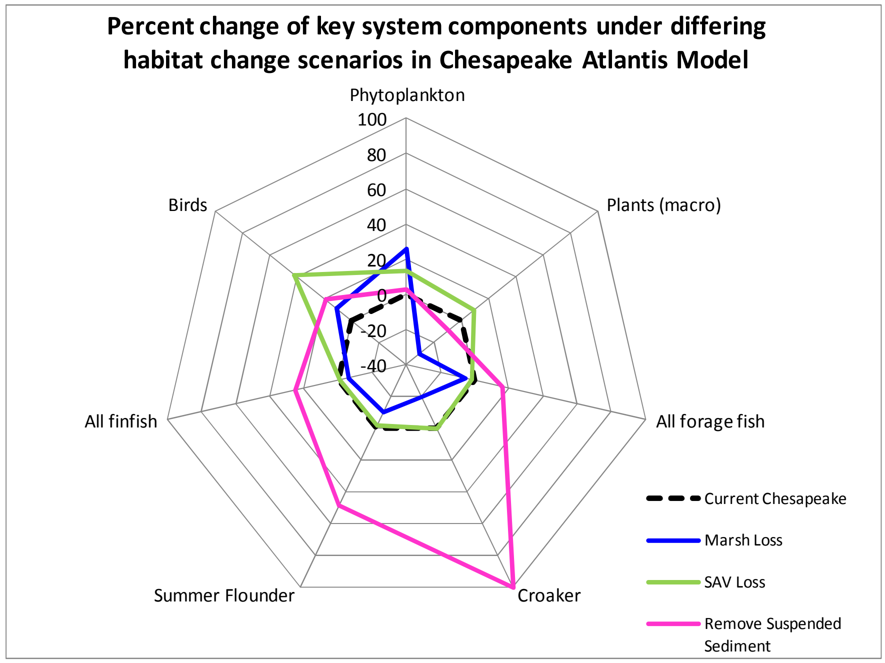
Influence of habitat change on the biology and ecology of the Chesapeake system

The Chesapeake Atlantis Model

Currently, there are multiple, ongoing and large-scale system changes taking place in the Chesapeake Bay system. Some of these changes are a consequence of climate change, while others are mandated by current regulations to improve Bay water quality. One consequence of climate change is more frequent, large storm events like type A and B hurricanes (Pore 1965) which will have specific effects on the Chesapeake system. One short term effect (with long term, and far-reaching consequences) is the projected loss of current, preferred marsh habitat in the system. Simulations suggest such marsh loss may produce a synergistic loss of submerged aquatic vegetation (SAV). Simultaneously, there have been ongoing, efforts coordinated by EPA to decrease both nitrogen and sediment loads to the system. Once likely physical changes to the system have been simulated by hydrodynamicists, the effect of these changes has to be understood in terms of the biological and ecological changes that are likely to result in the system. For this study, this is accomplished with an ecosystem modeling approach called "Atlantis."

The code for the model was developed by scientists at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia {Fulton, 2004 #1864;Fulton, 2004 #1866}. Atlantis integrates physical, chemical, ecological, and fisheries dynamics in a spatially-explicit, three dimensional model structure. The approach has been identified as the best ecosystem model in use by the U.N. Food and Agriculture Organization {Plagányi, 2007 #1828}, and has been used to advise decision-making for nearly a decade in Australia and it has been applied in multiple applications in the US as well (reviewed by Fulton et al., 2011).

(continued in sidebar, next page)

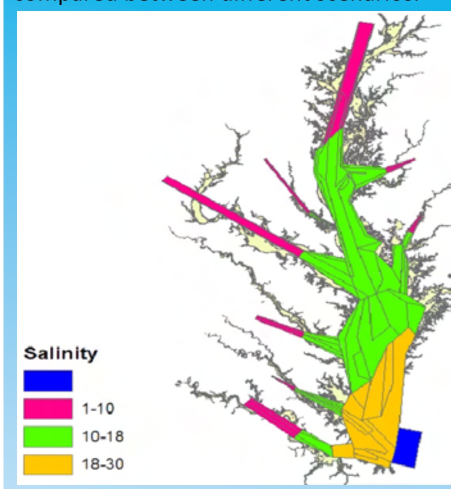


In this comparison of three different scenarios of habitat change, the productivity effects that result from the system changes are compared to a status quo scenario based on conditions of the current Chesapeake system (dashed line). Plotted lines are median values for 20-30 years of predicted ecosystem dynamics, where: (1) 50 percent of marsh (biomass and area covered) is lost (blue), (2) 50 percent of submerged aquatic vegetation is lost (green), and (3) suspended solids are decreased (pink).

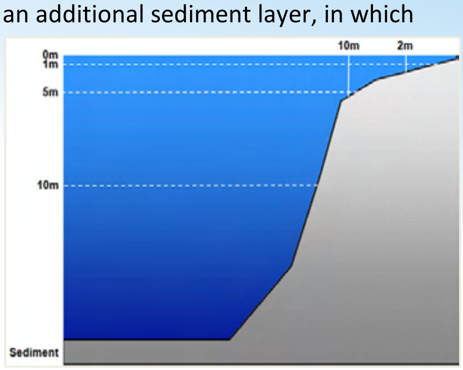
When marsh is lost, most fish groups decrease substantially, but forage fish decrease only slightly from status quo; however, submerged aquatic vegetation (SAV) production *also* decreases by 30 percent, while phytoplankton and birds both increase. In contrast, when the system suffers a loss of SAV, relatively little difference is seen in fish groups, while all other plants increase and birds increase by more than 40%. When suspended sediment loads are decreased, bird production again increases strongly, but under these conditions, *all* fish also become much more productive, resulting in a net loss of both SAV and marsh when compared to status quo conditions. (continued)

Influence of habitat change on the biology and ecology of the Chesapeake system

One of the greatest strengths of the Atlantis modeling approach is that it provides resource managers with information of the trade-offs predicted to result from different system changes (or management actions). In the plot above, all biological groups are modeled simultaneously, in nitrogen units, consequently, all axes are relative to one another, and trade-offs can easily be compared between different scenarios.



The Chesapeake Atlantis Model (CAM) is structured by salinity, depth, and bottom type. The 97 spatial polygons of the model are also divided into four depth layers and an additional sediment layer, in which



both anaerobic and aerobic bacteria live and cycle nutrients, and which allows both flora and fauna to live in and on (flora also contribute to nutrient cycling), and where bioturbators burrow and vertebrates forage. There are 56 active biological groups that grow, reproduce, and interact in CAM.

Though starting conditions of all scenarios are identical (except for the specified change from status quo), the biogeophysical Atlantis model predicts the differences between these potential system changes are substantial, and each realization will have unique societal impacts as well. This approach provides the needed connectivity between models that predict the physical effects of climate change to, in turn, inform socioeconomic models, providing resource managers with a full suite of societal trade-offs to consider in their decision-making.

Selected References

Fulton, E.A., J.S. Link, I.C. Kaplan, M. Savina-Rolland, P. Johnson, C. Ainsworth, P. Horne, R. Gorton, R.J. Gamble, A.D.M. Smith, and D.C. Smith. 2011. Lessons in modelling and management of marine ecosystems: the Atlantis experience. Fish and Fisheries 12(2):171-188.

Fulton, E.A., J.S. Parslow, A.D.M. Smith, and C.R. Johnson. 2004a. Biogeochemical marine ecosystem models II: the effect of physiological detail on model performance. Ecological Modelling 173(4):371-406.

Fulton, E.A., A.D.M. Smith, and C.R. Johnson. 2004b. Biogeochemical marine ecosystem models I: IGBEM—a model of marine bay ecosystems. Ecological Modelling 174(3):267-307.

Pore N.A., 1965. Chesapeake Science 6 (3), 172–182. Shen, J., Gong, W. 2009. Journal of Marine Systems,75, 198-215.

Plagányi, É.E. 2007. Models for an ecosystem approach to fisheries. Food and Agriculture and Organization of the United Nations, Rome, 108 p.