Vanishing and Emerging Ecosystems of Coastal Virginia: Climate Change Impacts and Adaptation

WILLIAM & MARY
VIMS
Virginia Institute of Marine Science
Initiative for Coastal Climate Change Research

Ecosystems are Changing Fundamentally

Human activities worldwide are transforming natural ecosystems. Certain ecosystem types are being lost, while completely new ones are emerging in their place.[1,2] "Emerging" or "novel" ecosystems have two key characteristics:[2] (1) they contain *new combinations of species*, which can change how the ecosystem functions, and (2) they *result from human activities* but nevertheless can persist without continued intervention by humans. Novel ecosystems often differ considerably from either wild or intensively managed systems, for example in fishery production, shoreline erosion control, and maintenance of water quality.

Climate Change in Virginia's Chesapeake Bay Region

On a global scale, a principal cause of the habitat alteration producing novel ecosystems is climate change,[3] which is expected to continue under all realistic scenarios of future population trends and economic activity. For example, in the Chesapeake Bay region, annual average temperatures of surface waters have increased by 0.8-1.1°C (1.4–2.0°F) in the last 60 years,[4] and the beginning of spring has advanced by about three weeks since 1960 (Figure 1).[5]

Virginia's coastal ecosystems are especially sensitive to such climate-induced ecosystem change because they occupy a unique biogeographic boundary between southern and northern marine regions; thus, many species are already near their range limits. Recruitment of commercially important fishes, acreage of underwater grasses, severity of fish and shellfish diseases, and strength of jellyfish blooms in Chesapeake Bay are all sensitive to modest changes in climate and their impacts on complex interactions among species.

Climate Change Effects on Chesapeake Bay Ecosystems

During earth's history, climate change has often shuffled species abundance and distribution to produce novel ecosystem types. But these processes are happening far more rapidly under

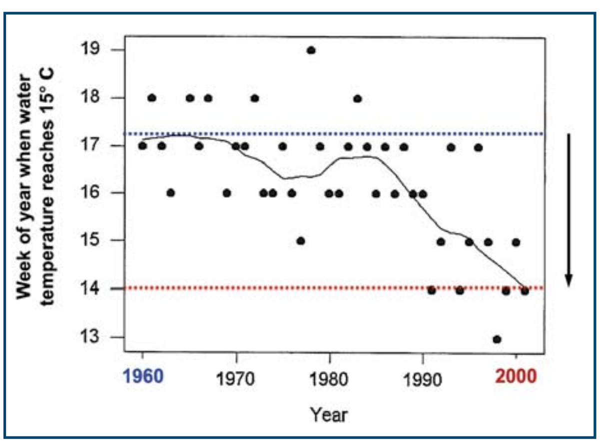


Figure 1. Spring now comes earlier to the Chesapeake by more than 3 weeks compared to 40 years ago, as shown by the first water temperature of the year above 15°C (59°F). From Ref 5.

Human impacts that produce novel ecosystems:

- Extinction or severe decline of native species
- Invasion of non-native species
- Pollution and habitat alteration
- Habitat loss and fragmentation

Experiments reveal how a changing environment affects fish populations and the base of the food web that supports them.

Although inconspicuous, small animals in seagrass beds provide essential food for commercially and recreationally important fish.

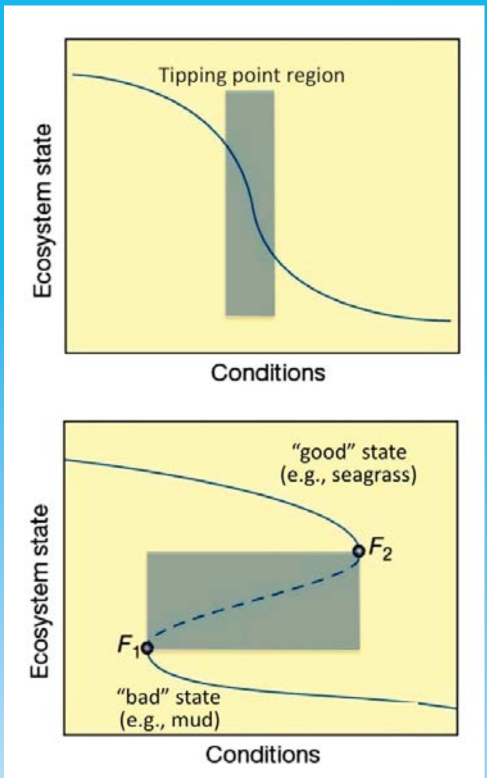


Figure 2. Gradual changes in the environment can shift an ecosystem rapidly (top) between alternate states ("good" to "bad") that are resistant to change (bottom). After ref 6.

Figure 3. Eelgrass, which forms an important nursery habitat for fish and shellfish, was lost suddenly in many areas of Chesapeake Bay during the extremely high water temperatures that hit the East Coast in August 2005.

human influence, and are interacting with pollution and habitat loss, so species have little time to adapt to the new conditions.

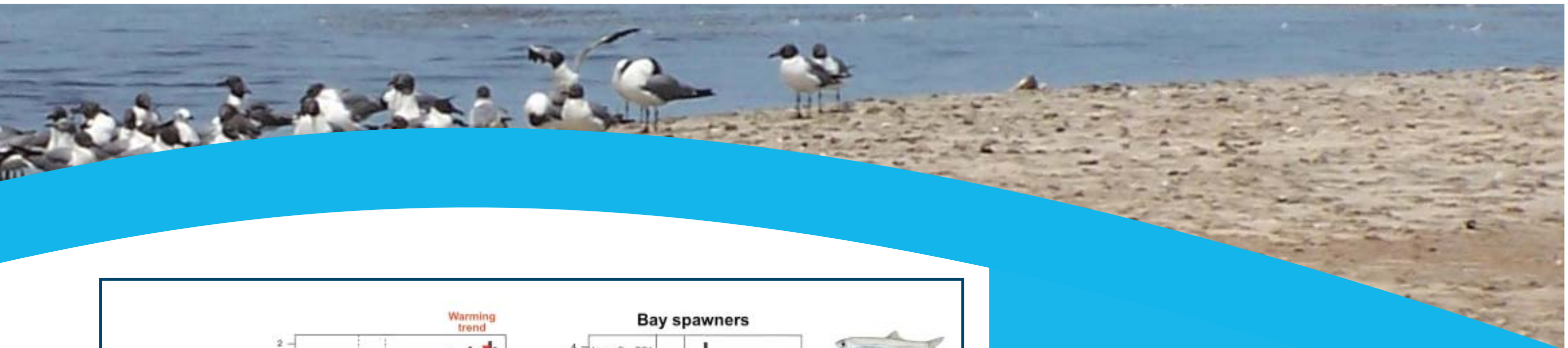
Gradual changes in environmental conditions such as water temperature do not necessarily produce gradual responses in the ecosystem (Figure 2)— a small change can cross a "tipping point", producing a sudden or large shift in the system. Such non-linear responses to a stressor can occur either because (1) the change pushes a key species over a threshold in its physiological tolerances, or (2) the stressor affects species differently, and disrupts the complex interactions among them.

Such complex relationships in ecosystems mean that a change is often difficult to reverse once it has occurred. A classic example involves submerged vegetation (Figure 2). Loss of seagrasses due to nutrient pollution destabilizes the underlying sediment and allows it to be mixed up into the water column. This suspended sediment in turn reduces light and interferes with re-establishment of grasses, even if nutrient loading is reduced well below its original level.[6]

The life cycles of all animals and plants are closely tied to temperature, so changing regional climate can compound other stresses to produce widespread and potentially irreversible effects on coastal ecosystems, and on the benefits they provide to human society, as summarized below.

Range Shifts and Loss of Critical Species. Globally, many marine species have shifted their distributions poleward as water temperatures have increased in recent decades. Of particular concern are effects on key species that support entire ecosystems. One such species is eelgrass (*Zostera marina*, Figure 3), an important nursery habitat for many fishes and shellfish. Eelgrass in the Bay is highly vulnerable to climate warming both because it is near the southern limit of its distribution, and because it's already under threat from poor water quality. In summer 2005, eelgrass disappeared from much of the Bay following record high water temperatures. Although the grass rebounded from buried seeds and rhizomes in many areas, it has not returned to others, resulting in continuing loss of nursery area. Other cold-water species that could be lost from the Chesapeake Bay include winter flounder and soft-shell clams.[7] Declines are also likely for economically important blue crab, menhaden, and rockfish, due to deterioration of habitat quality and increasing diseases as temperatures rise.

Climate and Fisheries. Over the last 50 years, the climate of the Chesapeake Bay region often shifted abruptly between different "regimes" lasting years to a decade. Conditions were cool and dry in the 1960s, shifting in the early 1970s to a warm phase lasting several years, then to a more variable warming trend through much of the last 30 years.[5] Recruitment of juvenile fishes in Chesapeake Bay is highly sensitive to this decade-scale climate variation (Figure 4). For example, springtime river spawners like



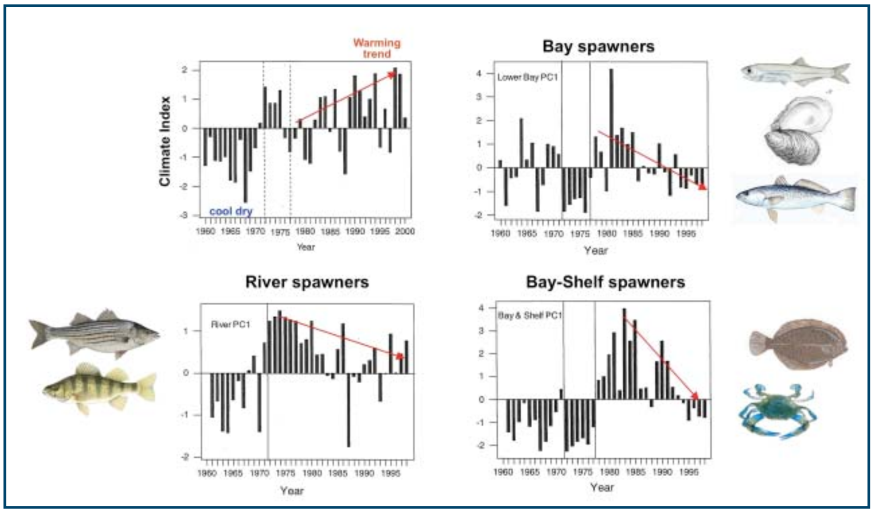


Figure 4. Changing climate regimes affect fish recruitment in Chesapeake Bay. A Climate Index based on average annual temperature, streamflow (precipitation), and wind stress shows sudden shifts between decade-scale climate "regimes" (top left). Fishes are highly sensitive to these climate shifts, and respond differently depending on their juvenile habitat requirements. After ref 5.

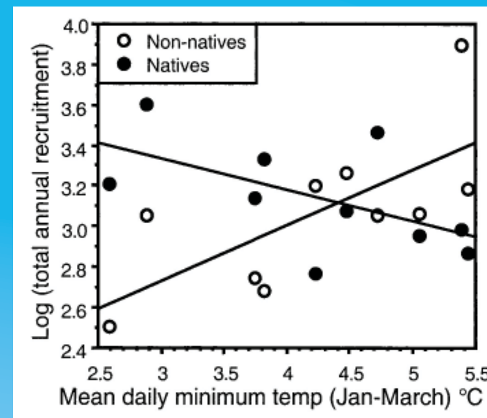


Figure 5. In New England, warming waters facilitated alien invasions, favoring non-native species of fouling invertebrates at the expense of native species. From ref 9.

striped bass recruited very well after the 1973 regime shift. In contrast, summer Bay spawners like oysters and weakfish showed poor recruitment at that time. These abrupt shifts offer a preview of potentially rapid future changes in Chesapeake Bay's ecosystems due to climate change.

Climate-mediated Invasions. The Chesapeake Bay has become home to at least 200 alien species during the four centuries since European colonization.[8] These invaders include the predatory Rapa whelk and, importantly, the oyster disease MSX *(Haplosporidium nelsoni)*. Invasion by non-native species (such as zebra mussels, which have recently invaded the Susquehanna River system that flows into the northern Bay) can have major impacts on ecosystems and is often facilitated by habitat disturbance or stress. Changing climate is one key stress (Figure 5). More information is available from the National Exotic Marine and Estuarine Species Information System (http://invasions.si.edu/nemesis/).

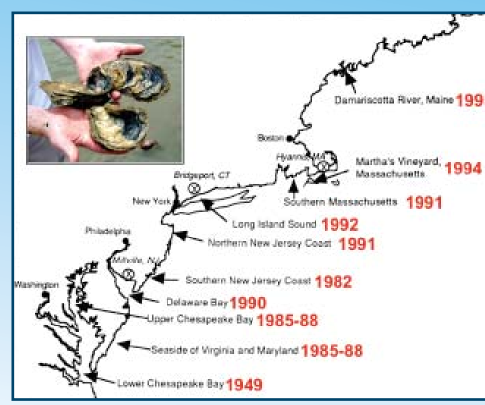


Figure 6. The oyster disease Dermo spread rapidly up the East Coast following a series of warm winters in the mid-1980s. Dates of first report shown for each site. After ref 11.

Altered Food-web Interactions. Changes in seasonal timing of plant and animal life events and invasion by non-native species can disrupt the seasonal match between animals and their food, with important consequences for society. For example, in Chesapeake Bay jellyfish are now "blooming" considerably earlier in the year than they did in the cooler 1960s. A potentially important consequence is that the jellies compete for food with fish larvae, potentially interfering with fish recruitment. Such changes in predator-prey interactions are common consequences of climate warming,[10] and would exacerbate the chronic problem of eutrophication in Chesapeake Bay.

Stripers from all along the East Coast use Chesapeake Bay as a nursery. They could face serious declines if eelgrass habitat in the Bay succumbs to warming.

Altered Disease Dynamics. The decline of Virginia oysters has been aggravated by diseases since the 1950s. Dermo *(Perkinsus marinus)* proliferates at high water temperatures and high salinities. In Delaware Bay, Dermo epidemics followed extended



periods of warm winter weather, and in the Chesapeake, outbreaks have occurred after droughts allowed salty water to penetrate up the tributaries. These trends in time are also reflected in the northward spread of Dermo with warming (Figure 6, previous page). Now the genie is out of the bottle, so to speak. Small changes in climate can strongly affect interactions between species, with important economic consequences.

Potential Human Responses to Coastal Ecosystem Change

Climate change is likely to exacerbate ongoing transformation of Chesapeake Bay into a novel ecosystem in which native habitat providers such as eelgrass and oysters have crashed, fish and shellfish that depend on them have declined, and alien species dominate. The simpler, less diverse ecosystems that result are less stable and often less valuable, hospitable, and desirable for humans as food and material resources, as well as places to live and for recreation.

Resource management policy traditionally assumed that if we leave things alone, they will stay more or less the same. In a warming world, that assumption is no longer tenable. Climate change is affecting our natural resources now. Effective management recognizes that change in ecosystems is inevitable, yet often unpredictable.

Dealing with continued change requires incorporating adaptive management into policy:

- Rigorously monitoring environment and living resources
- Systematically analyzing and learning from successes and failures
- Revising policy accordingly

References Cited

1 Ellis, E., and Ramankutty, N. 2008. Putting people in the map: Anthropogenic biomes of the world. *Frontiers in Ecology and the Environment.* In press.

2 Hobbs, R.J. et al. 2006. Novel ecosystems: theoretical and management aspects of the new ecological world order. *Global Ecology and Biogeography* 15:1-7.

3 IPCC 2007. Climate change 2007: Synthesis report. Summary for policymakers. Institution. Intergovernmental Panel on Climate Change (IPCC). Valencia, Spain.

4 Preston, B.L. 2004. Observed winter warming of the Chesapeake Bay estuary (1949-2002): Implications for ecosystem management. *Environmental Management* 34:125-139.

5 Austin, H.M. 2002. Decadal oscillations and regime shifts, a characterization of the Chesapeake Bay marine climate. American Fisheries Society Symposium 32:155-170.

6 Scheffer, M. et al. 2001. Catastrophic shifts in ecosystems. *Nature* 413:591-596.

7 Glick, P., Staudt, A., and Inkley, D., 2007. The Chesapeake Bay and Global Warming: A Paradise Lost for Hunters, Anglers, and Outdoor Enthusiasts? National Wildlife Federation. Reston, Virginia.

8 Ruiz, G.M., Fofonoff, P., Hines, A.H., and Grosholz, E.D. 1999. Non-indigenous species as stressors in estuarine and marine communities: Assessing invasion impacts and interactions. *Limnology and Oceanography* 44:950-972.

9 Stachowicz, J.J., Fried, H., Osman, R.W., and Whitlatch, R.B. 2002. Biodiversity, invasion resistance, and marine ecosystem function: Reconciling pattern and process. *Ecology* 83:2575-2590.

10 Visser, M.E., and Both, C. 2005. Shifts in phenology due to global climate change: the need for a yardstick. *Proceedings of the Royal Society B-Biological Sciences* 272.

11 Ford, S.E. 1996. Range extension by the oyster parasite *Perkinsus marinus* into the northeastern United States: response to climate change? *Journal of Shellfish Research* 15:45-56.

WILLIAM & MARY VIMS
VIRGINIA INSTITUTE OF MARINE SCIENCE
INITIATIVE FOR COASTAL CLIMATE CHANGE RESEARCH

For further information, visit
www.virginiaclimatechange.vims.edu
or contact us at
email: climatechange@vims.edu
Phone: (804) 684-7000

Prepared By
J. Emmett Duffy

Virginia Institute of Marine Science

Printed on recycled paper.