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Cc: Brian Czech

RE: Comments on the Fish and Wildlife Service's Strategic Plan for Responding to Accelerating Climate Change, SLAMM

In our comments on the Fish and Wildlife Service's Strategic Plan for Responding to Accelerating Climate Change, dated November 30, 2009 we suggested that the Fish and Wildlife Service (Service) re-evaluate the use of the Sea Level Affecting Marshes Model (SLAMM) to examine vulnerability of coastal marshes on National Wildlife Refuges to Sea Level Rise. Since writing those comments a new version of the SLAMM model, SLAMM 6.0, has been released with significant improvements. Given these refinements, Defenders believes that SLAMM 6.0 can have utility for assessing and communicating coastal marsh vulnerability to sea level rise when used appropriately. Below we discuss the improvements in SLAMM 6.0, outline best practices for using SLAMM for future refuge vulnerability assessments, and discuss how the model should be used to inform land management and acquisition decisions and to communicate vulnerability to the public.

SLAMM 6.0 addresses several well-recognized shortcomings of older models. Earlier versions of SLAMM did not adequately model the accretion process -- a fundamental component of marsh stability. The long term stability of marshes is determined by the relative rates of two processes: sediment accretion, which enables the marsh to expand vertically and horizontally, and coastal submergence (or relative sea level rise), which incorporates both global or eustatic sea level rise and local land subsidence. Because of the importance of accretion rates in determining marsh stability it is essential to have a tool that can represent the processes affecting accretion. Actual accretion rates vary over space and time and are determined by a variety of factors that influence sediment deposition and capture including habitat type, elevation, distance to river or tidal channel, elevation, tidal range, and salinity.[1] Herbivory and other forms of disturbance can also impact accretion. SLAMM 6.0 incorporates dynamic feedbacks based on elevation, distance to channel, and salinity. These three factors also address (to some extent) other aspects affecting accretion rates, such as vegetation and biomass. The salinity model, which is undergoing refinement as part of SLAMM 6.0 can be used when site-specific data indicate that accretion rates cannot be described on the basis of elevation and distance to channel alone.

[1] Morris, J.T., P.V. Sundareshwar, C.T. Nietch et al. 2002. Responses of coastal wetlands to rising sea level. Ecology 83: 2869-77.

Other improvements to SLAMM 6.0 include habitat switching functions which allow habitat changes to be specified based on the salinity model; an integrated elevation analysis which will summarize site-specific elevation ranges for wetlands as derived from LiDAR data or other high-resolution data sets; flexible elevation ranges for land categories to employ if site-specific data indicate that wetlands range beyond SLAMM defaults; incorporation of spatial maps of uplift and subsidence; an improved user interface; and improved memory management.[2] These changes enable SLAMM to more realistically model and incorporate site-specific data and processes, and improve the "user friendliness" of the tool.

Like all models, SLAMM 6.0 has limitations – it makes certain simplifying assumptions, excludes certain processes and factors, does not represent mechanistic accretion relationships,[3] and cannot model every process that affects coastal marsh vulnerability to sea level rise. For example, SLAMM still does not account for infrequent events that influence wetland development such as storms and floods. What is perhaps more important even than these limitations though is an understanding that the validity of SLAMM projections is entirely dependent on the data inputs used to run the model. SLAMM assessments are only as good as the data entered into the analysis and the user's knowledge of local processes. This is where user best-practices become critical.

As the Service continues to use the SLAMM model to assess coastal vulnerability to sea level rise on national wildlife refuges we have the following recommendations or suggested "best practices" for employing SLAMM analysis:

1. **Use the most recent SLAMM version available**. SLAMM 6.0 is the latest version of the SLAMM model, developed by Jonathon Clough of Warren Pinnacle Consulting, Inc with funding from the Nature Conservancy. SLAMM 6.0 is open-source and provides the refinements discussed above. This new version of SLAMM and all technical documentation can be downloaded here:
   http://warrenpinnacle.com/SLAMMFORUM/index.php?topic=55.0

2. **Use the highest quality of elevation data available at your site**. Because inundation is a function of slope, SLAMM relies heavily on the use of elevation data to assess vulnerability to sea level rise. Most elevation datasets, with the exception of LiDAR, have vertical accuracies from several meters to tens of meters depending on the data source.[4] Global sea level rise projections by the end of this century range from 1 – 3 meters depending on emission scenarios and the pace of melting sea and land ice. Mapping increments of sea

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2 Clough, J. and Fuller, R. 2009. SLAMM 6 Technical Notes. Completed Modifications to Model Code Under Contract to the Nature Conservancy. Draft.

3 Clough, J. and Fuller, R. 2009. SLAMM 6 Technical Notes. Completed Modifications to Model Code Under Contract to the Nature Conservancy. Draft.

4 Gesch, D.B., B.T. Guitierrez, and S.K. Gill. 2009. Coastal Elevations. In: *Coastal Sensitivity to Sea Level Rise: A Focus on the Mid-Atlantic Region.* A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [J.G. Titus (coordinating lead author), K.E. Anderson, D.R. Cahoon, D.B. Gesch, S.K. Gill, B.T. Gutierrez, E.R. Theiler, and S.J. Williams (lead authors)]. U.S. Environmental Protection Agency, Washington, DC, pp. 157-162.

level rise, particularly for the mid-century becomes problematic if the elevation data used has a vertical accuracy of greater than a meter, which is the case with much of our currently available Digital Elevation Model datasets. [5] LiDAR elevation datasets – currently the highest resolution datasets, routinely achieve vertical accuracies in the order of 15 cm and thus are well suited for impact analyses of sea level rise at the sub-meter scale as well as for mapping low-relief coastal landforms. LiDAR is not available in all areas of the country, but has become available in much of the Chesapeake Bay area, North Carolina, and other locations and should be employed where available. SLAMM may not be worth the cost in locations where LiDAR data and site-specific accretion rates are not available because results will have high uncertainty and likely do not merit the cost and effort expended to complete the analysis.

3. **Employ site-specific data and understand site dynamics**. Site-specific information that can be incorporated into the SLAMM model will improve the outputs of the model. Similarly, knowledge backed up by long-term datasets, of the dynamics that are occurring at the site is essential in order to critically examine the underlying assumptions and resulting projections from the SLAMM model and refine vulnerability assessments and management decisions.

4. **Monitor accretion rates and other variables that affect coastal vulnerability to sea level rise to incorporate changing conditions over space and time**. As stated above, modeling is not a substitute for continued monitoring to develop an understanding of the site-specific dynamics and how these will affect management decisions. Accurate estimates of inundation, marsh loss, accretion rates, habitat shifts, species loss and other factors related to coastal vulnerability should be monitored over time and across the Refuge System. When possible, monitoring targets, methods and data organization should be consistent across the Refuge System to encourage cross system assessment and analysis.

5. **Understand the limitations of the approach and use SLAMM as an estimate of what *may* happen in the future**. Despite marked improvements in SLAMM 6.0, the model still has limitations and like most models contains simplifying assumptions and will fail to accurately model all factors and processes occurring within a site. SLAMM's predictive power is strongest when used for regional comparisons of vulnerability between sites rather than vulnerability within a site and SLAMM projections are not a substitute for local knowledge. Management and land-use decisions based on SLAMM modeling should be flexible and continually refined and re-assessed with experimental, observational and other monitoring data as part of the adaptive management process.

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[5] Gesch et al. 2009 Coastal Elevations. In: *Coastal Sensitivity to Sea Level Rise: A Focus on the Mid-Atlantic Region.* A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [J.G. Titus (coordinating lead author), K.E. Anderson, D.R. Cahoon, D.B. Gesch, S.K. Gill, B.T. Gutierrez, E.R. Theiler, and S.J. Williams (lead authors)]. U.S. Environmental Protection Agency, Washington, DC, pp. 157-162.

6. **Employ SLAMM to communicate vulnerability and build support for climate change adaptation with policy makers, neighboring landowners and other stakeholders**. One of the strengths of the SLAMM model and associated products such as SLAMMView, is its ability to spatially depict vulnerability to sea level rise and changing habitat across the landscape. Use of maps produced with SLAMM can help in communicating the need for climate change adaptation policy and funding, land acquisition negotiations and educating the public about the impacts of climate change. Defenders encourages the Service to use vulnerability assessment such as SLAMM to communicate vulnerability with stakeholders and the American public.

While we believe these recommendations will improve the information obtained by using SLAMM, the Service should also critically weigh the costs and benefits of completing such labor intensive vulnerability assessments based on the level of detail really needed to make management decisions at each refuge. SLAMM analysis is a time intensive process, and the best practices we outline above may require substantial data collection and add additional cost. Money and time spent on SLAMM analysis could ultimately be used instead to fund management activities and land conservation on the ground. There may be decisions that can be made about the future management of each refuge without the fine-scale information derived from SLAMM. For instance, decisions to target upland areas upslope of existing marshes to allow marsh migration can likely be made based on existing information about sea level rise projections relative to coastal elevations.

We commend the strong commitment of the Service to climate change adaptation and we believe that vulnerability assessments form a core component of planning for and implementation adaptation. We encourage the Service to employ SLAMM and other available tools and approaches to assess vulnerability, but caution that these tools are only a part of a comprehensive approach to assessing vulnerability and planning for climate change adaptation. We continue to believe the Service's Strategic Plan serves as a model for how federal and state natural resources agencies should approach the formidable challenge of global climate change and its impact wildlife and natural resources and we look forward to working closely with the Service as it moves forward to implement the Strategic Plan.

Sincerely,

Noah Matson

Noah Matson
Vice President for Climate Change and Natural Resources Adaptation