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Charles S. Colgan
*University of Southern Maine*, ccolgan@miis.edu

Samuel B. Merrill
*University of Southern Maine*



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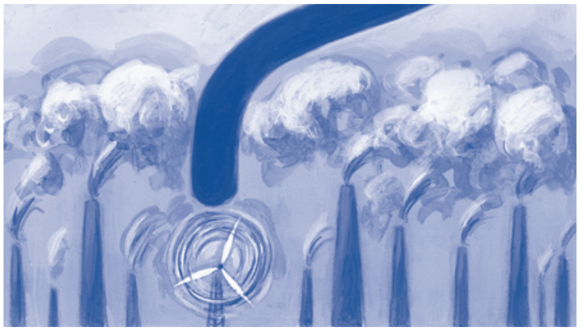


# The Effects of Climate Change on Economic Activity in Maine:

## *Coastal York County Case Study*

by Charles S. Colgan

Samuel B. Merrill

*Climate change can have significant ramifications for Maine's economy. If short-term projections for the next century are accurate, at minimum sea level rise will become increasingly noticeable in association with more severe and destructive coastal storms. Charles Colgan and Samuel Merrill evaluate risk estimates by presenting a case study of the projected consequences of sea level rise and coastal storm damage on the economy of the state's most vulnerable area, York County's coastal communities.*

## INTRODUCTION

Discussions of the economic effects of climate change are necessary, difficult, and controversial. They are necessary because economic effects are the way in which most people will most fully experience the realities of climate change. Thus, developing and sharing an understanding of these effects will motivate people to act. They are difficult because to all of the uncertainties surrounding the extent and speed of climate change must be added the uncertainties of the economist trying to translate unprecedented environmental change to the complex interactions of supply and demand. They are controversial because the economist is constrained to point out that there are likely to be positive aspects of climate change along with negative aspects, thus appearing to undercut the case for actions to limit climate change.

To begin to understand the dimensions of potential economic changes in Maine from climate change, it is necessary to examine the interaction of four different effects: changed outputs; changed opportunities; changed costs; and changed perceptions of time and risk. "Changed outputs" refers to changes in what is produced in Maine, particularly the goods and services currently produced based on natural resource inputs. "Changed opportunities" reflects the fact that the efforts to adapt to and mitigate climate change will create new opportunities for economic activities in Maine. There is already much discussion in the literature on climate change in Maine that covers these two aspects of the economics of climate change, so this paper will offer only a brief synopsis of what may happen under these headings.

"Changed costs" is a more subtle effect of climate change that will sometimes be difficult to discern and sometimes all too obvious. "Changed perceptions of time and risk" refers to the fundamental economic problem of how to assess the costs and benefits of different actions to mitigate climate change and to adapt to it. These two aspects of climate change represent the more difficult and complex economic effects and ones that have been little discussed in the larger conversations about climate change. This paper will examine these aspects in greater detail, using the analysis of one specific effect of climate change, sea level rise, in one area of Maine's coast, York County, to illustrate how the potential effects on costs, risks, and time need to be better understood.

> All discussions of climate change must start with the acknowledgment of the uncertainty surrounding the pace and degree of climate change itself.

All discussions of climate change must start with acknowledgment of the uncertainty surrounding the pace and degree of climate change itself. This uncertainty exists because many of the fundamental processes of climate change are still imperfectly measured and because a critical factor is the extent to which mitigation efforts are in fact undertaken and how effective they are. These uncertainties are reflected in the work of the organization that has become the reference point for many discussions of climate change, the Intergovernmental Panel on Climate Change (IPCC).

The IPCC suggests global surface temperatures could rise between 0.5 and four degrees Celsius (one to seven degrees Fahrenheit [F]) depending on which level of continued emissions occurs (IPCC 2007). But this will not be even across the world. In the U.S. Northeast, the Union of Concerned Scientists (UCS) estimates warming already underway will push temperatures up by 2.5 to 4 degrees (F) in winter and 1.5 to 3.5 (F) degrees in summer through about 2050. If by that time greenhouse gas emissions are not under significant control, the Northeast will see temperatures rise between 8 and 12 degrees (F) in the winter and six and 14 degrees (F) in the summer under the high IPCC scenario (Frumhoff et al. 2007).

For Maine, this means that average winter temperatures are already set to increase over the next 40 years from 24.7 degrees at the Portland Jetport to 26.5 to 28 degrees and could increase to an average of 32.7 to 36.7 degrees. Average summer temperatures at Portland are likely to go up from an average of 66.1 degrees to 67.6 to 69.6 degrees and could climb to an average between 72 and 80 degrees. In northern Maine, Caribou will likely see average winter temperatures climb from 13 to 15.5 degrees to 17 degrees, eventually rising to 21 to 25 degrees. Average summer temperatures in Caribou will rise from 63.3 to between 69 and 77 degrees.

These changes represent something close to the levels of change that are used in most climate change planning scenarios today. However, there are concerns that carbon dioxide ($CO_2$) emissions are occurring at a much greater rate than the IPCC projected (McKibben 2007), or that people have greatly underestimated the ecological consequences of the upper range of the IPCC scenarios (Zenghelis 2008). There is also concern that some of the effects of climate change may occur more rapidly than is commonly expected. Recent analysis of ice data from Greenland suggests sea level rise could occur very quickly (Stefensen et al. 2008).

> Maine already has significant economic activity in its energy and environment clusters, including a significant environmental engineering industry.

These scenarios have to be considered real possibilities, but they are difficult to interpret in terms of their probabilities of actually occurring. The discussion of climate change in this paper will thus be guided by the IPCC-UCS scenarios of gradual climate change over this century, with the major differences between low and high outcomes being the level of human actions to reduce greenhouse gas emissions.

## CHANGING OUTPUTS

Sustained warmer temperatures will significantly affect terrestrial, aquatic, and marine environments, leading to a number of changes in commercially important living resources. The result will be warmer ocean waters in which such critically important species as cod and lobster will no longer be found. Cold-water sport fisheries such as trout and salmon will also be lost. In the forest, the spruce and fir resource, which has been the bedrock of the pulp and paper and lumber industries, will gradually decline, to be replaced by a much more hardwood-dominated forest of the type found in Pennsylvania.

These changes in the availability of commercially important resources will alter the size and scope of Maine's natural resource industries. Maine without a lobster industry would surely be a different place. Many, perhaps most of the pulp and paper mills would close or significantly downsize, and there would be a much smaller lumber industry. But the changes will be gradual and offset by other changes in natural resource industries. Winter recreation will be more limited than it is today, but Maine will be one of the only places in the Northeast with any winter recreation. Skiing and snowmobiling will disappear entirely from southern New England and the Mid-Atlantic states. Northern and western Maine along with the northern parts of New Hampshire and Vermont will be the only places with sustained snow cover in many years. Warmer temperatures may extend seasons for such recreational activities as cruise ships and boating, and the Maine coast will still be an attractive place to come in summer. Average temperatures may rise into the upper 70s, but this will still be preferable to the average temperatures in the 90s that will come to characterize most of the neighboring regions to the south.

Longer growing seasons will permit farmers to expand the range of crops and animals in Maine agriculture. Lobster will likely disappear as a commercial species, but other marine species will gradually populate the Gulf of Maine and keep at least a small fishing industry in Maine. Even with warmer temperatures, it is likely that Maine will continue to be characterized by forest products, fishing, tourism, and agriculture well into the future, but each of these industries will likely be much different from today. Smaller forest products and fishing industries may be offset in part by the possibility of more robust agriculture and tourism.

The need to mitigate and adapt to climate change also presents Maine with opportunities to expand output of a large variety of goods and services. The most immediately apparent of these is the significant investment already underway and planned in alternative energy generation, particularly wind power. Significant industrial-scale wind power projects are operating or are under construction in western and northern Maine (see Parker, this issue). Even larger projects are contemplated for Aroostook County and offshore, which will need to be accompanied by large upgrades in electric transmission facilities. Proposals and research are also being directed at large-scale offshore wind installations. If fully realized, the development of wind power generation could be a major industry in Maine for the next decade. In addition, Maine's forests may no longer produce nearly as much lumber or pulp, but could be the source of biofuels such as cellulosic ethanol. Forests may also acquire a significant economic value for carbon sequestration.

Other opportunities exist in developing and marketing the expertise to deal with climate change. Maine already has significant economic activity in its energy and environment clusters, including a significant environmental engineering industry. In addition, the worldwide demand for environmentally and energy-efficient products is likely to grow significantly in response to climate change issues, creating significant opportunities for Maine firms that can tap these markets (Colgan, Merrill and Rubin 2008). Maine's ability to tap these markets is by no means assured, but the opportunities are there to be seized.

In sum, climate change will bring about significant changes in what Maine produces. Some of these changes will be calamitous for the communities that depend on resources likely to undergo drastic declines from warmer environments. The many coastal communities almost entirely dependent on lobster fishing are at the top of this list, but so are many of the communities in the forested zones that have already seen major declines due to competitive and macroeconomic pressures. But warmer temperatures will bring at least some opportunities to other traditional natural resource industries and the global effort to sustain economies without further rises in greenhouse gases will open significant economic development opportunities for many sectors and industries in Maine.

## CHANGING COSTS

The impacts of climate change on the costs of doing business in Maine are less visible than changes in natural resources. Unlike the changes in the resource industries, which will occur in Maine independent of events elsewhere, the key to determining the extent of the cost effects will be how change in Maine takes place relative to changes elsewhere. Since climate change is a global problem, it will affect costs everywhere. The key question is whether Maine will be disproportionately negatively affected.

Some changes in costs, like those in the natural resource industries, are fairly obvious. For example, Maine's warmer winters will reduce the costs of heating, but Maine's hotter summers will increase the costs of cooling. By and large, warmer winters will produce no great cost strains on Maine (Caribou will probably not mind having Portland's current winters), but Maine is ill suited to warmer summers. Air conditioning in residences and public buildings and in many commercial buildings is not as common as in regions to the south. With summer temperatures extending into May and October, the simple question of how Maine's public schools will adapt will become a serious issue.

Other changes in costs are not obvious. Water may become more scarce and costly in parts of Maine and will become a direct threat to economic activity in other parts. While climate change means gradually rising temperatures, most people will experience climate change as an increase in the frequency and severity of weather extremes, ranging from drought to floods. Maine's relatively moderate climate produces what is widely perceived to be a "water-rich" environment, but this will likely change as precipitation patterns become more variable and unpredictable.

Extended periods of drought could drive up water prices, or require more expensive investments in infrastructure to maintain water quality and quantity. At the other extreme, periods of high precipitation will require greater investments in infrastructure to manage flooding. Recent high-volume rain storms have already shown an alarming deficiency in the size of culverts needed to protect roads, and Maine is facing significant issues and rising costs in managing stormwater with existing water systems.

Another set of changing costs will emerge from the responses designed to mitigate climate change. The two most significant economic strategies proposed for mitigation are cap-and-trade systems and carbon taxes. Maine is already participating in a cap-and-trade system through the Regional Greenhouse Gas Initiative (RGGI) (see Bogdonoff, this issue). This approach will progressively ratchet down emissions, with those electric utilities able to do so most efficiently gaining an economic advantage. RGGI is just being implemented, so its effects on different states are still unclear. Federal cap-and-trade systems may be created within the next two years. Their effects are even more uncertain, particularly how a national system would interact with a regional one.

A carbon tax, which many economists believe is the most effective strategy for mitigating climate changing emissions, is more uncertain as a policy measure. If one were enacted, Maine's heavy dependence on fossil fuels would make the state vulnerable to disproportionate increases in costs, at least in the short run. However, in the long run, the state's response to a carbon tax could offset these cost disadvantages.

## ESTIMATING RISK

Like so much of the rest of climate change-related predictions, these observations about changing costs are highly uncertain. This is not only to say that we know little about the exact extent of the change in costs or of the timing, but that at this stage it is difficult to assign a risk estimate to these changes. A risk estimate implies that a measured probability of occurrence can be made and that that probability of occurrence can be associated with an estimate of vulnerability. Such risk estimates are common in short-term situations; the National Weather Service issues flood or coastal flood watches and warnings based on relatively precise estimates of the probability, size, and location of precipitation events. Longer-term versions of such estimates are more difficult.

The translation of uncertainty into risk is important because a possible danger that has a probability, even a range of probabilities, associated with it can be fit into decision making more easily than one that cannot be described in any quantitative way. Risk estimates, however imprecise, are thus a critical way in which the dangers associated with climate change can be communicated.

Risk estimates are the product of two separate calculations: the probability that an event will occur and the extent of vulnerability to the consequences of that event. One of the areas where it is possible to develop such risk estimates is in coastal areas where the effects of sea level rise, a major element in climate change, will be a particularly critical issue.

The IPCC projects that if simply the historic rates of global sea level rise from 1961 to 2003 were to continue, sea levels would rise by 15 centimeters (cm) (six inches) by the end of this century. This is an annual average of .18 millimeters (mm) per year (.007 inches per year). However, from 1993 to 2003, global sea level rise accelerated to a rate of 3.1 mm per year (.12 inches per year). If this trend were carried forward a century, it would result in a sea level rise of 31 cm, or about one foot. These estimates do not take into account any acceleration of sea level rise from additional global climate change (IPCC 2007).

Factoring in climate change requires use of assumptions about the level of greenhouse gas emissions and the consequent changes in temperature. The IPCC low-emissions scenario, which would actually require significant and rapid reductions in the emissions of greenhouse gases, would yield sea level rises of about 30 to 35 cm. In other words, just to stay on course for only an additional one foot rise in sea level would require drastic reductions in greenhouse gases. More plausible greenhouse gas emission scenarios yield sea level rise estimates of between 25 and 58 cm (10 to 23 inches). The IPCC estimates are considered conservative by some. Sea level rise of 61 to 138 cm (2 to 4.5 feet) above 1990 levels has also been projected (Rahmstorf 2006).

In their adaptation of IPCC global scenarios to the effects of sea level rise on the Northeast, the UCS identifies consequences under three general headings: flooding, erosion, and adaptation. Linear projections of sea level rise of the type estimated by the IPCC leave the impression that the effects of sea level rise will be gradual, taking years or decades to be noticed. However, the effects will primarily be experienced in the increased frequency and intensity of storms hitting the coast, a phenomenon that is already being experienced. Rather than a gradual change, sea level rise will become more and more noticeable in association with more frequent and violent weather events (Frumhoff et al. 2007).

Coastal storms causing severe erosion along the Maine and York County coasts are relatively frequent occurrences. Such storms include occasional tropical cyclones (hurricanes) and the much more frequent extra-tropical cyclones in the winter, where the storms are known by the dominant wind directions, either northeasters or southeasters. Such storms were destroying property along the York County coast in the 19th century. Recent events with major damages include two northeasters that hit in the winter of 1978 and were among the most costly natural disasters in Maine's history (Colgan 1979) and the Patriot's Day storm of 2007. The worst coastal storms on record in Maine were hurricanes Carol and Edna, which hit within a two-week period in 1954 (Maine Emergency Management Agency 2007). Certain sections of the York County coast are well known for the damages they routinely suffer from even average winter storms. Camp Ellis, which is the southern end of the Saco Bay beach system, is the best known of these, although the problems at this particular site as with others are greatly exacerbated by man-made interventions.[1]

Sea level rise matters a great deal in determining the destructive potential of coastal storms. The major source of damage from these storms is the combination of storm surge (water pushed toward the shore by the force of wind circulation) and normal astronomical tides. The resulting "storm tide" can result in tide levels as much as three to 3.6 meters (10-12 feet) above normal high tides.[2] Storm tides result in coastal flooding events that can extend significantly inland from the "normal" shoreline. If the time of the surge also coincides with times of maximum onshore winds, the damage from the combination of tide, wind-driven waves, and the wind itself can be catastrophic. This is essentially what happens when hurricanes such as Andrew (1992) or Katrina (2005) hit the south Atlantic and Gulf of Mexico coasts.

Not only will sea level rise increase the amount of water that may be formed into a storm surge, but climate change and rising sea levels will also be associated with a significantly increasing severity of coastal storms. This increase in the frequency of damaging storms arises from sea level increases alone and the resulting increase in damages. It does not take into account increases in the absolute frequency of tropical or extra-tropical cyclones, a subject that climatologists and meteorologists are still debating.

## COASTAL YORK COUNTY CASE STUDY

The development of risk estimates can be illustrated by examining the possible consequences of sea level rise and coastal storm damage on the economies of those communities in Maine likely to be most vulnerable, the coastal communities of York County.

### *The York County Coast and Its Economy*

Nine towns in York County border the ocean. From south to north they are Kittery, York, Ogunquit, Wells, Kennebunk, Kennebunkport, Biddeford, Saco, and Old Orchard Beach. Together with Scarborough and Cape Elizabeth in Cumberland County, these towns form the arcuate ("bow-shaped") embayments section of the Maine coast (Kelley, Kelley and Pilkey 1989). The ~500 linear kilometers (km) (~300 miles) of the shore line in this area are dominated by salt marsh, relatively flat land, and beaches. A series of granitic headlands (for example, Black Point in Scarborough, Moody Point in Wells, and Cape Neddick in York) anchor the ends of the major beach systems.

Not only will sea level rise increase the amount of water that may be formed into a storm surge, but climate change and rising sea levels will also be associated with a significantly increasing severity of coastal storms.

The majority of Maine's 37 km (23 miles) of beach shoreline are found in this region, including the single largest beach system in Maine, the Saco Bay beach system which runs 11 km (seven miles) from Pine Point in Scarborough to Camp Ellis at the mouth of the Saco River in Saco. Other major beach systems

**The SLOSH Model**

The SLOSH model estimates four levels of possible impacts depending on the assumption about the strength of the hurricane based on the Safir-Simpson scale. Only category 1 (minimal hurricanes) to category 4 storms are estimated as there is not known to have been a category 5 (Katrina or Andrew-level intensity) in northern New England, and there is some question as to whether a category 4 storm has ever occurred here.

Historically, New England and Maine are more likely to be affected by the class of intense extra-tropical storms known as north- and southeasters than by tropical cyclones such as tropical storms and hurricanes. Extra-tropical storms are typically somewhat less severe than hurricanes, with sustained winds usually in the gale force to storm force range (35–75 knots), that is, below hurricane force. The SLOSH model thus models weather events that are technically relatively rare in Maine. However, we believe the use of the model is appropriate at least as a first approximation of risks because sea level rise (apart from any intensification of storms that may result from climate change) will increase intensity of extra-tropical storms above historic levels.

in the region include Goose Rocks in Kennebunkport; Gooch's in Kennebunk, the Parsons-Drakes-Moody beach in Wells; along with the Wells-Ogunquit system, and Long Sands and Short Sands beaches in York.

This region is typical of the New England coast from Cape Elizabeth south to Cape Anne, and is more typical of the Atlantic coast as a whole than is the rest of the Maine coast. North and east of Cape Elizabeth, the Maine coast is less characterized by marsh and beach and more characterized by flat lands and ledge, with some mountain features such as on Mt. Desert Island. The southwestern coast of Maine is thus the region where the geology of the Maine coast most clearly faces the challenge of sea level rise.[3]

The communities of the York County coast are among the oldest in Maine in terms of human habitation. Native Americans spent their summers along the shore long before the arrival of European colonists because of the abundance of fisheries and the climate. European populations settled in the region for the same reason from the early 17th century on. The first summer colony opened in Old Orchard Beach the year Maine became a state (1820) and later in the 19th century, the region became a major destination for the "rusticators" from Boston and New York after train and steamship services were established.

The legacy of this period of development for summer recreational purposes is seen today in the large proportion of the region's housing stock that is still held for seasonal use. Almost 25 percent of housing units in the nine coastal communities is seasonal housing, compared with 17 percent for York County and 15 percent for Maine. The towns range from a low of 3.4 percent seasonal housing in Kittery to a high of nearly 66 percent of all housing units in Ogunquit. But the coastal towns are more than just summer colonies. They constitute about a quarter of the land area of the county, but their year-round population is half of York County's population, and their population density more than twice the county level.

The region has been evolving over recent decades into an economy that combines summer recreation with suburbanization. Lying between the growing urban areas of Portland to the north and Portsmouth-Dover-Rochester to the south, York County coastal towns have developed a diverse economy. The education and health services sector was the largest employer in 2006. This was closely followed by manufacturing, then accommodation and food, which is the third largest sector. This sector becomes the largest employer in the third quarter, increasing jobs by 50 percent during the summer months. Together with a 16 percent growth in retail employment during the summer, the nine communities see an increase of nearly 14 percent in summer employment compared with annual average levels. Combined, the nine communities generated $1.5 billion in wages in 2006, which was 65 percent of all the wages paid in York County that year. In sum, these nine towns are a significant economy. Their combined annual average employment was eight percent of Maine's employment in 2006 and was larger than 11 of Maine's 16 counties.

### *Analyzing the Impacts of Increased Coastal Storm Intensity*

As discussed earlier in this article, the climate models indicate that the probability of major damaging coastal storms will increase. The study by Frumhoff and others (2007) did not model the increase in Maine; the closest site modeled was Boston. There they found that the probability of a storm that used to occur every 100 years (or which had a one percent chance of occurring in any one year) would increase to every two or three years (depending on emissions scenario). This is a rise in probability to between 33 percent and 50 percent of such a storm happening in any one year, an enormous increase in risk. The question then becomes, what are the vulnerabilities to this risk?

Vulnerability is a function of the number of economic assets exposed to the hazards created by storms and the size of those hazards. In measuring vulnerable assets in coastal York County, the nearly 12,000 seasonal homes, the vast majority of which are close to the shoreline, are clearly a major vulnerability. Damage to these properties was extensive in the 1978 storms, though most were rebuilt. Because geo-located data on these properties is unavailable, it is difficult to measure the relationship between coastal storms and residential properties.

It is possible, however, to estimate effects on economic assets involved in trade and commerce through the use of employment data from the Quarterly Census of Employment and Wages, a program jointly administered by the Bureau of Labor Statistics in the U.S. Department of Labor and state departments of labor, including the Maine Department of Labor.[4] Beginning in 2003, the data were geo-coded so that each establishment (place of employment) was coded with a latitude and longitude. This permits the data to be located within a geographic information system (GIS) relative to other features. Base maps, including town boundaries and road maps, were provided by the Maine Office of Geographic Information Systems (OGIS). The vulnerability to coastal flooding for the region was defined by an overlay from OGIS that maps the results of the SLOSH (Sea, Lake, and Overland Surge from Hurricanes) model for the entire Maine coast. The SLOSH model was developed in the 1980s by the National Oceanic and Atmospheric Administration (NOAA) for use by the Federal Emergency Management Agency (FEMA) and the Army Corps of Engineers. It is specifically designed to analyze storm surges.[5]

TABLE 1: **Economic Activity at Risk within SLOSH Model Zones**

| | Establishments | Annual Average Employment | Average Third Quarter Employment | Total Annual Wages ('000s) |
|---|---|---|---|---|
| Biddeford | 24 | 183 | 209 | $4,511 |
| Kennebunk | 32 | 274 | 341 | $5,338 |
| Kennebunkport | 67 | 524 | 812 | $11,835 |
| Kittery | 7 | 121 | 119 | $7,026 |
| Ogunquit | 13 | 88 | 167 | $1,817 |
| Old Orchard Beach | 103 | 470 | 977 | $7,345 |
| Wells | 19 | 176 | 260 | $3,700 |
| **Total** | **265** | **1,836** | **2,886** | **$41,572** |

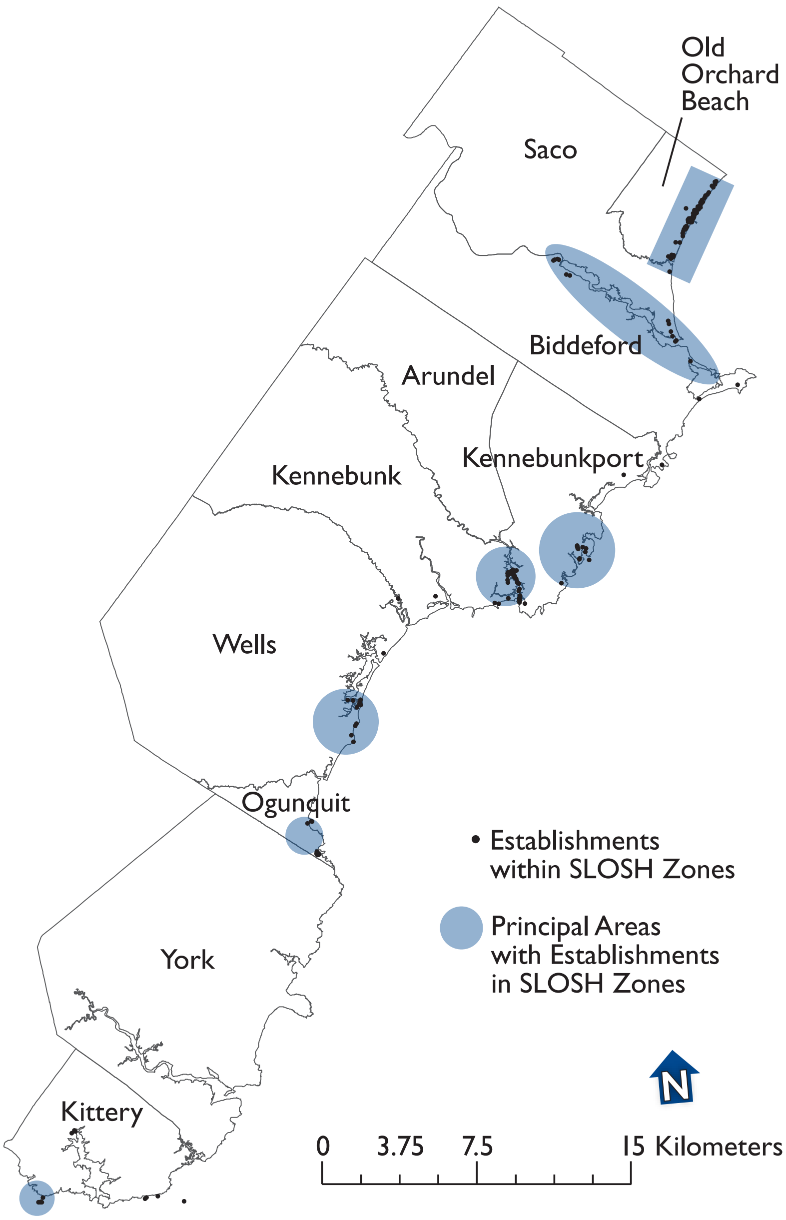
TABLE 2: **Proportion of Economic Activity at Risk within SLOSH Model Zones**

| | Establishments | Annual Average Employment | Average Third Quarter Employment | Total Annual Wages ('000s) |
|---|---|---|---|---|
| Biddeford | 2.9% | 1.7% | 1.8% | 1.3% |
| Kennebunk | 5.5% | 5.1% | 6.1% | 2.9% |
| Kennebunkport | 26.8% | 42.1% | 47.0% | 35.5% |
| Kittery | 1.6% | 1.5% | 1.4% | 1.7% |
| Ogunquit | 6.0% | 6.1% | 6.6% | 6.0% |
| Old Orchard Beach | 28.9% | 26.1% | 34.6% | 18.4% |
| Wells | 4.1% | 4.6% | 5.7% | 3.4% |
| **Total** | **5.9%** | **4.1%** | **5.7%** | **2.7%** |

### *Economic Risks of Sea Level Rise*

The analysis of the possible effects of sea level rise is conducted in two phases. In the first phase, only those establishments located within the "at-risk" zone predicted by the SLOSH model are examined. In the second phase, establishments located outside but proximate to the SLOSH model zones are examined to reflect the possible effects of higher estimates of sea level rise. Table 1 provides the summary data by town

FIGURE 1: **At-risk Establishments in SLOSH Model Zones**




and region for the economic activity at risk as predicted by the SLOSH model and Figure 1 shows the location of the major at-risk areas.

A total of more than 260 employment establishments in the nine towns are at risk from coastal flooding, employing on average in 2006 more than 1,800 people. This number goes up by 57 percent in the summer to nearly 3,000 employees. Annual total wages for the at-risk establishments totaled $41.6 million. The largest effects in terms of establishments and employment are estimated to be in Old Orchard Beach and Kennebunkport; the former town has the largest summer effects, while the latter town has the largest annual average effects. As a result, Kennebunkport also has the largest impact in wage terms.

Table 2 (page 73) shows the proportion of each town's economy found in the at-risk area predicted by the SLOSH model. Old Orchard Beach and Kennebunkport have the highest proportion, with Kennebunkport showing nearly half of third-quarter employment at risk.

The at-risk economic activity defined by the SLOSH model is broken down by category of storm in Table 3. The geography of these towns dictates that the SLOSH model projections for most towns result in narrow bands of additional risk beyond category 1. Categories 2 through 4 are shown combined, except in Old Orchard Beach where the geography of the beaches and marshes yields more distinctive zones. Overall, the at-risk establishments from category 1 storms account for about 70 percent of annual average employment. Old Orchard Beach has the most at-risk economic activity beyond category 1.

The "beyond category" establishments raise the question of whether the SLOSH model presents a complete picture of the activity at risk. There are several reasons to expect that it does not. The SLOSH model does not take into account the increase in sea levels predicted for this century, so if even the sea level rise related to the lower-emission scenario occurs, the SLOSH model predictions used here will be conservative. In Wells, a one meter (three foot) rise in sea level, the level expected by the end of the century even with no additional climate change, inundates a substantial portion of the salt marsh behind the Moody-Drakes Island beaches and the northern portion of Wells Beach (Slovinsky and Dickson 2006). This prediction of flooding is before any effects of storm surge. This analysis takes the zone of flooding into close proximity to Route 1 in Wells and does not incorporate the effects of storm surge from even a moderately strong coastal storm.

This analysis suggests that there are likely some risks from even low rates of sea level rise to areas beyond the SLOSH model zones, located along Route 1 in Wells and Ogunquit. The results of this analysis are shown in Table 4 (page 76). The effect of these higher sea level rise scenarios is to expand significantly the impacts on year-round economic activity in these communities.

Our analysis indicates that climate change and sea level rise pose significant and at least roughly quantifiable risks to the economy of coastal York County communities. The vulnerability arises from significant economic assets in close proximity to a shoreline that will be retreating with sea level rise and which is already exposed to significant damages from coastal storms. That exposure will increase, perhaps dramatically, because of the increasing frequency of severe coastal storms and associated storm surge. The results suggest that businesses and other establishments could experience damage from coastal storms ranging from minor to complete structural failure on a regular basis with regular property losses and increasingly frequent periods of lost employment and economic production.

**TABLE 3: At-risk Activity from Sea Level Rise**

| | Category | Establishments | Annual Average Employment | Average Third Quarter Employment | Total Annual Wages ('000s) |
|---|---|---|---|---|---|
| Biddeford | 2–4 | 24 | 183 | 209 | $4,511 |
| Kennebunk | 1 | 27 | 246 | 309 | $4,587 |
| | 2–4 | 5 | 29 | 32 | $751 |
| Kennebunkport | 1 | 54 | 395 | 606 | $8,127 |
| | 2–4 | 13 | 129 | 207 | $3,707 |
| Kittery | 1 | 7 | 121 | 119 | $7,026 |
| Ogunquit | 1 | 13 | 88 | 167 | $1,817 |
| Old Orchard Beach | 1 | 58 | 275 | 638 | $4,436 |
| | 2 | 7 | 21 | 32 | $317 |
| | 3 | 26 | 150 | 255 | $2,170 |
| | 4 | 12 | 25 | 52 | $422 |
| Wells | 1 | 14 | 154 | 231 | $2,934 |
| | 2–4 | 5 | 21 | 29 | $766 |
| | Beyond Category | 26 | 345 | 447 | $7,228 |
| Category 1 Total | 173 | 1,279 | 2,070 | | $28,927 |
| Category 2–4 Total | 92 | 557 | 816 | | $12,645 |
| Category 5 Total | 26 | 345 | 447 | | $7,228 |

Of course, factors such as building construction, site-specific topography and geology, and specific actions taken to mitigate the potential for damage cannot be seen at this level of analysis. The interpretation of a finding of at-risk using this analysis is that the risk may be sufficiently large now or in the not-distant future that detailed assessment of site and building risks should be considered expeditiously.

## RESPONDING TO INCREASED HAZARDS

The ultimate damage to the economy of York County and Maine will depend on the frequency of damaging events and then on the response and recovery to the events. The net risk depends also on what happens after the storms. Coastal storms have been doing damage to the southern Maine coast for more than a century, and each time properties have been repaired and rebuilt, often with government subsidies. The nation's commitment to helping people get their lives back together after a natural disaster is entirely humane, but results in a tendency to keep repeating the same errors about the location of property in high hazard areas (Heinz Center for Science Economics and the Environment 1999).

It is also possible that long before storm surge reaches the hotels or restaurants along Route 1, the beaches that draw tourists to southern Maine will have disappeared to erosion, and there may be little left of the tourist economy to be affected. Certainly the shorefront property owners along the built-out stretches of

**TABLE 4: At-risk Activity from Sea Level Rise Beyond SLOSH Model Predictions**

| | Establishments | Annual Average Employment | Average Third Quarter Employment | Total Annual Wages ('000s) |
|---|---|---|---|---|
| **Additional Activity** | | | | |
| Ogunquit | 122 | 10,207 | 4,498 | $18,529 |
| Wells | 156 | 17,145 | 5,291 | $34,134 |
| Total | 278 | 27,352 | 9,789 | $52,663 |
| **Revised Totals (SLOSH Model Plus High Sea Level Rise Scenarios)** | | | | |
| Ogunquit | 135 | 858 | 389 | $20,346 |
| Wells | 175 | 1,443 | 463 | $37,834 |
| Total | 310 | 2,301 | 852 | $58,180 |
| **Revised Totals as Percentage of Town Activity** | | | | |
| Ogunquit | 62.5% | 59.0% | 15.3% | 66.9% |
| Wells | 37.5% | 38.1% | 10.2% | 35.2% |

beach in towns such as Wells and Ogunquit face a major loss from sea level rise before most of the employment establishments are affected. But this merely demonstrates that estimates of potential economic losses examined here are incomplete and probably low.

It may also be the case that long before storm damages increase from sea level rise, the issue will manifest itself as another example of how costs will change as a result of climate change. Even if the exact timing and nature of possible effects from enhanced storm surge associated with sea level rise cannot be foreseen at this point, the "canary in the coal mine" of the problem will be found in the way these risks are addressed by the property and casualty insurance industry. The consequence of more frequent and more damaging coastal storms may not be the physical destruction of businesses and other establishments, but their economic destruction when insurance becomes unavailable, or unavailable at any price that allows profitability.

Hurricanes Andrew and Katrina were the largest single events in the history of property insurance in terms of damages paid out, and the industry is keenly aware that it cannot afford to stay in business if such events are to go from once a decade to once every one or two years. The federal flood insurance program exists because the private insurance industry cannot profitably underwrite the risks of floods in many areas, including many coastal areas. In the wake of Hurricane Andrew, Florida had to establish a statewide pool of property insurance (the Citizens Property Insurance Corporation) to bear the risks that the private insurance industry will no longer bear.

Although New England does not share Florida's exposure to tropical storms and its extreme vulnerability to sea level rise, we may also face issues with insurance companies choosing to limit their liabilities. According to the article "Insurer Seeks Big Cape Hike" by Bruce Mohl in *The Boston Globe* on April 27, 2007, property insurance rates are skyrocketing on Cape Cod, to the point where the inability to get insurance has frozen the property transfer market for short periods of time. Massachusetts, like Florida, has had to develop its own state-run insurance pool for hazard areas such as Cape Cod.

Will these public insurance systems, in combination with private insurance, federal flood insurance, and the government's long-standing policies to make it easy to recover from natural disasters allow sea level rise and coastal storm damage to remain just a painful, but occasional inconvenience? Nobody knows, but there are reasons to suspect not. Public insurance programs in Florida and other states are considered significantly underfunded if a series of catastrophic events follow one another in short order. According to Julie Patel in an article in the *South Florida Sun-Sentinel* from May 28, 2008, Florida's public insurance system has found that higher rates are necessary, but has been blocked by the governor and legislature from raising their rates. With sea level rise and climate change, this type of policy gridlock is the likely future, which also means that even the federal government's role as the insurer of last resort will come under significant strain at some point.

There are still questions about what to do in the face of significant changes in threat levels from coastal storms, even in the unlikely event of completely successful efforts to reduce the rate of global warming. Maine actually is one of the first states to explicitly build assumptions about global warming into the regulation of building on sand dunes. Maine's sand dune regulations, first enacted in 1988, restrict development subject to 500-year floods and prohibit the rebuilding of structures more than 50 percent damaged by storms unless the owner can demonstrate the site will remain stable in the face of a minimum two-foot rise in sea level (Chapter 355 of the Department of Environmental Protection Regulations).

These regulations address issues on sand dunes and beaches by establishing a policy known as "managed retreat" or "adaptive response" (Vestal et al. 1995). If the analysis in this paper is correct, then the applicability of this policy may have to be extended further away from the shore than it is presently. Or if the shore itself retreats, then the policy will have to be applied to a changing shoreline.

One implication of this analysis is that local governments may wish to examine some form of adaptive response policy for new development in the coastal hazard areas, which themselves must be redefined to be consistent with global warming and sea level rise expectations. Which scenario is chosen as the basis for policy actions is a matter communities will have to settle for themselves. But new development in these areas is somewhat more likely to come in the form of different types of commercial development, simply because so much of the shoreland suitable for residential development is already occupied.

Other options, such as engineering approaches to provide "reactive protection" also will be proposed and will have to be reviewed for their short- and long-term cost effectiveness. In general, retreat strategies are usually more cost effective in the long term than engineered protection strategies (Vestal et al. 1995), but this is a generalization that should be tested on a site-by-site basis.

While federal and state policies set the stage for action, municipalities will be at the forefront of responding to the increased impacts of sea level rise and coastal storms. Municipal governments through their land use, infrastructure, and economic development decisions must begin to identify vulnerable assets and map strategies for challenges that are both quantitatively and qualitatively different from what they have been used to. The analysis in this paper suggests that each community along the York County coast needs to significantly increase the involvement of its local business community in the discussions around these elements of local responsibility.

Financial resources will be needed for the planning process and any future actions such as reinforcement or relocation of assets (see Merrill, Sanford and Lapping, this issue). State governments also have a key role to play in helping municipalities initiate and sustain such processes. Numerous agencies and organizations are organized around offering help of this type, such as the Maine State Planning Office, Sea Grant, NOAA, and the Environmental Protection Agency (EPA), including EPA's New England Environmental Finance Center at the University of Southern Maine.

While federal and state policies set the stage for action, municipalities will be at the forefront of responding to the increased impacts of sea level rise and coastal storms.

Mitigation of risks from increased frequency and intensity storm surge events is a collective responsibility, and public, private, and nonprofit organizations must work together to help coastal communities to protect their assets. To the extent that this public-private partnership can be understood and supported by a diversity of Maine residents, preparations for massive storm surges are more likely to be completed by the time they are in demand.

## CONCLUSION

The hazards to Maine's economy from climate change are real, but like the path and speed of climate change, they are still unknown in important ways. Better understanding of the risks of climate change to peoples' livelihoods and property is a vital part of preparing the way for effective action. It is not the case that people do not recognize that climate change is a real threat, but Americans tend to view climate change as a threat that will affect other people in other times and places and not likely to be of immediate concern to them (Leiserowitz 2005). A better understanding of the risks, probabilities, and vulnerabilities of climate change on the economy in Maine is the mechanism that may translate perceptions of climate change as someone else's problem to our problem.

**Charles S. Colgan** is a professor of public policy and management at the Muskie School of Public Service at the University of Southern Maine. He is chair of the Community Planning and Development Program and associate director of the Maine Center for Business and Economic Research and the University of Maine System Center for Tourism Research and Outreach (CenTRO). He also chairs the State of Maine Consensus Economic Forecasting Commission.

**Samuel B. Merrill** is an adjunct faculty member at the Muskie School of Public Service, University of Southern Maine, and projects director at the New England Environmental Finance Center, housed at the Muskie School. Through his work at the Finance Center, he aims to extend creative approaches to environmental protection and management, especially regarding the associated "how-to-pay" questions.

## ENDNOTES

1. At Camp Ellis, the issue is a jetty built out from the mouth of the Saco River. The jetty keeps the mouth of the Saco from silting up, but at the cost of starving the southern end of the Saco Bay beach system for replenishment sands. Other problem areas in York County include Wells Harbor, which suffers similar conflicts between the needs of navigation and beach nourishment.
2. Normal tides can vary significantly. "Spring" tides (the highest tide of the month associated with the full moon) can be a foot or more above "mean high tide" making the total storm tide even more serious.
3. Portions of the City of Portland, with its extensive waterfront built on the Fore River and already subject to periodic inundations along Commercial Street, must be considered another high hazard area.
4. These data were provided by the Maine Department of Labor to the authors pursuant to a confidentiality agreement that prohibits the release of any data that could show the employment of any single establishment.
5. The geo-located establishment data contain some errors. Where these could be identified they were removed from the dataset before analysis. Although some of the erroneous data points appear on the

maps, the employment data is not included in the analysis. The identified errors affected less than one percent of employment across the region. All data were referenced to the North American datum of 1983. Locational errors for establishments and the boundaries of the SLOSH model zones should be minimal, but where establishment locations touched SLOSH model boundaries, the establishment was only included in the higher effects category. For example, an establishment located on the boundary of the category 2 and 3 effects zones was included only in analysis of category 3 and above effects.

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