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...
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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.

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. 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. Recruitment of juvenile fishes in Chesapeake Bay is highly sensitive to this decade-scale climate variation (Figure 4). For example, springtime river spawners like...
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/).

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.

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