Sea Level Rise

Overview:

- Locally, seas will most likely rise about one foot by 2050, while estimates for later in the century diverge widely (2 to 6.5 feet), depending on present and future emissions of greenhouse gases.
- The primary mechanisms of sea level rise are changing in their relative importance, and while currently dominant factors such as warming water are already well-understood, the most important future factors are not.
- Because coastal erosion and shoreline change involve complex natural processes, land loss due to inundation by rising waters (though easier to predict and model) is probably less significant than the indirect effects of sea level rise, e.g. storm waves, flooding, and wetland loss.
- Responses to sea level rise involve difficult tradeoffs, often pitting short-term economic interests against the natural environment and long-term sustainability.

"I stand before you as a representative of an endangered people." Maumoon Abdul Gayoom, former President of the Maldives, at the 1992 U.N. Earth Summit[1]

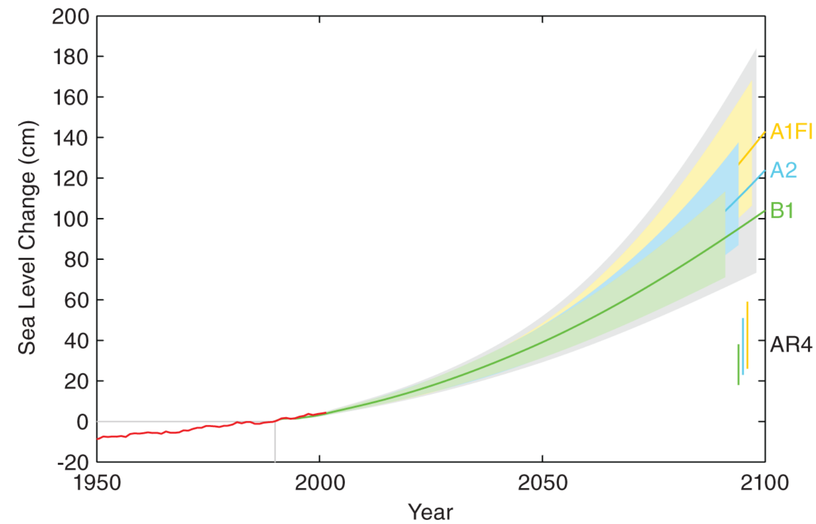
With a maximum elevation of about 7.5 feet, the Maldive Islands may simply cease to exist by the end of this century, or even sooner, depending on one's definition of "exist." The conservative estimates of sea level rise given by the IPCC in 2007 indicate a future with so little habitable land that most of its 269,000 residents will be forced to leave the country. More recent projections that attempt to incorporate the effects of the melting Greenland ice sheet paint an even grimmer picture. The island nation is expected to be almost completely underwater by the end of the century solely due to sea level rise, and probably gone entirely once storms and erosion are considered. Much sooner than that, even following the older estimates of the IPCC, it will be largely uninhabitable due to a lack of freshwater for drinking and agriculture caused by changing rainfall patterns and saltwater intrusion into aquifers.

Fearing a future life as a nation of refugees, in 2008 former Maldivian President Mohamed Nasheed announced plans to seek the purchase of a new homeland in India, Sri Lanka, or Australia with funds drawn from their very large tourism economy[2]. It is an ambitious (and not yet realized) solution that if successful raises profound questions: When an entire population relocates, does the state move with it? How does a sovereign nation located on land purchased from, and surrounded by, another maintain its independence and culture? Even more concerning, other Pacific island nations (such as Kiribati, Tuvalu, and the Marshall Islands) face similar existential threats but lack the wealth to pursue such a solution.

Climate change is of great importance to islands everywhere, but compared to the threat of imminent annihilation facing low-lying Pacific atolls, the situation on Martha's Vineyard is manageable. There will always be sufficient land and drinking water to support basic survival; however, sea level rise threatens many aspects of the Vineyard's natural environment, economy, and quality of life. A closer present-day analogue for our future may be the Seychelles Islands. The economy of the Seychelles, like ours, is driven by tourism, typically hosting twice as many visitors as its year-round population. These tourists are drawn to an unspoiled environment with pristine beaches that is rapidly disappearing. Complete inundation of the land is essentially impossible in the next century, but enormous amounts of the most valuable areas are currently being lost. There is sufficient drinking water to support the population, but reserve supplies can drop to as little as 30 days worth[3]. It would be wise to observe the adaptation efforts of the Seychelles and other islands over the coming decades to learn from their successes and avoid repeating their mistakes.

Sea level rise: past, present, and future

During the last century, global sea level has risen a bit more than seven inches. This amount is an average, though, with substantial local differences; seas have risen nearly a foot in New England. Over the last three decades the global rate of rise has doubled, and is presently approximately 3 mm (just over 0.1 inches) per year. This too is an average; sea level rise in a given year is heavily influenced by ocean currents and the amount of ice that melted, which is dependent on weather and other factors.



The effect of different levels of greenhouse gas emissions on sea level rise becomes especially pronounced later this century. The curves labeled A1FI and B1 (corresponding to the high and low emissions scenarios used in this report) represent a summary of results from studies conducted since the IPCC's 2007 report (depicted in the AR4 bars). Figure from NAS pg. 267, Vermeer and Rahmstorf, 2009)

In the short term, simple extrapolation of the current rate can provide a simplified estimate of future change. From 1932 to 2000, sea level rose about 0.1 inches per year at Woods Hole beyond the global rise, with a similar increase at Nantucket from 1965 to 2000[4]. Combining the local sea level rise of the past 35-68 years with the global rate of the past three decades results in a rough estimate of an inch every five years. Given the evidence that the rate has been accelerating recently, and the time lag between warming of the atmosphere and warming of the ocean (which means that literally nothing can be done to slow sea level rise in the immediate future), this should probably be treated as a minimum estimate.

Looking beyond the next few decades, there is great uncertainty in the projections for sea level rise. The most frequently cited predictions in major media are still those from the IPCC's landmark 2007 Fourth Assessment Report. Though now outdated, and almost certainly wrong, this is understandable because of the fact that the emissions scenarios created in that report represent an enormous amount of economic and scientific research and modeling, and are still extremely valuable tools to the more current efforts to estimate sea level rise. Even at the time of release, it was known that their projections for sea level rise – 8 inches to 2 feet by the end of the century – were too low. The IPCC acknowledged this, arguing that because so little was known about certain processes, most important the melting of ice sheets, it was better to ignore these factors than to guess about their magnitude.

Since the IPCC's 2007 report, we have learned that ice sheet melting is an extremely important, perhaps even paramount, factor (see box "Changing Change"). Newer studies that attempt to account for this, and also incorporate more recent trends in warming and emissions, produce much higher predictions of sea level rise. A scientific consensus is possibly emerging for a central estimate of 3 to 4 feet by 2100, but even this is at once too specific and too small, if we continue on the "business as usual" high-emissions scenario developed by the IPCC. Summarizing several recent studies, this scenario could be expected to lead to total sea level rise of 3.3 – 5.6 feet by 2100. Projections based on the lower emissions scenario result in 2.1 – 3.6 feet by the end of the century.

One useful perspective is that locally, we should expect a similar amount – around one foot – of sea level rise by 2050 as we experienced over the previous century[5]. That is, over the next few decades we face sea level rise that is faster than ever, but still similar in kind to what we are confronted with today. It is toward the end of the century where the truly hard-to-fathom amounts of sea level rise are possible. This is also where the effects of the different emissions scenarios diverge; without large reductions in fossil fuel usage, we are much more likely to see the higher end of the projected range, or even "catastrophic" scenarios of (sometimes much) greater than 6.5 feet which, while generally downplayed by major scientific organizations (see box, "Scientific Reticence"), are not out of the realm of possibility.

Causes of sea level rise

The many causes of sea level rise can be roughly grouped into five categories, three of which primarily drive the rise in global sea level, with the remaining two largely explaining local and regional variation.

Thermal expansion of water

Water – even in its liquid form – expands as it warms. This effect is proportionally small (barely noticeable in a pot on your stove), but a small relative increase to the massive total volume of the world's oceans (about 310 million cubic miles) is significant. Thermal expansion of the ocean is responsible for about half of all sea level rise that has occurred since the industrial revolution.

Because of its great size and the high heat capacity of water, the ocean is the most important heat reservoir on the surface of the earth. In regard to climate, this is a double-edged sword. Up to now (and for the near future), the ocean has served as a buffer against more severe and rapid climate change, with 80 to 90% of the excess heat trapped by greenhouse gas emissions going toward warming the ocean. Unfortunately, there are serious downsides, both immediate (sea level rise) and long-term: storage of excess heat in the ocean only serves to delay land-based warming, and contributes to the fact that regardless of our actions some degree of warming will persist far into the future.

Melting of mountain glaciers and ice caps

Mountaintop glaciers and ice caps have been melting at a rate roughly proportional to overall sea level rise, constituting about a quarter of the total sea level rise observed over the last 50 years. They will continue to be an important contributor over the near- to medium-term, but their potential total impact, and the risk of sudden change, is limited. The complete disappearance of mountain glaciers and ice caps would result in a bit over two feet of sea level rise. Long-term, the most significant consequences of melting mountain glaciers are the local impacts, in particular flooding and loss of drinking water, on communities that in many cases lack the resources to adapt effectively.

Melting of ice sheets

Tackling the huge uncertainty regarding the melting of the world's great ice sheets in Greenland and Antarctica is perhaps the most important, and fascinating, area of current climate science. The potential magnitude of melting is enormous – the equivalent of 23 feet of global sea level rise sits frozen on top of Greenland, with another 197 feet sequestered atop Antarctica – but so is the time scale, with a complete melting only possible hundreds to thousands of years away. However, in recent years, melting of these ice sheets has accelerated and will likely continue to. Melting in Greenland has increased 30% over the past 30 years and is now a significant contributor to global sea level rise. In the medium-term (decades, but not centuries from now), loss of ice in Antarctica may be the most significant factor, with major changes already occurring, sometimes suddenly. The Larsen-B Ice Shelf, a chunk of ice 2,018 miles across and about 650 feet thick, disappeared over the course of six weeks in 2002.

The mechanisms driving these changes are only now coming into focus. Obviously, warmer air temperatures melt ice on the surface more rapidly, which then flows into the ocean; however, this is a relatively small component that cannot explain the rapid increase in total melting. Like frozen rivers, glaciers flow from their upland source, where they are formed by snowpack, to the ocean, where they gradually melt. Over the past 15 to 20 years, something is causing them to flow faster[6].

Changing Change

The most important root cause of global warming to date – the release of heat-trapping gasses into the atmosphere – will continue to be so into the foreseeable future. But the relative importance of the forces causing ocean levels to rise is changing. In The Rising Sea, Orrin Pilkey and Rob Young present two helpful lists. Ranked in order of importance (highest at the top), the causes of sea level rise are[1]:

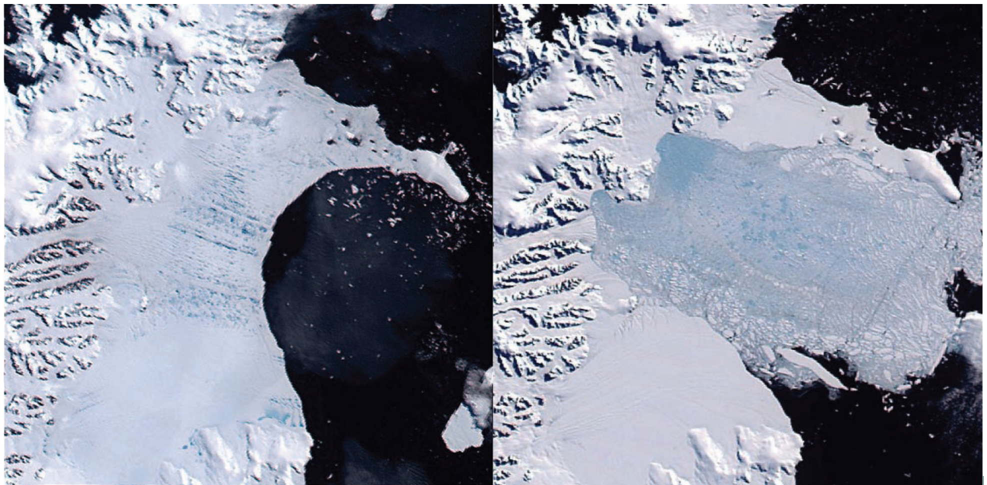
20th Century

- Thermal expansion of the oceans
- Mountain glacier melting
- Melting of the Greenland ice sheet

21st Century

- Melting of the West Antarctic ice sheet
- Melting of the Greenland ice sheet
- Thermal expansion of the oceans
- Mountain glacier melting

Unfortunately, the causes and effects of ice sheet melting are only now coming into focus. Enough is already known to project that this will be a major contributor to sea level rise, but enough doubt regarding the mechanisms remains to make precise numerical predictions of total sea level rise impossible, and to cast confusion (sometimes intentionally) over the issue.



The Larsen-B Ice Shelf, pictured in Jan. 31, 2002 (left) and March 17, 2002 (right). The light blue areas are actively collapsing and forming icebergs at the time of the imaging. (Figure from NAS pg. 265, MODIS imagery from NASA)

One explanation is that meltwater at the surface trickles down though crevasses to the land surface below, lubricating the interface where ice and bedrock meet. Another set of hypotheses focuses on the intersection of the glaciers' edges and the ocean, where calving of icebergs into the sea is happening more rapidly. For example, where glaciers meet the sea they often create large tongues or shelves of floating sea ice that serve to buttress the glacier, slowing its discharge into the sea; with the collapse of this plug of ice, the glaciers are freed to flow more quickly. More broadly, because water contains more heat energy than air, warming oceans will have an especially profound effect on melting where glaciers are most exposed. Most likely both types of factors are important, but the second has gained favor at the moment due to the rapid change observed in Greenland, which is more exposed to warming water (arriving from the tropics) than is Antarctica, which is shielded from warmer waters by a circumpolar current. Also, the "lubrication" hypothesis would predict greater flow in the summer than winter, which has not been confirmed.

Subsidence and Uplift

Substantial regional variation in sea level rise exists, primarily due to tectonic forces. Like a see-saw oscillating over geologic time, the subtraction of massive weight due to the retreat of glaciers causes the land to bounce back up, and eventually back down again. In some areas, for example the Pacific Northwest, the land has risen so much over the last century that apparent sea level is actually lower. However, for most of the country, including New England, subsidence, or sinking, of the land is causing local sea level rise to be greater than the global average. Across 50 years (1958 to 2008), the sea level in most of New England rose 2 to 6 inches beyond the global average increase. Most of this is caused by subsidence, with a smaller (but soon to be larger) portion due to our proximity to the melting Greenland ice sheet.

Changing ocean currents

Climate change threatens to upset long-standing ocean currents, some of which shield the ocean from extreme or rapid warming. One example is a sort of "conveyor belt" operating in the North Atlantic that carries warm water from the tropics northward via surface currents (the Gulf Stream), and then returns colder water through the deep ocean layers. Melting of the Greenland ice sheet is likely to reduce the strength of this current, as increased runoff of freshwater (which is less dense than seawater) causes less heat to be carried downward at the northern end of this conveyor belt. Such a weakening would have profound impacts on global climate change, but also contribute to local sea level rise across the North Atlantic. Boston and New York City could see an additional 6 to 8 inches of sea level rise due to this process alone[7]. A complete breakdown of this current, unlikely but possible during the next century, would have unpredictable but likely devastating consequences.

Impacts of sea level rise

Shoreline change and coastal erosion

Science cannot currently provide satisfying answers for what to expect in regard to the impact of sea level rise on shoreline change and coastal erosion. The majority of this change is caused by factors other than sea level rise; clearly, the Vineyard's shores have always been in flux, with some beaches growing and many important ones retreating, long before sea level rise was a major factor. But in addition to natural, historic causes of shoreline change, climate change contributes to erosion by fostering more powerful storms with bigger waves, storm surges and flooding, and wetland destruction. Anyone who has visited a south shore beach following a major storm knows intuitively that beach is lost when waves batter the base of a cliff or overtop the dunes, not because the global bathtub overflows a fraction of an inch every year. But that fraction of

Scientific Reticence

"I suggest that `scientific reticence', in some cases, hinders communication with the public about dangers of global warming. . . . Scientific reticence may be a consequence of the scientific method. Success in science depends on objective skepticism. Caution, if not reticence, has its merits. However, in a case such as ice sheet instability and sea level rise, there is a danger in excessive caution. We may rue reticence, if it serves to lock in future disasters.

I believe there is a pressure on scientists to be conservative. Papers are accepted for publication more readily if they do not push too far and are larded with caveats. Caveats are essential to science, being born in skepticism, which is essential to the process of investigation and verification. But there is a question of degree. . . . when an issue with short time fuse is concerned." James Hansen, 2007[8]

We include this insightful quote both as a reminder of the serious consequences of underestimation, which gets considerably less attention than climate change "skepticism," and to recognize an important limitation of the present report. While the advocacy mission of the Vineyard Conservation Society calls for reporting on possible "worst-case scenarios," we have chosen here to emphasize our other mission– education – which requires us to hold to scientific consensus, focusing on well-vetted studies, median projections, and likely ranges. But Hansen's cautionary note, and any evidence that catastrophic climate change is increasingly possible, should be taken seriously.

an inch allows those big waves and storm surges to penetrate deeper inland, and stay there longer, where human structures and the natural environment are simply less prepared for water.

As the Northeast Climate Impacts Assessment Synthesis Team describes the situation in their 2007 report, "Quantitative projections of future shoreline change remain hampered by the innate complexity and even randomness of coastal dynamics, and by the difficulties of projecting storm frequency and intensity." This is true, but even if those processes could be effectively modeled, the wide range in expected future sea level rise makes specific predictions of future shoreline change impossible. The differential impacts of three and four feet of sea level rise on coastal erosion are simultaneously unknown and enormous; never mind the differences between two feet and six.

Recognizing these limitations, for further information of local shoreline change we direct the reader to two sources. First, the most comprehensive and accessible treatment of coastal change is a recent special report published by the Vineyard Gazette[10]. It features specific studies of Island beaches, looking at historical and present changes, using interviews with residents and experts to present the best understanding we have of coastal erosion processes occurring at a given site.

Second, the Martha's Vineyard Commission, who have been studying these issues for decades in the course of their regional planning work, have recently released a series of maps indicating what areas would be flooded under different sea level rise scenarios. The maps, created by Chris Seidel and popularized by Phil Henderson's Rising Seas presentation, are now available for download at the VCS website. They are very detailed, showing for example the location of specific homes and docks, but it must be emphasized that they only reveal the impact of a static sea level rise, not increased coastal flooding or the effects of other factors on shoreline change. Even so, they allow for informed speculation regarding what areas will likely be underwater or nearly so in coming decades, including iconic locations like Five Corners, the Oak Bluffs harbor, and much of downtown Edgartown; a large portion of the land surrounding the Great Ponds; and priceless beaches along the south shore from Squibnocket to Wasque.

Other impacts

Though shoreline change due to simple inundation of low-lying areas is the most dramatic effect of sea level rise, the other impacts are likely more significant. Climate change is expected to produce more powerful storms and heavier rainfall events in our region; sea level rise greatly compounds this problem, as small changes in sea level translate into very large impacts on storm surges and flooding. The loss of wetlands as they become consumed by the open ocean is extremely important in its own right (see Ecology section), but will indirectly contribute to coastal erosion because of their role in buffering the coasts from storm damage. Unfortunately, wetlands are being lost at exactly the time they are needed most. Finally, as rising seas push further into the water table, saltwater intrusion threatens drinking water supplies. These changes are in our immediate future, and are to some extent unavoidable.

Melting Arctic Sea Ice

Recent data from satellites launched by the European Space Agency suggest that sea ice in the Arctic is melting faster than previously believed. Only 7,000 cubic kilometers of ice remained by summer of 2012, down from 13,000 in 2004. Roughly extrapolating these preliminary results (with the caveat that future melting could easily be faster or slower than any given eight-year period) suggests that by 2022 there could be no ice remaining in the Arctic for at least one day in the summer[9].

The melting of sea ice contributes very little directly to sea level rise, because this is ice that is already floating in water (think of a glass of iced tea melting in the sun). However, the observation of faster-than-expected melting is an ominous indication regarding current warming, and the loss of sea ice does create a dangerous feedback mechanism. Ice is more reflective than water, so an Arctic Ocean without ice cover will absorb more heat from the sun. This will contribute to overall global warming, exacerbating the other forces that are driving sea level rise.

But it is also true that while very small rises in global sea level can cause substantial problems, those problems become very unpredictable and almost inconceivably destructive with larger amounts of sea level rise.

Smart Adaptation

To further an honest discussion about climate change, it is necessary to report as best as possible the scientific consensus regarding the most likely amounts of sea level rise (about 3 to 5 feet by 2100) and the range of reasonable possibilities (2 to 6.5 feet, with an outside shot at much more or slightly less). The challenge in choosing these numbers is that the well-established processes that are certain to (continue to) cause sea level rise contribute the smaller portion of the total, while the rest is made up of factors which are either not yet possible to quantify (melting ice sheets) or uncertain to occur (changing ocean currents).

For the purpose of public planning, however, it may be more prudent to consider the upper range; surely there are certain projects that should not be undertaken even if there is only a tiny chance that it would be affected by extreme sea level rise. The trouble in choosing an upper limit is in deciding what is sufficiently improbable. Melting of the entire Greenland ice sheet would lead to a global sea level rise of about 20 feet (and even more locally); however, this will take a few centuries and would require continued heavy usage of fossil fuels far into the future, long past the point where climate change impacts would be obviously devastating – even to the wealthy industrial nations responsible.

The US Global Change Research Program suggests that 6.5 feet of rise by the end of the century may be a reasonable upper bound. This corresponds well with the recommendation of geologists Orrin Pilkey and Rob Young in The Rising Sea: that for planning purposes, communities should assume a sea level rise of seven feet by 2100. In High Tide on Main Street (another excellent and accessible resource on sea level rise, along with Pilkey and Young's work), oceanographer John Englander makes the point that intelligent adaptation requires that we accept that there is a range of sea level rise predictions, but that we must also act with a long-term perspective[11]. If reality more closely resembles the lower end of the projections, adaptation measures may allow coastal homes and infrastructure to last many decades longer than expected; however, in the very long run (perhaps centuries rather than decades) they will inevitably be lost.

Adaptation measures are typically grouped into three categories: hard armoring, soft stabilization, and retreat.

Coastal armoring

Throughout most of the 20th century, the favored method of holding onto retreating shores was the construction of hard points to prevent the movement of sand and protect the roads and buildings behind them. Seawalls, groins, revetments, and jetties built by the Army Corp of Engineers (or following their guidelines) have come to define much of the nation's coasts. Unfortunately, in addition to being very expensive, hard armoring protects the land directly behind it at the expense of its surroundings. By interrupting natural processes that have operated for millennia, down-current beaches and wetlands shrink or disappear as they are deprived of the sand needed to replenish themselves.

Locally, we are less reliant on hard armoring, but there are locations (e.g., the Oak Bluffs harbor) where pre-existing commercially important development will almost certainly be preserved (at great expense) by continuing to maintain and expand hard shoreline protection. The town beach at Squibnocket demonstrates both the value and ultimate limitations of this ap-


The Squibnocket Beach parking lot following Hurricane Sandy. (Photo by Sara Hoffmann)

proach. Without the seawall, the sand beach would be located far inland today and the parking lot long gone, possibly leading to the loss of public access. Construction of the seawall has therefore bought time to enjoy a valuable town resource. However, that time appears to be running out (in 2013 town residents sought refunds for their parking passes due to the loss of beach sand), and the town must now plan not only for losing the beach, but also the challenge of decommissioning a seawall and parking lot before they crumble into the sea.

Soft stabilization

More temporary, but less harmful, solutions involve the nourishment of beaches with new sand or stabilization with natural materials. In Massachusetts, beach nourishment is made more challenging due to strong restrictions on offshore mining of sand. Nourishment projects on Martha's Vineyard are especially difficult, as the only sufficiently large sources of sand nearby are considered by the Division of Marine Fisheries to be valuable fish and shellfish habitat that would be damaged by the mining process[12]. More realistic at the moment, and currently ongoing at many of our eroding beaches, are stabilization projects using biodegradable materials and the planting of native species to stabilize the sand. This is the area of adaptation where ingenuity and technological innovation could be most valuable.

Managed retreat

While the previous two categories may roughly correspond to the methods of the past and the present, respectively, the Vineyard's future may be characterized mostly by retreat, whether by choice or not. A 2011 report from the EPA dismisses shoreline armoring and soft stabilization as generally too expensive and/or ecologically damaging[13]. The EPA now strongly advocates for managed retreat through the promotion of rolling easements and other methods to encourage compliance (such as reducing government support for coastal development and protection, and making it clear to homeowners that they will not receive assistance to rebuild following losses). A recent report from the state on adaptation measures takes a more favorable view of soft stabilization but also emphasized the need to minimize what they term "repetitive losses," a goal that is antithetical to continuation of expensive temporary measures, and which can only truly be accomplished through retreat[14].

Choices regarding adaptation measures will pit various economic interests against one another, for example those of homeowners and the shellfish industry. Protection of valuable residential real estate threatens the shellfish industry, whether it is the destruction of wetlands through building of revetments and groins, or damage to offshore fishing areas caused by sand mining for beach nourishment. Island-wide planning is essential to balance these interests and to coordinate action in more cost-effective and less ecologically damaging ways. A local shoreline vulnerability study would be invaluable to assist in this planning[15].

The largely natural shoreline (apart from the harbors and downtown areas) is a crucial aspect of the Vineyard's local character. Coupled with the high costs of the other adaptation measures, this suggests that in many locations some sort of retreat will occur, whether well-planned or not. It is in our interest to manage coastal development now to both facilitate successful managed retreat efforts, and to reduce the economic cost and environmental damage of poorly managed (or accidental) retreat where it occurs.

Notes

1. Orrin Pilkey and Rob Young (2011), The Rising Sea, Island Press.
2. Randeep Ramesh, The Guardian (Nov. 10, 2008), “Paradise almost lost: Maldives seek to buy a new homeland”
3. Ronald Jumeau, Seychelles Ambassador, Talk of the Nation, National Public Radio (Sept. 22, 2010)
4. Chris Zervas, NOAA Technical Report, July 2001 (website) tidesandcurrents.noaa.gov/
5. Heather Goldstone, Climatide (Oct. 27, 2011), “Tough decisions about sea level rise face push-back” (website) http://climatide.wgbh.org/2011/10/tough-decisions-about-sea-level-rise-face-push-back/
6. For an excellent introduction, see two interviews with WHOI oceanographer Fiamma Straneo: their magazine, Oceanus (www.whoi.edu/oceanus/viewArticle.do?id=73766), and WCAI radio program, The Point (www.wgbh.org/programs/The-Point-298/episodes/Greenland-Glaciers-28720)
7. Yin et al. (2009), Model projections of rapid sea-level rise on the northeast coast of the United States, Nature Geoscience 2, 262 - 266
8. James Hansen (2007), Scientific reticence and sea level rise, Environmental Research Letters 2.
9. Robin McKie, The Guardian (Aug. 11, 2012), “Rate of Arctic summer sea ice loss is 50% higher than predicted”
10. Vineyard Gazette (Aug. 16, 2013), Special report: Coastal erosion
11. John Englander (2012), High Tide on Main Street, The Science Bookshelf.
12. Tom Dunlop, Vineyard Gazette (Aug. 16, 2013), “Natural forces that created the Vineyard will inevitably reclaim it, experts say”
13. James Titus (2011), Rolling Easements, EPA Climate Ready Estuaries Program
14. Massachusetts Climate Change Adaptation Report, 2011, Executive Office of Energy and Environmental Affairs and the Adaptation Advisory Committee
15. Liz Durkee and Chris Murphy (2012), interviewed by Marnie Stanton for “An Island in Conflict: What to do about Climate Change” (video)

Much of the background information used in this report is drawn from three large synthesis reports that represent the scientific consensus regarding global climate change. Factual statements without individual endnotes are drawn from one or more of these reports: *Advancing the Science of Climate Change* (National Academy of Sciences), *Global Climate Change Impacts in the United States* (US Global Change Research Program), and *Confronting Climate Change in the U.S. Northeast* (Northeast Climate Impacts Assessment Team, a collaboration of the Union of Concerned Scientists and other independent scientists). See the first section, Emissions Scenarios and Global Climate Change for further explanation.