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AN AGENDA FOR RESEARCH ON THE ECOLOGY, EVOLUTION, AND CONSERVATION OF TIDAL-MARSH VERTEBRATES

THE SYMPOSIUM CONTRIBUTORS

In this volume, we have taken a major step toward a more holistic view of the ecology, evolution, and conservation of tidal-marsh vertebrates. We provide strong evidence that numerous global issues of environmental and conservation concern face tidal-marsh biota, and that tidal marshes are a model system used in studying fundamental issues of biogeography and evolutionary biology. Future investigations into the ecology of tidal-marsh vertebrates will require a more comprehensive and comparative approach than has been employed. For beginning investigators, in particular, who are interested in doing pioneering work based on comparison and synthesis of processes among regions, the tidal-marsh system offers considerable promise. In an effort to further catalyze this research, we offer the following menu of activities, themes, and questions that provide a framework for progress in the study of tidal-marsh vertebrates:

1. A uniform global inventory of the distribution of tidal marshes, categorized by salinity and vegetation type. Such an inventory needs to be made available on a web site for tidal-marsh researchers throughout the world.
2. An increase of research on the Quaternary (Pleistocene, Holocene, and very recent) history of tidal marshes, focusing on their extent, distribution, and floral composition through time. Every effort should be made to apply the research broadly and with an explicitly geographic comparative component. Results of such a comprehensive historical survey could be presented along with the current tidal-marsh distribution, in a web atlas that is periodically revised and updated.
3. Standardized inventory and monitoring data for tidal-marsh vertebrates. This effort can begin by application of the tidal-marsh monitoring protocols for birds developed in Conway and Droege (*this volume*), and expanded to small mammals and reptiles and conducted in representative tidal marshes along all coastlines.
4. More comparative work focused on tidal-marsh taxa (vertebrate, invertebrate, and plant) living along different coastlines. Most current work, as seen in this volume, has been concentrated in North America. Globally comparative research would provide better tests for functional and adaptive hypotheses that were originally developed from studies focused on individual marsh systems.
5. More work integrating the role of physiological, trophic, life-history, and social factors in shaping adaptations to tidal marsh environments. Along with this, we need to develop models for the factors that drive and inhibit divergence of tidal-marsh populations from their inland source and sister populations.
6. More fine-scale genetic and morphological studies from less well known coastlines to determine if the differentiation described for North American taxa is mirrored elsewhere.
7. Continued inventory work on basic distributional data on which vertebrate species occur in tidal marshes and how dependent they are on this habitat. Such data may exist already in the published or un-reviewed literature, but they need to be compiled into usable and accessible formats. In cases where published data are lacking, faunal inventories should be initiated.
8. More work on tidal-marsh trophic-resource relationships throughout the world and how these compare to freshwater systems. This would include more information on the diet of terrestrial vertebrates, quantitative monitoring of terrestrial marsh arthropods, marine invertebrates, seeds, fruits, and other edible vegetation, and experimental analysis of the relationship between vertebrates and their food base.
9. Empirical monitoring and modeling approaches to determine how the distribution of different species will respond to regional habitat loss and changes in the floristic composition and vegetative structure of tidal marshes resulting from sea-level rise. We have seen how the reproductive success of tidal-marsh birds (and probably mammals and reptiles as well) is delicately balanced

between avoiding predation and flood loss. We need to develop predictive models for how changes in mean sea level and changes in the frequency of severe storms might influence flooding regimes, and how this will effect the survival and reproductive output of tidal-marsh vertebrates. Sea-level rise and changes in the hydrology of coastal estuaries also portend changes in salinity; how this might affect less specialized saltmarsh species would be an interesting question of applied physiological ecology.

10. Research focused on the facility with which tidal-marsh species adapt to radical changes in dominant vegetation caused by the advent of invasive species. Tidal marshes appear to be particularly prone to invasions by dominant species of plants. Given the low diversity of the tidal-marsh flora, such invasions have a major impact on the structure and function of marsh ecosystems. Similar studies should be conducted also on the impact of invasive fauna (such as rats, mice, nutrias, and opossums). Finally, more work needs to assess the impact of invasive mollusks and other non-native invertebrates on tidal-marsh systems.
11. More research on the effect of pollution and toxic chemicals on vertebrates in the marsh systems, especially those that are threatened and endangered. Tidal marshes are particularly vulnerable to the inputs of pollutants, nutrients, and wastes from agricultural and industrial development applied within the watersheds that support them, as well as chemical spills and contaminants introduced from the coastal marine waters. Furthermore, tidal marshes are often the recipient of broad-spectrum pesticides for mosquito control applied repeatedly throughout the season, a practice that may be exacerbated by the perception that the habitat is a source of vectors for emerging diseases, such as West Nile virus.
12. Greater integration with efforts to maintain populations of threatened and endangered species associated with non-tidal-marsh habitats in the same estuarine systems.

In spite of the aforementioned holes in our scientific understanding of vertebrates in tidal-marsh ecosystems, coastal-wetland ecosystems have hosted considerable research efforts. One of the problems we must overcome is the tendency for the balkanization of past research not only by discipline, but also by focal taxa and coastline and estuary of interest. We therefore recommend the formation of an international congress focused on biological conservation and ecological research on tidal-marsh wildlife, with the explicit goal of increasing the interchange of information between researchers on different continents and coastlines. We would encourage the program to be broadly interdisciplinary, covering areas that we as ornithologists and wildlife biologists need to understand in order to make sense of the ecology, evolution, and conservation of tidal-marsh vertebrates. We believe that, coupled with a renewed research agenda, we can go forward towards catalyzing a global approach to tidal-marsh biodiversity.

Finally, researchers of tidal-marsh systems are often motivated by their desire to positively influence the conservation of this fascinating ecosystem. Regular meetings of scientists and policy makers could advance conservation of tidal marshes from the different coastal areas to share and evaluate approaches that are working to conserve and restore coastal wetlands. At this time, tidal-marsh conservation is not the priority focus of any one organization approaching the issue from a global perspective. The development of such an organization or network focused on tidal marshes from a global perspective would be a major step forward in meeting this goal of drawing attention to the heretofore under recognized tidal-marsh global resources. We cannot afford to do otherwise.