Change "Based on a deposition scenario that maintains current emission levels to years 2020and 2050, the simulation forecast indicates no improvement in water quality"."Based on a deposition scenario that maintains current emission levels to up to years 2020 and 2050, the simulation forecast indicates no improvement in water quality over either of these periods".
4-24	15	Change from "will likely not improve the acidification of lakes" to "will not likely improve the recovery from acidification".
4-24	15-17	Delete this sentence.
4-24	24-25	Change "At this time, it is unclear why ANC initially improved and is now declining" to "It is not known what has caused this temporal pattern of ANC in this case study".

4-25	Table 4.2-4	Indicate what “+/-“ columns signify.
4-26	3	Change “changed statistically” to “did not significantly differ”.
4-26	19	Change “industrially generated acidifying deposition” to “acidic deposition”.
4-26	21	Change “is” to “was”.
4-31	3	Change “Based on a deposition scenario that maintains current emission levels to 2020 and 2050" to Based on a deposition scenario that maintains current emission levels to years 2020 and 2050".
4-31	12	Change “country” to ”U.S.”.
4-31	13	Change “across populations” to “across various populations”.
4-31	14	Change “picked” to “selected”.
4-31	15	Change “to make estimates of regional extent of condition (e.g., number of lakes, length of stream)” to “to make regional estimates of surface water conditions”.
4-31	21	Change “to be susceptible” to “to be especially susceptible”.
4-32	24	Change “area” to “areas”.
4-32	32	I don’t believe the term “ecoregion” been defined in the document.
4-28	2	Change “industrially generated acidifying deposition” to “acidic deposition”.
4-34	10	Change “SO_2" to “SO_x”.
4-34	13	Change “One hundred 17 lakes of the 169 lakes modeled for critical loads are part of a subset of 1,842 lakes in the Adirondack Case Study Area” to “ Of the 169 lakes modeled for critical loads, 117 of these lakes were within 1,842 lakes in entire the Adirondack Case Study Area”.
4-34	14-15	Delete “which include all lakes from 0.5 to 2,000 ha in size and at least 1 m in depth”.
4-34	21	Change to “13% *of the total population*”.

4-34	22	Change “some lakes would have never had ANC” to “some lakes would have never had ANC”.
4-34	24-25	Change “estimate based on the critical load alone” to “estimate based solely using the critical load criterion”.
4-34	26	What is meant by “natural”? Does this refer to current conditions or preindustrial concentrations? The term natural with respect to surface water acidity needs to be defined. It might be clearer to discuss the role of DOC in these waterbodies that have historically low ANC.
4-35	20	Change “the same” to “similar”.
4-36	12	Change “a host of catchment processes and environmental factors that affect the level of base cations (e.g., Ca^+, Mg^+) concentrations and the sinks of nitrogen and sulfur in the lake and terrestrial catchment” to “a series of biogeochemical processes that produce and consume acidity in watersheds”.
4-36	19-21	Change “Although ANC does not directly affect the health of biotic communities, it ameliorates acidity-related biotic stress that provides an “ecological indicator” of overall integrity of the ecosystem” to “Although ANC has not generally been used as a parameter for predicting the health of biotic communities, it provides useful information of the potential acidity-related biotic stress and hence is a useful “ecological indicator”.
4-36	22	Delete “then”.
4-37	9-10	Change “To convert surface water concentrations into surface water fluxes, multiply by runoff (Q) (in m/yr) from the site” to Surface water concentrations are converted to fluxes by multiplying concentrations by runoff (Q) (in m/yr)”.
4-37	12	Change “between plants and soil is ignored” to “between plants and soil is negligible”.
4-37	19-21	This sentence is confusing. Certainly the nitrogen and sulfur biogeochemical fluxes and transformations affect acidity.
4-40	1-3	This is not just a problem for the United States. The estimate of weathering rates (including the generation of base cations) is a major limitation for many biogeochemical analyses and interpretations
4-42	22	Delete “a coniferous tree species” and “ a deciduous tree species”.

4-48	6	Delete “and forest”.
4-62		The following statement “Collectively, these results suggest that the health of at least a portion of the sugar maple and red spruce growing in the United States may have been compromised with the acidifying total nitrogen and sulfur deposition in 2002; even with the lowest level of protection, half the states contained sugar maple and red spruce stands that were negatively impacted by acidifying deposition” will receive considerable attention. It is important that any caveats be provided on these results so that the interpretation is placed in the most complete picture of the state of the science.
4-65	10	Change “was” to “is”.
4-66	17	Does the “average critical loads” have any real meaning in the context of setting critical loads. I would suggest that the range is the most important and demonstrates and clearly shows how edaphic factors can have a major influence on critical loads.
4-67		Figure 4.3.9 See previous comment with respect of providing the values for average critical loads.
4-68		Figure 4.3.10 See comment above on the use of average critical loads in this figure.
4-69		The discussion of uncertainty is important and highlights some of the issues related to the actual calculation of critical loads. It may be over stretching the uncertainty analyses to suggest that “If all or a large majority of estimates indicate that the critical load of a system is exceeded with current total nitrogen and sulfur deposition rates, the probability is high that deposition is greater than the critical load and that the trees and vegetation in that system are being negatively impacted by acidification”. The use of the term “probability” seems out of place and suggests that this approach has a stronger statistical underpinning than is the actual case. The key factor is what are the range of values that affect these calculations and how confident are we in using these values in making these calculations. Similarly the term “certainty” would suggest more confidence in these estimates than may actually be the case.
4-71	3-5	This type of calculation in which it is clearly shown how different values can be obtained for critical loads based upon specific edaphic factors (e.g., parent material acidity) is a useful approach and show how this factor can have a dramatic impact on these calculations.

5-2	24	Change “resulting in increased productivity (e.g., of algae or aquatic plants)” to “resulting in increased primary productivity”.
5-2	25	Change “increases, dissolved” to “increases with concomitant increases in organic matter production, dissolved”.
5-4	24	Change “for a portion of the nitrogen input” to “for a portion of this nitrogen input”.
5-8	21-22	Delete “Therefore, if the susceptibility is known and held constant, a curve can be created”.
5-9	10	The determination of on the nitrogen inputs in “pristine” conditions is a difficult task. I agree that providing some upper and lower bounds is a useful approach.
5-10	19	Change “fish” to “seafood”. Throughout this section change wording so that is clear that the entire “seafood” resources, not only fish are being considered.
5-11	5	Change “fish” to “seafood”.
5-12	10	Change “and reduce” to “and reduced”.
5-14	7	Change “are” to “were”.
5-14	14	Change “175 million days” to “175 million participant days”.
5-14	15	Change “more than 35 million days per year” to “more than 35 million participant days per year”.
5-14	19	Change “including climate, biological, and water regulation; pollution detoxification; erosion prevention; and protection against natural hazards” to “including those important for the quality and quantity of water and effects on climate including impacts from storms”.
5-15	13	Change “defining” to “determining”
5-29	3	Change “under suspicion of eutrophication”likely to be subject to eutrophication”.
5-29	31	Not sure if “in prep” information should be cited.
5-47	2	There is a mixture of aquatic and terrestrial ecosystem benchmarks in “Figure 5.3-2. Benchmarks of atmospheric nitrogen deposition for several

		ecosystem indicators" with the inclusion of the diatom changes in the Rocky Mountain lakes.
5-57	7-8	I am not sure that the following statement is valid: "However, the ecological benchmarks suggested for alpine ecosystems were comparable to the benchmarks from CSS and MCF ecosystems". At a minimum some supportive statements are needed.
5-64	10-15	The discussion on amounts of nitrogen in throughfall appears to suggest that these differences are due to differences in atmospheric deposition. Although some of this difference may be due to the amounts of atmospheric deposition, the importance of canopy exchange in contributing to nitrogen in throughfall may also be important. See also on page 5-68 with respect to the establishment of critical loads based upon throughfall nitrogen flux.
5-67	1-3	The statement that "increased litter deposition may facilitate faster rates of microbial decomposition initially but may reduce decomposition over the long term because of changes in the C:N ratio and increasing lignin content over time" needs clarification.
5-72	1	Change "classic" to "documented".
5-75	17	Delete "from nitrogen-saturated forest soils".
5-75	17	Change "into streams" to "into streams of the northeastern U.S.".
6-2	31-32	Change "aquatic environments" to "aquatic and terrestrial environments, including wetlands,"
6-2	33	Delete "surface water".
6-11	1	Change "emissions" to "deposition".
6-12	24	Change "its global warming potential" to "its global warming potential per molecule".
6-14	14-15	Change "Nitrogen deposition can affect the patterns of carbon allocation because most growth occurs above ground" to "Nitrogen deposition can affect the patterns of carbon allocation between above and below ground production".
6-14	15	Change "This increases the shoot-to-root ratio" to "Increased nitrogen availability increases the shoot-to-root ratio".

6-11	20	Change “Reducing SO_x” to “Reducing SO_x emissions”.

Dr. Kathleen Weathers

Weathers Response to REA

I appreciate the enormous work involved in putting this REA together. It was (and is) a Herculean effort.

I have included brief comments—some overarching, some specific—on many of the chapters in the REA, and on the charge questions.
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Executive Summary

While I like the idea of Figure ES-1, I think some of the pieces are a bit misplaced and mislabeled. For example, mobile anions might be depicted in association with cation leaching, and to what are "soil processes" meant to refer (e.g., NO3—meaning nitrification?).

Figure ES-2. I am a fan of using multiple colors in Figures only when their purpose(s) are clear, or clearly identified. At first glance, I'm not sure what the different colors are meant to depict (if anything) in this, and other figures in this document. Ditto for shapes. I suggest either identifying the significance of both in the Figure legend, or (re)considering carefully their use.

Figure ES-4: The recreational fishing example here, and throughout the document, in fact, would benefit from a footnote, or a few lines in the text that give a clear explanation about why and/or how the effect of fish stocking or invasions, an important driver in species distributions and abundance, can be separated from the effects of acidification via deposition.

Pages ES-12, 13—it would be a good place to note some brief caveats about where this spatial estimation is likely to underestimate (or perhaps overestimate) deposition (e.g., high elevation ecosystems, heterogeneous terrain, and regions with significant snowfall). It would also be useful to note in the figure legends what the spatial resolution is for these maps.

Page ES-16 (line 14): I think that MAGIC and other models are used to estimate (vs determine).

Note how the "critical load approach" boxed here either parallels, or does not, that used by Europeans and others.

I think it very important to note, and put in context, when, where, and how natural (vs anthropogenic, or strong mineral) acidification occurs (terrestrial and aquatic). (The language exists in chapter 4.) Nothing more than a brief mention is necessary in this Executive Summary.

What determines when references are included, or not included, throughout the REA and especially appendices? Mostly the text is not referenced (beyond the ISA), except when it is!

Chapter 1:
There is reference to "the latest scientific knowledge," yet many of the references I noticed in this document are from quite some time ago.

1-10, line 26: the term "total nitrogen" should be qualified here. Sometimes total is referred to as having captured all the vectors of N, i.e., having estimated dry, wet and cloud or fog deposition.

1-12, lines 18-19??

1-14, lines 4-6 and a few other places in this document: In these systems, atmospheric N deposition is the main source of new N to the system, but it may also travel through vegetation and soil before getting to headwater streams and lakes, depending upon where they sit in the landscape and by what they are surrounded. Perhaps what was meant here was headwater streams and high elevation lakes that are above treeline? This statement should be clarified here and elsewhere in the document.

1-19: I agree with the paragraph starting on line 7 (and the bulleted list preceding it), and thus Figure ES-4 (depicting relationships) challenges my sensibilities. I'll be interested to be reminded of its heuristic utility.

Chapter 3:

I suggest adding the spatial scale/resolution to the figure legends of all of the figures that show spatial data.

3-2: While it is reasonable that cloud or fog deposition could not be considered for lack of monitoring data, there are places throughout the document where the qualitative result of this (necessary) omission could be pointed out (e.g., for example, eastern high elevation sites where cloud/fog has been shown to contribute significantly to N and S loads).

3-24. It would be useful to report under "spatial allocation of gridded data to case study areas" how many (roughly) grid cells were used/study area. Given the coarse resolution of the CMAQ data, it seems possible that the Hubbard Brook Experimental Forest, for example, could contain few grid cells

3-26: For the data that span a 4-year time period, "trend" analysis is dubious. Analysis of the long-term record at Hubbard Brook suggests that detection of statistical trends took more than 3X that time period.

3-90s: I expected to read more about the uncertainties associated with complex terrain in this section. It is one of the important drivers in uncertainties for estimating dry deposition and a major challenge to estimating deposition.

Chapter 4:

Overall, I found most sections of this chapter to be confusing, and in need of significant editing--for clarity, for completeness, for accuracy, especially in the aquatic section. As a result, I have not made detailed comments, rather I have identified some general (and a few specific) issues.

It might be helpful to discuss charge balance early on.

As I've suggested before, defining what is meant by such terms as "health" of terrestrial and aquatic ecosystems is important if the word is going to be used.

I suggest adding a section on terrestrial-aquatic linkages.

There are many figures in this section (and in the Appendix) that are identified as showing declines (by x%, for example) over time, yet no regression, or trend analysis seems to have been performed, rather a line graph has been generated and trends/declines suggested. In the case of the associated appendix, lines may have been fit to the data, but there is not information about what kind of a polynomial fit may have been used, why, and what its significance is, for example. It is important to support the assertion of trends or declines over time with appropriate trend analyses and documentation.

I like the idea of using boxes. However, many of the boxes need editing as well.
The box on page 4-16 was particularly convoluted.

4-15: critical load approach –there seem to be a few different definitions and interpretations throughout the REA. It would be helpful to standardize.

4-17: I assume signs of improvement mean that NO3 and SO4 have decreased in surface waters of the ADK case study. See my comments, above, about the lack of trend analyses.

4-24: what are "slight" signs of improvement, or what does it mean to have "not resulted in much improvement?"

Figure 4.2-21. Fix spelling on title.

Terrestrial Effects

4-36: what's it mean to account "for the effects input of Cl-?

The connections between tree "health," direct and indirect tree responses, and growth responses should be made clear. And again, it is necessary to define what is meant by health (box on 4-44).

4-45. Many things affect the provisioning of services, of course. Some contextual statistics would be useful in this section, especially about some of the other factors that might affect these two species' productivity.

4-51: What percentage of the area used for the HBEF is covered by red spruce?

4-61: what area (ballpark) do the FIA plots cover for each of the species?

Chapter 7, Synthesis:

Much of the first part of the synthesis chapter is a reiteration of other chapters in the REA. I think that the focus should be more actual synthesis among these chapters.

I prefer the use of ecosystem structure or function (vs processes, as used throughout the REA).

Is change the right operative word/focus here?
7-2, line 13 changes can be or are quantified? tense?

Figure 7-1: see comments above about the use of color, or not. In this figure, color obscures the text.

7-3, line 19, Knowledge about the relationships, whether direct or indirect,...
Foliar injury is not really a process. Perhaps it's the change in structure that affects a process (photosynthesis) that is the point of this example? The examples at the bottom of this page could be clarified.

7-5, first para: I like the idea of this—clarifying which data are best suited to informing a policy on welfare effects, but it wasn't clear to me the current answers, i.e., I was looking for a clear path to answering the question.

7-5: Nitrogen is known to limit growth and productivity. S is necessary, but not identified as limiting, usually. The text should be changed. Reproduction of ecosystems? *Anthropogenic* acidification *can* cause...This paragraph could use some editing.

See earlier comment on the statement that atmospheric nitrogen deposition is the main source of new N. It's the main source of new N to ecosystems, and subsequently to most headwater streams...

7-6, line 1: Nitrogen deposition can alter ecosystem processes, such as primary production and nutrient cycles...

Figure 7.1.3 needs a little more description in the legend. Are the deposition ranges from the modeling and estimates in this REA, or are they estimates provided in the studies cited for the effects noted? I like the idea of this kind of figure that can be used to synthesize across systems and depositional loads.

7-17, line 6, will remain unmonetized because?

In regard to some of the specific charge questions asked:

Case studies:

Uncertainties: I am inclined to ask what kinds of uncertainty analysis are necessary from the policy making perspective, as well as how best the myriad scientific uncertainties that exist can be communicated in such a way that it is obvious which are the most "important" (e.g. have the biggest effects). Finally, I would ask how uncertainties can be communicated in such a way that they do not undermine what is known. Currently, I do not think that uncertainties are as well characterized as they might be.

I agree that it is in aquatic systems where the most direct and clearest effects of acidifying deposition have been shown. However, Chapter 4 should be significantly improved to make it useful to that process.

Acidification:

The first question is tied to the definition of critical loads, and critical loads approach. Isn't the question really are these the critical loads?

Synthesis:

The idea of ecosystem services focuses on the work that ecosystems do in service of humans. A focus on ecosystem services can limit understanding of ecosystem structure and function. However, it has purchase in the scientific community. And, in the REA the definition of welfare effects given on page 7-1 underscores the fact that discussing ecosystem services may be a useful way for scientists to translate ecological function into welfare effects.

Understanding will be enhanced significantly through generating better estimates of (all important chemical forms of N and S, especially NHx and organic N) deposition (including wet, dry and fog) to complex ecosystems, through long term experimental manipulations, and process studies that included linked biogeochemical studies.