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Sea Grant Connecticut

WRACK LINES

Volume 17, Number 1, Spring/Summer 2017

CHANGING CONNECTICUT

Big Changes are Happening Close to Home

LONG ISLAND SOUND CHANGES • LEGAL CHALLENGES / SEA LEVEL RISE • PLANKTONIC PROBLEMS

Sea Grant
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From the EDITOR

CHANGING CONNECTICUT


Wequetequock Cove

Change is in the air! We shouldn't be surprised, after all, it's New England. Recently, I was asked to speak about what's changing in Connecticut, from the coastal perspective. I mentally put together a list, but like Pinocchio's nose, it kept growing longer and longer. The result was a theme for this issue of *Wrack Lines*, "Changing Connecticut".

It features some, certainly not all, major changes, explained by experts. From tiny beasties that fuel the food web of Long Island Sound to the landscape itself, to the flora and fauna, sea level, legal policies, people's attitudes, to the very landscape itself, change is happening rapidly. They may sound unrelated, but they're all interwoven. All these changes pose new questions that require new answers and solutions.

Another change will have happened by the time you read my letter. The next issue of *Wrack Lines* will have a new editor. After nearly 30 years with Connecticut Sea Grant and UConn, I have decided to begin the retirement journey. I am proud of the fact that *Wrack Lines* has continuously published for 17 years and will go on. It has been a pleasure serving you. I also want to profusely thank our wonderful graphic designer, Maxine Marcy at the UConn Design and Document Production Center. She has worked magic to make the magazine come alive.

Speaking of change, you may have heard about the proposed budget threat to cut Sea Grant from the federal budget, which would in effect eliminate the program. However, we know that many of you reached out to your legislators to sing our praises and that many will continue to support us. We thank you and hope we can continue to serve you and your community in the future.

Farewell,

Peg Van Patten

Wrack Lines editor

About our cover:
Aerial photos on the cover (Barn Island Dike), this page, page 3 and 4 are courtesy of Jeff Simon Photography.

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Of Interest

As Connecticut's Landscape Goes, So Goes the Sound

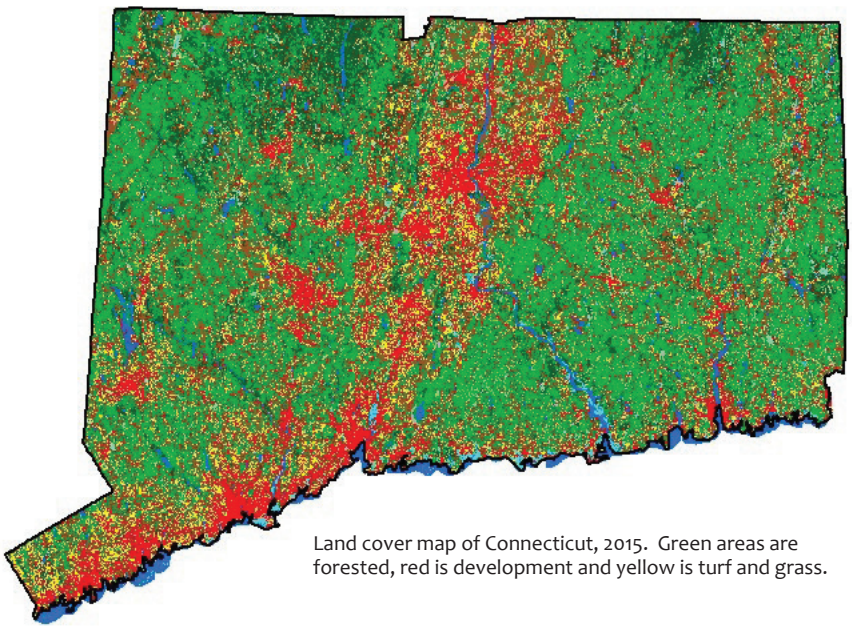
by Chester Arnold, Jr.

No elegant diagram of the water cycle is required to illustrate the basic truth that a water body is only as good as the water draining into it. Since this water is greatly affected by the land over which it runs, and since 99% of Connecticut drains to Long Island Sound, it becomes clear that Connecticut's landscape and the health of the Sound are intimately related.

This aerial photo of Barn Island in Stonington, Connecticut shows the intimate connection between our landscapes and the Long Island Sound.
Photo: © Jeff Simon.

For this and a lot of other reasons, it's important to have a handle on the changes occurring on the face of Connecticut. Charting these changes is the central purpose of *Connecticut's Changing Landscape*, a longstanding research project of the University of Connecticut Center for Land Use Education and Research (CLEAR). Connecticut's Changing Landscape (CCL) uses remote sensing technology to study the land cover of Connecticut and how it has changed over time. Land cover is what's physically on the surface of the land, such as forest or development. It is closely related to, but distinct from, land use, which is what is planned or permitted for a given area of land ("residential," "commercial," "protected open space"). A large and ever-increasing body of scientific research is uncovering the many relationships between land cover and the health of our natural resources, from wildlife to water.

The CCL study uses the tried-and-true Landsat series of satellites, which allows us to go back as far as 1985 for imagery that can be compared "apples-to-apples". The satellite measures the reflectivity of the land surface and this information is converted, after much computer processing and some best professional judgment, into land cover datasets made up of millions of 30-meter pixels (short for "picture elements," and I bet you didn't know that!). In these days of high resolution imagery on your phone, a study that produces data in 30 meter (100-foot) squares may seem a bit, well….20th Century. But, as CLEAR's geospatial expert Emily Wilson, who creates all the study's charts and maps, points out, "30-meter data is still the best way to look at large areas like Connecticut over long periods of time. High resolution imagery is too complex and expensive to convert to statewide land cover datasets at this point, although we are working on it in collaboration with the NOAA Office for Coastal Management. But with the Landsat imagery we can go into the past and look at change over time, which is the big reason why we did the Changing Landscape study."



Land cover map of Connecticut, 2015. Green areas are forested, red is development and yellow is turf and grass.

What's Trending?

CCL is nationally unique in terms of both the number of sampling datasets and the total time span covered -- seven datasets (1985, 1990, 1995, 2002, 2006, 2010, 2015) spanning 30 years. Multiply that by 12 land cover categories, and you have a lot of data to sift through. So, in this article we will hit only a few big-picture highlights, but you are encouraged to explore the information for yourself using our interactive online "story map" *(please see End Note to find out how)*.

The CCL study gives us two basic types of information: land cover status for a given sampling date, and land cover *change* between any two sampling dates, including the entire 30 year period. The colorful image on this page shows shows the most recent (2015) land cover map for the entire state, with each color denoting one of the land cover categories. The map might look smashing on your living room wall, but we'll need to look at a couple of graphs to get a feel for our current status.

The image on page 6 is a pie chart that shows the 2015 breakdown between the major land cover categories of the study. The five most common land covers (excluding water) are forest (57%), followed by development (19%), turf/grass (8%), agricultural fields (7%), and other grasses (2%). For an urbanizing state, the large percentage of forest might seem surprising, but in fact Connecticut has far more forest cover now than during the height of our agricultural past (although as we'll see, that number is declining). It's important to note, however, that "forested" land cover does not imply pristine unbroken forest, but simply means that trees are the predominant element of the landscape. Another striking fact is that the turf/grass category, which is made up of the manicured short grasses (lawns, ball fields, parks, golf courses) that are part and parcel of developed areas, now exceeds the agricultural field class; this has been the case since sometime between our 2002 and 2006 sampling dates.

Change over the entire study period of 1985 to 2015 is summarized in the image on the bottom of page 7. The center line marked with a "0" is the "no change" line; bars above the center line denote increases over time, and bars below denote decreases. This blocky tale of the "winners" and "losers" from the past 30 years perhaps tells the overall story best: there have been large increases in the development-related classes, which have come at the expense of decreases in the forested

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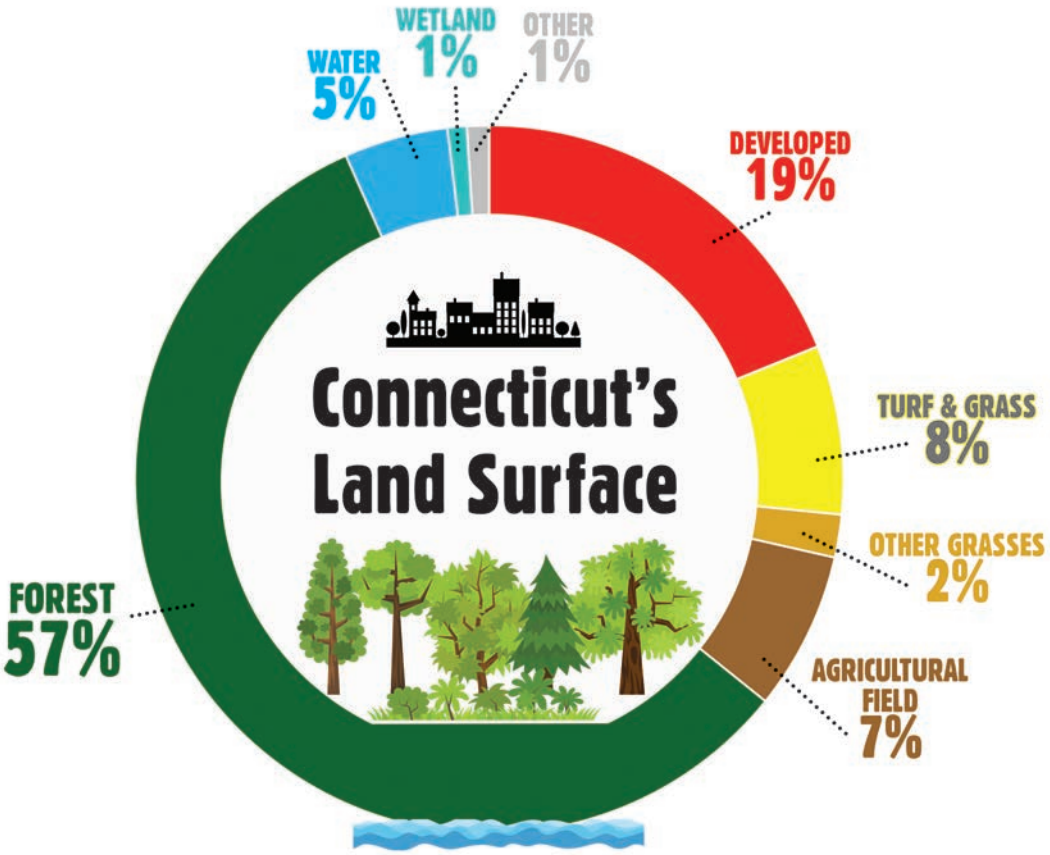


Percentage of Connecticut's land surface in 2015.

and agricultural field classes.

Of course, a bar chart is only so satisfying. The best way to look at change is with the study's "change maps," which can be zoomed into the town level (or even closer) to look at the location and form of what's been happening since 1985. The image on the top of page 7, taken from the CCL Story Map, shows the change map for an area in the southwestern part of the state that has experienced higher than average development. Although we can't be certain of the land use, the squiggly format of the new developed (red) areas strongly suggests a proliferation of residential subdivisions.

And you're telling me this because....?

Land cover change is not of itself good or bad. As noted, however, studies from around the country continue to link various land cover metrics with impacts to natural resources. The most well documented and perhaps also well known is the relationship between the amount of impervious cover in a watershed and the health of the water body to which the watershed drains. Man-made hard (impervious) surfaces such as roads and roofs short-circuit the water cycle, increasing stormwater runoff and creating associated flooding, erosion, water pollution, and aquifer recharge problems. Hundreds of studies from across the country, done in different ways and in different landscapes, show that waterway health starts to decline at relatively low levels of watershed impervious cover, perhaps around 10% (although this number varies). Since the CCL developed class is based on a predominant signal of impervious cover, the growth of this category is not in most cases good news for the rivers, streams and ponds of Connecticut.

And, of course, neither is it good news for the ultimate receiving water, Long Island Sound, which is why the 2015 Long Island Sound Study Comprehensive Conservation and Management Plan (CCMP) has specific goals on reducing impervious cover, and its connection to waterways, in the greater watershed. An increasingly popular strategy to accomplish this "disconnection" of impervious surfaces is the suite of development practices known as Low Impact Development (LID) or, in some cases, "green infrastructure." But that's for another article…

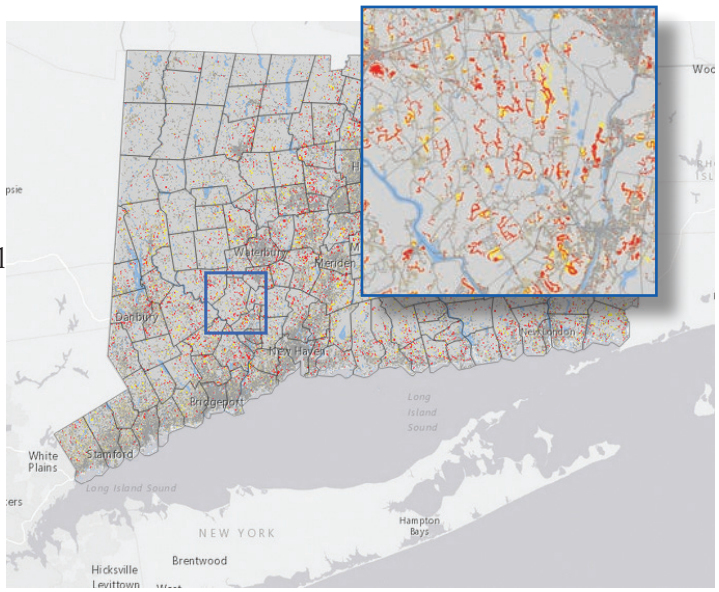
The CCL can tell us many things beyond the implications of basic land cover change. Follow-up studies done by CLEAR have looked at land cover change in specific areas, or in specific ways, that extend our understanding of the impact of our development patterns on natural resources. For instance, riparian (streamside) corridors are known to be important for a host of reasons, including habitat protection, water temperature regulation, and pollutant processing. As part of a CCL-based study of the Lower Long Island Sound Watershed done in 2011, CLEAR looked at land cover change in 100-foot and 300-foot corridors to either side of the region's streams, rivers, lakes and ponds. As a result, the CCMP has the goal of *increasing the percent area of natural vegetation within 300 feet of any stream or lake in the Connecticut and New York portions of the Long Island Sound watershed to 75% by 2035 from the 2010 baseline of 65%.* This is a complicated task involving both restoration and protection of these critical areas above and beyond what is provided by state Inland Wetlands and Watercourses regulations. But at least we have a baseline from which to measure progress, and maps to show where restoration and/or protection are needed most.

Using the data

The solutions to the problems documented by Connecticut's Changing Landscape are complex and multi-faceted. The changes we see in the CCL maps, and around us each day, are the result of a complicated mix of drivers that includes, among other things, historic development patterns, changes in modes of transportation, shifts in population and consumer preferences, and, most important of all, our home rule system of land use decision making that puts almost all the power in the hands of 169 different municipalities. But a solid understanding of where we are, and where we have been, is a good foundation for planning where we want to go. CCL information is being used to that effect in a wide variety of ways by a broad spectrum of organizations.

As noted, in 2011 the Long Island Sound Study funded CLEAR to do a CCL expansion to cover the lower Long Island Sound basin, including developing maps for watershed-level impervious cover and riparian corridor land cover that, as we've seen, have been used as the basis for several goals of the LISS CCMP.

"Combining CLEAR's land cover data with our ongoing coastal and marine research has proved very valuable over the years in furthering our understanding of the Sound," says Mark Tedesco, Director of the EPA's Long Island Sound Office. CCL maps and data are frequently incorporated into municipal and regional Plans of Conservation and Development, and are used in the State Plan as well. The Connecticut Council on Environmental Quality uses other CCL metrics (forest fragmentation and changes to the agricultural field class) in its annual reports on the state of Connecticut's environment.



Change map, 1985-2015, from an area in Southwestern CT (inset). Red areas show new developed areas and yellow areas show new turf/grass areas.

CCL data has been used by the Connecticut Department of Energy and Environmental Protection in the development of water resource regulations, including the first impervious cover-based Total Maximum Daily Load (TMDL) regulation in the country, and the statewide bacteria TMDL. And recent research supported by Connecticut Sea Grant uses CCL data as part of a model that looks more closely at sources of nitrogen to coastal embayments around the Sound. Finally but importantly, CCL data is used not only by academics throughout the state for classroom teaching but also for research into a host of environmental issues that connect to land cover.

The biggest of the big pictures is this: Connecticut is urbanizing. Well, duh. We knew that. But Connecticut's Changing Landscape helps us to understand the whens and wheres, and sometimes even the whys, of these changes, and their implications to the health and sustainability of our natural resources, including Long Island Sound. Now comes the hard part: using the information to help us change the pattern and design of our manmade world so that our development footprint drops a couple of shoe sizes.

END NOTE:

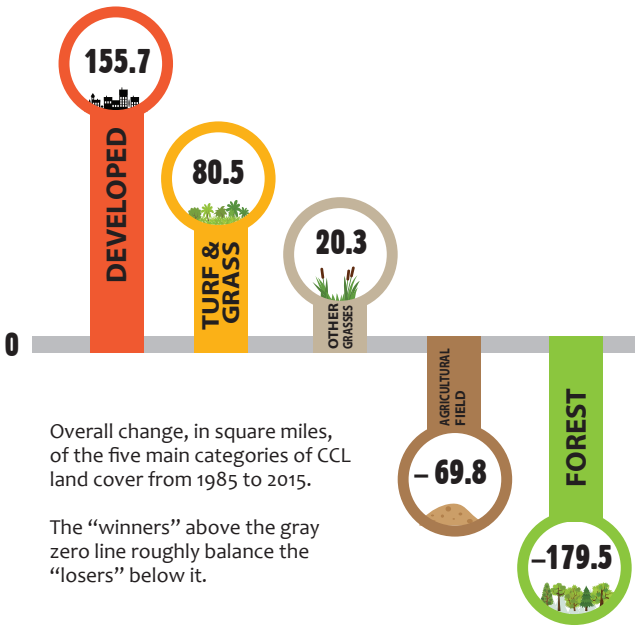
You can explore the data and maps yourself using CLEAR's new CCL "story map!" Story maps are a relatively new interactive mapping application that enables the combination of online maps with text, pictures, graphs and videos to tell a more compelling story than maps alone could do. In it, you'll be able to delve much more deeply and locally into the information provided in this article, so check it out! http://clear3.uconn.edu/viewers/ctstory/

CLEAR's CCL story map won first place in a national story map contest sponsored by the geospatial industry leader, Esri Corporation.

ABOUT THE AUTHOR:

Chet Arnold is a Water Quality Educator with the Department of Extension and the Director of the UConn Center for Land Use Education and Research (CLEAR).

Statewide Change, 1985-2015 (square miles)



Overall change, in square miles, of the five main categories of CCL land cover from 1985 to 2015.

The "winners" above the gray zero line roughly balance the "losers" below it.

33 species in Long Island Sound

COLD ADAPTED SPECIES

A. Windowpane Flounder
B. Ocean Pout
C. Longhorn Sculpin
D. Sea Raven
E. Fourspot Flounder
F. Fourbeard Rockling

D.

A.

E.

B.

more abundant north of Cape Cod than south of New York

behaviorally adapted to cold temperatures some to subfreezing

prefers approximately 3-15° C

spawns at the lower end of their temperature tolerance

C.

Long Island Sound's Fish Community Responds to Climate Warming:
Big Changes Close to Home

by Penny Howell

Some people look at Long Island Sound and see a quiet waterscape, with no large surf or waterfalls, which looks like nothing much is happening. However, this scene is very deceiving. The Sound is an estuary, the second largest on the Atlantic coast. Estuaries are those few places on Earth where salty seawater mixes with freshwater flows from rivers (there are four major ones: Thames, Connecticut, Quinnipiac, and Housatonic). Add to that terrestrial groundwater and surface runoff, energy inputs from the tides, wind, and water currents, and you have a fantastically energetic system in a relatively small area. Because of their high rate of production and turn-over, estuaries are biologically diverse: The Sound provides protected nursery and feeding grounds for over 100 species of finfish, at least that many invertebrate species, as well as the more visible multitude of shore birds, ducks and seals. The CT DEEP* Fisheries and Water Protection Divisions have recorded this diversity for decades through several long-term monitoring programs: a standardized Sound-wide Water Quality Survey and Marine Resource (Bottom Trawl) Survey, and a Coastal Seine Survey carried out at eight intertidal beach areas.

The Resource Survey, which began in 1984, samples 40 locations per month in spring (April, May, June) and fall (September, October). The species list for this program totals 102 finfish species and rises every year. Over the time series of the Survey the relative abundance of these fish species has changed dramatically. Fish are cold blooded and the rising water temperature of the Sound, documented by the Water Quality Survey, has affected different species based on their temperature tolerance and preferences. When the common species are divided into two groups, one adapted to tolerate a cooler temperature range and one adapted to tolerate warmer temperatures, an obvious trend emerges: the abundance of the cold-adapted group has declined while the abundance of the warm-adapted group has more than made up the difference, especially in the fall when water temperatures are highest. The number of warm-adapted species has also increased substantially since 2000, while the species number of cold-adapted species has not appreciably declined. The result is a slight increase in overall abundance and a larger increase in the diversity of fish species in the Sound. The Coastal Seine Survey, which targets young-of-year and forage species in the intertidal zone in September, has recorded the same changes in the fish community since it began in 1988. This means that warm-adapted species are moving into the Sound not only to feed but also to reproduce young. As this warming trend continues, warm-water mid-Atlantic species, such as scup, black sea bass and butterfish, will migrate into the Sound sooner on the calendar, stay longer and in greater numbers to feed and reproduce. Competition between these fish and the Sound's iconic cold tolerant species-including winter flounder and rainbow smelt, not to mention lobsters-will most likely increase.

Of course the reason for these changes is increasing water temperature. The CT DEEP Water Quality Survey has recorded water temperature and other physical data monthly, and biweekly in summer, at locations stretching the length of the Sound since 1991. These data, along with several other datasets from New York and federal agencies, were used to develop a high resolution model of the Sound that characterized temperature change beginning in 1979 until current time. Over that time period, the annual mean temperature of the Sound increased 1.4^{0}C (~2.1^{0}F). This increase is biologically significant since it has occurred over such a short time period: 30-40 years is a blink of the eye on a geological scale. This exercise showed

*CT Department of Energy & Environmental Protection

F.

continued on next page

A.

that the Sound is warming up about twice as fast as the Atlantic Ocean. Estuaries like the Sound have evolved to capitalize on change, but that change must be gradual and predictable enough for the many parts of the Sound's ecosystem to keep working as they have for centuries. So far the Sound's menagerie is keeping up and doing very well!

ABOUT THE AUTHOR:

Penny Howell recently retired as Senior Fisheries Biologist for the Connecticut Department of Energy & Environmental Protection, Fisheries Division. She continues to be involved with marine resource research and management issues.

WARM ADAPTED SPECIES

A. Hogchocker
B. Northern Kingfish
C. Striped Searobin
D. Northern Puffer
E. Smallmouth Flounder

37 species in Long Island Sound

C.

- more abundant south of New York than north of Cape Cod
- behaviorally avoids temperatures <10° C
- prefers approximately 11-22° C
- spawns at higher end of their temperature tolerance

D.

B.

E.

Marshes on the Move

by Peg Van Patten

Tidal marshes, those uber-productive wetlands that connect the shore and sea, are changing. They are eroding away in many parts of Connecticut's coast due to rapidly rising sea levels in the Northeast, but in some instances are migrating landward. Marshes support a vast array of wildlife and vegetation, improve water quality, and protect communities from storm impacts. What most people don't realize, however, is the host of complicated questions that arise as marshes try to migrate inland; for example, how fast are marshes changing? Does salty water coming in kill trees? Sediments brought by incoming tides are deposited as always at ebb tide, but in places where accumulation exceeds erosion and new marsh is able to form, the process runs smack into what was the marsh upland. In the upland areas, which were at a higher elevation, shrubs and trees grow.

Shimon Anisfeld, a Sea-Grant sponsored researcher at Yale, wondered how the transformation process would go. Would trees die off from the intrusion of salty water coming in, allowing the establishment of marsh grasses, or would the upland trees and shrubs remain, hindering the formation of new low and high marshes? He and his team are sampling and watching Sherwood Island, Barn Island, Hammonassett, and other marshes over time. So far, they believe that the trees are in fact slowly dying off, which is considered a good sign for new marsh.

Yale researcher Shimon Anisfeld and his research team collect upland marsh sediment samples at Hammonassett State Park in Madison.

Can Copepods Cope?

Research uncovers planktonic problems

by Tyler G. Martin

In marine scientist Hans Dam's laboratory at UConn Avery Point live myriad tiny animals that skitter about in a safe and comfortable tank of seawater. While they're almost impossible to see with the naked eye, these small, transparent creatures play a vital role in the aquatic food chain of Long Island Sound. They are known as copepods, and according to Dam they may be in trouble.

If this is the case, so are the rest of us. Climate change and warming temperatures in the temperate waters of Long Island Sound may threaten their survival, and with it, the sustainability of the valuable fisheries in the Sound that depend upon them to nurture their young.

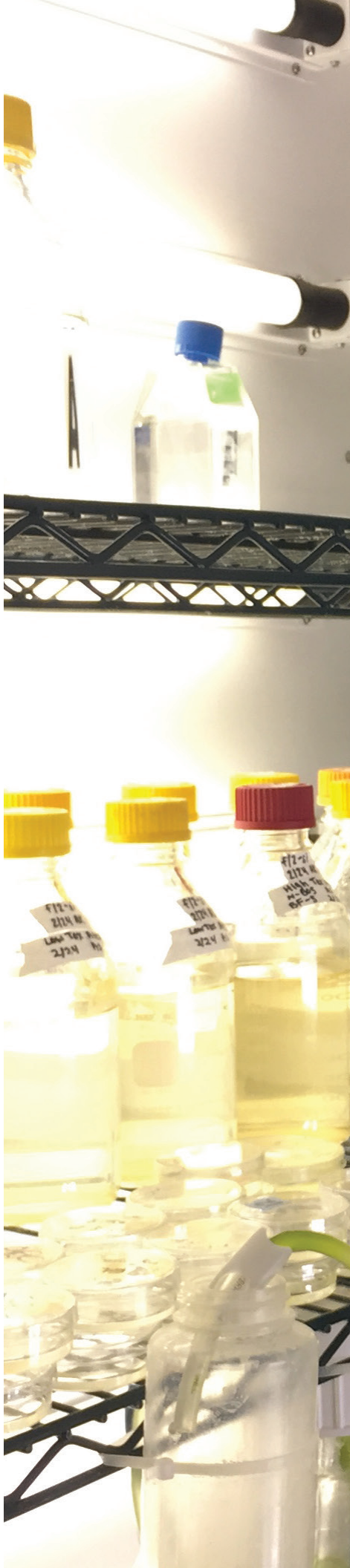
That is the concern behind Dam's research and a two-year project he has undertaken with funding from the Connecticut Sea Grant program. The project is looking at the ability of copepods to withstand rising water temperatures and occasional blistering heat waves. Dam said he developed this interest as an undergraduate at the University of Washington, where he acquired a passion for plankton, the microscopic plants and animals that are swept about by the tides and currents of the sea.

"Funny, people think that the ocean is dominated by large fish, but that's only a small fraction of what lives in the ocean" said Dam in a recent interview. "Most of the life is tiny, some of them you can't see, but they're superabundant and they drive the biology of the ocean." Dam noted that he likes fish, but they're too difficult to work with. "Unlike fish, copepods lack complex behavioral patterns, making them just simple enough to make sense of," he said. "They grow fast so you can keep them in the lab. If you try to experiment with fish it would take years; with copepods it takes weeks."

Acartia tonsa, a microscopic copepod, has drastically changed its range because of climate. Photo: H. Dam

Copepods may be small and simple, but they're the foundation for the food web of the Sound, he said. They are a main source of food for the nurseries of all varieties of fish. They are, Dam's former post-doc research assistant, Michael B. Finiguerra adds, the essential links in the food chain to higher marine organisms. "Much of the fish in the Sound consists of stripers, bluefish or flounder. When they're larvae, they eat copepods." says Finiguerra. "Any disruption to that relationship could affect that fishery, and if copepod populations drop with the spawning of blue fish, those larvae won't have any food to eat."

Finiguerra said that both he and Dam are analyzing the effects of weather extremes,



Hans Dam evaluates algal cultures used to maintain copepods in his lab at UConn Marine Sciences.

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such as heat waves on copepods. Because copepods are cold blooded, they are susceptible to temperature changes, and when temperatures are near the maximum for copepod performance even the smallest change can affect the population to a serious extent. "Can copepods deal with a heat wave in their own generation?" asked Finiguerra, "and can this heat wave have an effect on future generations of copepods?"

Finiguerra noted that the copepods are "the link between the grass of the sea, the phytoplankton, and all the higher order organisms." That is why marine scientists like Dam who study this Lilliputian marine world are worried about rising temperatures that have taken place in bodies of water like Long Island Sound as a result of climate change. This temperature increase has been a noticeable problem in the Sound since the 1940's, with almost a 2 degree Celsius increase in the waters since that time, he said. That doesn't sound like much, but it's already had a perceptible impact on the copepods, according to Dam. With the warm water came two big consequences for plankton in the Sound, he said. With copepods there is an inverse relationship between size and temperature, with warmer waters there are smaller copepods. "That means the fish larvae that depend on the species for food are eating smaller organisms."

Secondly, he said, the smaller species have also started to become more prevalent in the winter because the winters have become warmer. The cold-water copepods now have a competitor. "Fish are particular. They have preferences for what they eat," said Dam. "You might see that the fish here in wintertime aren't doing that well. We're seeing that some of the fish are being replaced." Through this latest project, the scientists want to know just how prevalent that is. "Are the species attuned to cold water going to suffer? And to what extent can these species deal with environmental changes to better suit themselves?" Dam said.

To do experiments, copepod samples from the Sound are collected and brought to the laboratory at the Avery Point campus. There they are bred and raised for a few generations under standard conditions, to remove any previous environmental and maternal effects. As Dam mentioned: "We treat them like royalty, raise them in the exact same conditions for three generations to remove their previous history." Then, they expose copepods to simulated heat waves for different periods of time and measure their fitness, survivability and ability to reproduce. Because of the short lifespan of the copepod–just a few weeks–the scientists can test for the adaptation of the individuals in a few generations. Through the simulation, they were able to test what happens to the copepods if heat waves happen early or late in their season of growth.

"If there's an early heat wave, can they cope with the change? What about those that survive and their descendants when they appear in the next year?" he said. Will the ones that survive a heat wave create descendants that won't do as well in colder conditions next time around? The issue pits plasticity, the ability of the individual organism to acclimatize during their lifetime, against evolutionary adaptation (genetic changes across generations). Surprisingly, no one before has looked at the comparison of copepod plasticity vs. their evolutionary adaptation in response to heat waves.

The results of this research thus far may have important implications for fisheries, with the threat of climate change and increasingly warmer waters impacting the growth and food source for many fish larvae. "Their (copepods) growth and behavior will be dictated by the change in climate in each region, and their ability to adapt," said Dam.

Since wrapping up their heat wave simulations both Dam and Finiguerra have focused their attention on ocean acidification occurring in the Sound as climate change increasingly adds carbon dioxide to the waters. "People often ignore copepods affected by acidification because they don't have calcareous shells" said Finiguerra. "They think that copepods aren't affected in a similar way to clams, oysters and other shelled organisms."

The acidification of the water according to Dam "has metabolic consequences such as requiring the copepods to spend more energy maintaining their vital processes than to work on reproducing and growing larger." Ocean acidification and temperature may be working together to stunt the overall population growth of these copepods.

For fisheries, warming and acidification bring serious conservation issues to the table. "Species can be extremely plastic," said Dam. "But the question is: How wide is their temperature or pH envelope and will climate change push them out of it?" The lack of a sustainable food link between primary producers and consumers is likely to have a very tangible effect in the near future. "The kinds of fish out there may look entirely different. It might not be a fishery that's sustainable for consumption." Dam and Finiguerra both hope their work will better inform fisheries management and policymaking for Long Island Sound and other waters.

ABOUT THE AUTHOR:

Tyler G. Martin enjoys science writing and is a UConn alumnus.

Connecticut's Legal Challenges in the Face of Sea Level Rise

by Audrey Elzerman

Yard damage in Old Lyme following Superstorm Sandy. Photo: J. Barrett

Imagine you are a property owner along Connecticut's shoreline and you share a common seawall with your neighbor. Now suppose a storm, one like Superstorm Sandy, destroys that seawall. Do you need permission to rebuild your seawall to protect your property from further erosion, and from whom? What happens if you rebuild, but your neighbor does not? If you suffer further erosion in the next storm, do you have a legal claim against your neighbor or your town? Can you interfere with your neighbor's right to enjoy and use his property as he sees fit if his choices are causing damage to your own?

Connecticut's shoreline is changing more than ever as a result of sea level rise and storm activity. "Storms Irene and Sandy, as well as subsequent nor'easters, have had a major impact on the Connecticut shoreline, causing major erosion in some areas and accretion in others," says Bruce Hyde, Land Use Educator with the University of Connecticut's Center for Land Use Education and Research (CLEAR). The state and its municipalities and property owners must plan for and respond to these physical changes—a process that is raising new types of legal questions.

CLEAR and Connecticut Sea Grant are working together to help governments and property owners prepare for and adapt to shoreline change. One of the ways they do this is through the Connecticut Climate Adaptation Academy (CAA), which addresses questions and concerns associated with climate change and sea level rise. In November, 2015, a CAA workshop, Legal Issues in the Age of Climate Adaptation, provided state and municipal officials and other Connecticut residents the chance to learn and ask questions about Connecticut's regulatory challenges and how shoreline change will affect their interests.

CLEAR and Connecticut Sea Grant partnered with the Marine Affairs Institute at Roger Williams University School of Law (MAI) and Rhode Island Sea Grant Legal Program to follow up on the workshop. MAI staff run the Rhode Island Sea Grant Law Fellow Program, which connects law students with organizations in need of legal research and analysis on ocean and coastal issues. Through this program, I have been working to answer legal questions raised by workshop attendees. We began by separating the questions into four areas, including:

- potential liability of the state, towns, and officials to tort claims brought by property owners;
- potential for regulatory takings resulting from erosion and inundation;
- shifting property and regulatory boundaries resulting from erosion and beach nourishment projects; and
- permitting and liability issues for flood and erosion control structures.

In each area, we researched the Connecticut laws, regulations, and cases needed to answer the questions raised by participants. This research was then compiled into a series of four fact sheets. Hyde says, "in these fact sheets, municipal officials and coastal residents will find information on legal issues pertaining to shoreline protection, property rights and government liability, as well as for longer-term issues such as those caused by sea level rise."

This article provides highlights from my findings in each area. Additional information and detail on each of these topics, including the fact sheets, are available online on the CLEAR website, at: http://climate.uconn.edu/caa/.

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Government Tort Liability

Liability for damage or harm to a person or property as a result of wrongful conduct is known as tort liability. Local governments and governmental entities, their employees, and members of their boards and commissions may be subjected to tort lawsuits in connection with municipal activities like identifying properties at risk of future sea level rise. For example, if a town does not inform the owner of a property it identifies as potentially at risk of flooding, and that property is damaged, may the owner successfully sue the town? What about town employees or board members who made the decision? And conversely, if a town provides flood risk information in a coastal resiliency plan, and property values are reduced in at-risk areas, could affected property owners successfully sue the town or its employees? We analyzed Connecticut's statutes and cases to determine whether and under what conditions the state, a municipality, or government officials may be liable to property owners under tort law for such damage claims.

Generally, the state has sovereign immunity from tort lawsuits based on its decisions, even if they result in damage to individual property owners. Local municipalities and their employees are also protected from liability by statutory and common-law immunities in Connecticut, as are members of municipal boards and commissions.

The general rule is that a municipality is immune from liability for negligence unless the legislature has enacted a statute limiting that immunity. In Connecticut, property owners may sue a local municipality for damages resulting from the municipality's negligent performance of "ministerial" acts. Ministerial acts are those that are done in a set manner without any exercise of judgment or discretion, like issuing a driver's license. Ministerial acts are written out by ordinance, regulation, rule, policy, or other directive.

Conversely, municipalities are not liable for acts or omissions which require the exercise of judgment or discretion—so-called "governmental acts." The law provides immunity for governmental acts and omissions in order to protect the freedom of municipal officers to make decisions independent of the threat of lawsuits. Based on my research, most coastal land use decisions made by municipalities and their agents are discretionary and not ministerial. As a result, no negligence liability is likely for approving or denying permits or for informing residents of areas subject to heightened flood risk. Other specific statutory immunities, such as for permitting decisions, would apply even if general immunities did not.

On the other hand, Connecticut law provides several exceptions from governmental act immunity, including acts that involve malice, statutes that explicitly assign liability to a municipality, and any circumstance that demonstrates to a public official that failure to act would be likely to subject an individual person to imminent harm. If any of these exceptions applied, a municipality could be liable; however, these exceptions are narrowly tailored and have not been used in lawsuits surrounding coastal management decisions.

Government Takings

The "takings clause" is a provision in both the federal and state constitutions requiring the government to compensate property owners when its actions "take" private property. We reviewed federal and state takings cases to determine when and how state regulations may require the government to compensate a property owner for limiting the use of his or her land.

A taking may occur through physical occupation of property or through a regulation that unconstitutionally restricts the use of property. Takings law cannot be changed through legislation alone because it is grounded in the federal and state constitutions. As a result, local and state governments must either plan for payment of compensation when enacting laws and regulations that will result in takings or tailor their efforts to avoid causing a taking.

Under *Lucas v. South Carolina Coastal Council*, any regulation that deprives a property owner of complete beneficial or economic use of his or her property is a *per se*, or total, taking under the federal constitution. Prior to *Lucas*, Connecticut courts adopted a similar, but even broader, "practical confiscation" test in *Bauer v. Waste Management of Connecticut*, under which a taking was held to occur when a regulation deprived a property owner of any "economically viable use of his land other than exploiting its natural state" –even if the regulation removed less than 100% of the value of the property. Connecticut courts have not significantly reconsidered *Bauer* since *Lucas*, however, so the continuing importance of the practical confiscation test is uncertain.

A regulation that diminishes the value of property but does not give rise to a *per se* taking may nonetheless require compensation. Courts determine whether a taking has occurred in such cases under the federal constitution by applying a three-factor balancing test laid out by the Supreme Court in *Penn Central Transportation Co. v. City of New York*. Connecticut courts apply an analogous three-factor balancing test to determine whether an action has created a "significant restriction" on land use that must be compensated. The three factors considered to determine whether a regulatory taking has occurred in Connecticut are: (1) the degree of diminution of the value of the land; (2) the nature and degree of public harm to be prevented; and (3) the alternatives available to the property owner. Government inaction can also result in a taking in the rare case where the government failed to

carry out a mandatory action and the property owner detrimentally relied on it happening.

Recent federal takings decisions have shed new light on takings related to flood control infrastructure. In *Arkansas Game & Fish Commission v. U.S.*, the Supreme Court held that the U.S. Army Corps of Engineers could be held liable under takings for harm to state forest areas caused by deviations from the Corps' normal water diversion operations spelled out in its Water Control Manual. In *St. Bernard Parish v. U.S.*, the Court of Federal Claims similarly determined that the Corps could be liable for failure to properly maintain the Mississippi River Gulf Outlet, resulting in increased hurricane-related storm surge and flooding in New Orleans. These holdings suggest that creation and maintenance of such infrastructure may both result in takings liability for responsible governments if they enhance coastal flooding in other areas or fail due to improper maintenance.

These cases suggest that Connecticut municipalities should carefully consider the takings impacts of regulations. When making regulations related to coastal management and land use, they may be subject to liability—especially if they create flood or erosion control structures that cause harm in unprotected locations or which may fail if improperly maintained.

Property and Permitting Boundaries at the Shoreline

The determination of the boundary between public and private areas of the shoreline can be a topic of substantial interest and dispute, especially as the environment changes over time. Two separate types of boundaries exist at the shoreline: *property* boundaries that separate private property from public trust lands, and *regulatory* boundaries that define where state agencies have jurisdiction for implementation of state law.

Sand erosion in Old Lyme after a coastal storm. Photo: J. Barrett

Coastal property boundaries are based on common law principles expressed in cases, which define the shoreline boundary in Connecticut as the mean high-water mark. As a result, anything above the mark is private property, and lands (including submerged lands) below the mark are held in trust for the public by the state.

Regulatory boundaries under the state Coastal Management Act are based on the "coastal jurisdiction line" (CJL), which is based on a "specifically determined elevation." Under Connecticut law, any "dredging, erection of structures and placement of fill in tidal, coastal or navigable waters" waterward of the CJL requires a permit from the Department of Energy and Environmental Protection (DEEP). The CJL does not affect or alter common law principles or the locations of the property lines that are determined based on those principles.

We analyzed how these two boundary lines may shift over time as a result of sea level rise and shoreline change. Both property and regulatory boundaries may shift over time as a result of sea level rise and gradual and sudden changes in the shoreline, but they do so differently.

Changes in the property boundary depend on whether shoreline change occurs gradually or suddenly. The shoreline may change gradually through accretion and erosion, or it may undergo sudden changes, which are known as avulsion. Storms are a classic avulsive events that may change a shoreline dramatically in a short space of time. Beach nourishment, or the addition of sediment to restore a shoreline or widen a beach, is also classified as avulsion. Shoreline property boundaries shift landward and waterward due to erosion and accretion. However, avulsion does not move property lines. As a result, property owners may restore their land back to the property line if lost to a storm; however, they do not gain title to new beach areas added as a result of nourishment.

The location of the CJL is affected by shoreline changes, but is unaffected by the speed of that change. As a result, the CJL will move inland or waterward due to either accretion and erosion or avulsion. If the CJL moves landward after an avulsive event, then a permit logically will be required for recovery of areas that remain private property but previously were landward of the CJL. DEEP has simplified the permitting process in such cases by issuing a "General Permit for Coastal Storm Response" that authorizes landowners to undertake certain activities in preparation for or response to coastal storm events without an individual permit or certificate. The general permit goes into effect after a declaration by the DEEP Commissioner and authorizes certain activities to recover land lost to avulsion. Federal permits, however, may also be required before storm response activities can begin.

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Flood and Erosion Control Structures

Flood and erosion control structures protect much of Connecticut's shoreline. A wide variety of flood and erosion control structures are used along Connecticut's coastline. These include structures placed in the water, along the shoreline, or inland, and they include "armoring" and "green infrastructure" approaches. Coastal flood and erosion control structures are subject to federal, state and local permitting. A structure's location and design will determine who can deploy it and the permitting process. This section reviews some of the key permits that may be required.

At the federal level, any structure waterward of the high tide line requires a permit from the U.S. Army Corps of Engineers under section 404 of the Clean Water Act. At the state level, structures waterward of the CJL require a permit from DEEP. Minor projects meeting certain conditions, including repair of a flood and erosion control structure, are presumptively approved. Other projects will require an individual permit or may be authorized under a Certificate of Permission. Finally, the municipal zoning commission must approve the coastal site plan for all proposed shoreline flood and erosion control structures landward of the CJL. Structures must be approved if "necessary and unavoidable" to protect certain types of property, including infrastructure and houses built prior to 1995.

Seawalls and breakwaters are two common types of flood and erosion control structures of interest to stakeholders that illustrate differing permit requirements for structures placed on land and in the water. Breakwaters, by definition, are placed in the water. As a result, they are on public land and therefore require public agency leadership. Once proposed, they will require permits from both the Army Corps and DEEP, as well as municipal approval. Permitting for seawalls depends on where they are located. Seawalls located partially or wholly below the CJL will in most cases require both a DEEP permit and a federal Section 404 permit. Conversely, no permit is required from either DEEP or the Corps for a seawall located above the CJL and high tide line. In such cases, however, municipal approval is required through the coastal site plan review process. And seawalls located both above *and* below the CJL will require municipal, state, and federal approvals.

Permitting and construction of flood and erosion control structures may also give rise to lawsuits challenging government action or seeking damages from neighbors.

Denial of a permit for construction of a seawall may lead a property owner to consider lawsuits to challenge the permit process and decision or to seek damages from the loss of property. Legal challenges by property owners to Connecticut permit requirements as a whole have been denied by the state courts, so successful challenges to the permit would need to allege a specific failure during the permitting process. A successful suit of this type would most likely result in reconsideration of the permit application rather than financial penalties.

Lawsuits among neighbors may arise if a seawall pushes waves onto neighboring properties or causes increased erosion there. Similarly, declining to build or failing to maintain a seawall may allow erosion behind a seawall constructed by a neighbor. Theories of liability in such cases may include violation of the duty to provide lateral support, trespassing, and/creating a private nuisance.

No Connecticut cases have yet addressed questions of nuisance based on seawall construction or maintenance, but such questions have been raised elsewhere. A series of Washington cases held that claims under both nuisance and trespass by a plaintiff against a neighbor for causing seawater flooding as a consequence of increased seawall height could proceed even though the defendant had obtained a permit for the seawall from the state agency. Similarly, Massachusetts courts have allowed nuisance, trespass, and negligence claims arising from erosion related to construction of groins and revetments. Each such case has turned on whether the plaintiff could show that the structures caused substantial harm to the plaintiff. The existence of a state permit for the activity has not barred recovery in these cases; on the other hand, violation of permit conditions, including the duty to maintain a seawall, could be relevant factors supporting liability.

Conclusion

Understanding Connecticut law related to liability and permitting around the shoreline is critical for municipalities and others seeking to carry out governmental duties without incurring current or future legal costs. In many instances, state law shields towns and their officials from liability, but in some instances, municipal decisions may give rise to liability from takings or other sources. Municipalities can identify potential liability through careful forward planning, a task that is increasingly important due to sea level rise and increased storm activity affecting shoreline properties.

ABOUT THE AUTHOR:
Audrey Elzerman is a Rhode Island Sea Grant Legal Fellow.

Coastal towns awash in hard choices

by Angela Bazydlo

We see it on the news–video footage of waves crashing violently against seawalls, water flooding streets and making them impassable, beaches eroding, and waterfront homes collapsing into the surf. As sea levels rise, officials and residents of coastal communities must make decisions about whether and how to address these problems. The solutions can be costly, and all involve tradeoffs.

Robert Johnston, Clark University professor of economics and director of the George Perkins Marsh Institute, shared insights into research he's conducted in communities that grapple with these issues in a recent talk, "The Economics of Sea Level Rise, Coastal Vulnerability and Adaptation: Choices and Tradeoffs in New England."

Johnston has spent roughly 25 years conducting research in natural resource economics, including work with experts who use biophysical modeling to forecast the consequences of coastal storms and flooding, identifying which coastal areas are likely to flood and the resources that are likely to be affected. Through focus groups and questionnaires, he then works with the residents of coastal communities to determine how they value these impacts–be it effects on homes, beaches or coastal habitats–and what measures they would be willing to take to protect these natural and built resources. His research on coastal adaptation has been supported by agencies including the Northeast Sea Grant Consortium (through the MIT and Woods Hole Sea Grant College Programs), the National Science Foundation, and the Delaware Department of Natural Resources and Environmental Control.

Johnston shares his research findings with officials from the local to federal level and says the greatest impacts of this information are often at the local and regional levels.

"Currently, local and regional decisions are often made with little economic information, and the information that is available can be misleading," he noted. "For example, coastal adaptation decisions are often justified based primarily on 'replacement cost,' or the predicted monetary cost to repair structures damaged in a flood. But the cost to fix something is not the same as the benefit that thing provides. Because of this, decisions based on replacement costs alone can make society worse off than they are now."

Coastal property in Connecticut, after Sandy caused erosion.
Photo by Adam Whelchel, TNC

And Johnston says there's a difference between social benefit and monetary cost.

"Economics isn't all about money and markets and income. Economics is about tradeoffs, and the type of decisions that are best for society," Johnston said.

Among the questions often faced by seaside communities: When and how should vulnerable areas be protected? Where protection is warranted, should it be accomplished using built structures such as seawalls or natural infrastructure such as coastal wetlands with the capacity to absorb and slow floodwaters? To what extent are residents willing to accept greater risks to some coastal assets in order to protect others – what tradeoffs are they willing to make? What level of cost are community residents willing to bear to protect valued built and natural assets? How should communities balance the protection of private property rights with other adaptation priorities, for example, if residents wish to build or rebuild homes in flood-prone areas?

Local officials are often surprised by his findings.
Johnston noted a 2012 study he conducted in Delaware Bay, in which the "no action" policy alternative—wherein the state would take no action to protect the studied communities from ongoing beach erosion—was the option that generated the greatest net benefit to Delaware residents. This outcome was a surprise to many officials and stakeholders, and motivated decision-makers to consider new options for protecting vulnerable communities.

He also referenced an experiment he conducted post-Hurricane Sandy in the Connecticut towns of Waterford and Old Saybrook, two seaside communities that are geographically close but have very different vulnerabilities.

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Home being raised in Old Saybrook, now a typical sight on the Connecticut shore. Photo: Judy Preston

With funding from the Northeast Sea Grant Consortium, Johnston worked in partnership with Adam Whelchel, director of science at The Nature Conservancy in Connecticut, and his team to forecast possible effects of coastal storms and flooding on the two towns through 2025, and conducted more than a dozen focus groups with residents to discuss different adaptation methods. Based on the outcomes of these focus groups and forecasts, he developed and administered a "choice experiment" questionnaire to determine what kinds of adaptations residents would be willing to fund through additional taxes and fees, based on their votes over many different adaptation options with different forecast outcomes and costs.

In both communities, Johnston's research found high values for the protection of natural assets such as beaches, and negative values associated with the construction of new hard defenses like seawalls. Surprisingly, most residents placed relatively low values on the protection of waterfront homes.

In Old Saybrook, for example, Johnston found that the residents were willing to pay to avoid widespread construction of new hard defenses. Although Old Saybrook residents valued home protection, they were not willing to accept "hardening of the shoreline" in order to achieve this protection. Research also revealed differences between the two communities. While both communities valued the protection of coastal marshes, values for marsh protection were higher in Waterford where these natural habitats are scarcer.

These results came as a surprise to some officials in the two towns, as they contradict the commonly held belief that the protection of homes and roads from flooding is a top priority of coastal residents.

"Contrary to popular belief, most residents in these areas do not place high value on communities taking action to protect private property from flooding. Residents tend to view private property protection as the responsibility of individual homeowners," Johnston explains. "They would prefer to

see scarce public resources used to protect natural assets such as beaches that benefit the entire community."

While the owners of waterfront property gain the benefits of adaptation that protects these properties, the costs associated with these actions are typically spread among people who may or may not benefit directly.

"There are important equity issues at play," explains Johnston.

Because officials in these communities may hear from only a small number of vocal residents on these issues, they can get a skewed perspective on public values.

"This is why research of this type is so important," notes Johnston. "It reveals the values of the entire public, whether or not they choose to show up at a public meeting or write letters to public officials. We often find a substantial difference between the values of the broader public and the values of the distinct few who are politically active."

Johnston emphasizes that findings such as these would remain unknown without the work of economists and other social scientists.

"We don't always know what the answers are, and that's why we do research. That's why it's so important to do what we do here at Clark."

ABOUT THE AUTHOR:
Angela Bazydlo is associate director of Media Relations at Clark University in Worcester, Mass. Angela publicizes University news, campus events and student achievements, and promotes faculty scholarship and expertise.

Residents of coastal Old Saybrook said that while they value home protection from storms and flooding, they preferred not to have hard structures built. Scene is Plum Cove in that town. Photo: Judy Preston

WHERE HAVE ALL THE BABY HORSESHOE CRABS GONE?

by Jo-Marie Kasinak and Jennifer H. Mattei

The American horseshoe crab, *Limulus polyphemus* is one of four species of horseshoe crabs in the world and is the only species which lives along the Atlantic coast of the United States, including in Long Island Sound (LIS). Horseshoe crabs are arthropods and are more closely related to spiders and scorpions than true crabs. The adults are habitat generalists, thus can tolerate a wide range of water salinities, temperatures, and dissolved oxygen concentrations; consume a variety of prey items; and are not choosy about thier mates. These characteristics have allowed the horseshoe crab to survive for over 450 million years; their basic shell morphology remains essentially unchanged from their fossil ancestors that swam with the dinosaurs. These remarkable benthic invertebrates are important ecologically; providing food for migratory shore birds, and habitat for epibionts, and economically; where they are harvested for bait by fishermen, and for their blood to be used in the pharmaceutical industry. They spend most of their lives in the water, only coming up to beaches to spawn during the early summer. During one spawning season a female horseshoe crab will make several nests, and can lay up to 120,000 eggs.

Top Left: Newly hatched horseshoe crab larva.
Photo: M. Beekey

Where have all the baby horseshoe crabs gone? Long time passing…When will they ever learn, when will they ever learn?

(Lyrics borrowed from Pete Seeger, popularized by Peter Paul & Mary, 1960s)

We were recently given the opportunity by Connecticut Sea Grant to explore the land-sea interface of the Sound from the perspective of juvenile horseshoe crabs. In Connecticut, it is highly unlikely that any shoreline is left that has not been modified in some way by human activity. Much of that shoreline is uninhabitable for young horseshoe crabs.

Our past studies of adult spawning horseshoe crabs have demonstrated that the population in Long Island Sound is reproducing well below its maximum rate and we are trying to find out why. We observed that only 12% of the spawning crabs are newly molted young adults (based on shell condition). For the Sound's population to increase, more juvenile horseshoe crabs need to survive through the 10 years of development required for that terminal molt to occur and to make it into the breeding population. Of the millions of eggs that are deposited on our beaches every May and June only a fraction of the hatchlings (~0.001%) make it to adulthood. Estimates from a study in Delaware found that only 3 in 100,000 horseshoe crab babies survive their first year of life!

Our Sacred Heart University research team consisting of professors, graduate and undergraduate students surveyed 14 beaches (all known to have spawning adult crabs) for juveniles from Rye, New York to Greenwich, Connecticut and all the way east to Groton. We also checked several islands off the Connecticut coast and included trips to Block Island and Plum Island. A third of the beaches we surveyed looked perfectly habitable and flat yet were devoid of any juveniles. When we did find a beach with juvenile horseshoe crabs, usually in late June through September, we would find newly-hatched individuals (young of the year with a shell width ranging from 5-13mm). There were generally less than 100 individuals found during an afternoon search at low tide. We would also find a dozen or so juveniles from 20-40mm, 1-3 years old based on size. After that, larger, older juveniles were rare to absent. On rare occasions we might find a molt larger than 50cm. Where are all the baby horseshoe crabs? On our trip to Block Island we found them!

Adult horseshoe crab age distribution consisted of 33% newly molted adults and 50% middle-aged crabs. This type of age distribution is typical for a stable or expanding population. The survey of juvenile horseshoe crab sizes on Block Island ranged from 5 to nearly 100 millimeters (mm). We only had two days to conduct our survey but during that time we also found many larger molts of older juveniles (between 100 and 150mm). As for many aquatic species, appropriate nursery habitat is essential to the survival of juvenile horseshoe crabs. Great Salt Pond on Block Island had it all. The water was clear and calm. The horseshoe crab food--benthic invertebrate populations—were abundant and diverse, as compared to 10 other beaches along the Connecticut coast. Based on historical use records, pollution was minimal; human waste, pesticides, and fertilizer use have been particularly restricted.

Once we arrived back in Connecticut we decided to check out Barn Island. It is known as one of the most protected salt marshes left in the area. There had to be juveniles in these salt ponds!

We searched but could not find any evidence of horseshoe crabs. No tracks, no molts, nothing. Later, we found out that these ponds have been intensely managed for mosquito population control. Thus, the waters have a long history of pesticide use.

Interested in learning more about juvenile horseshoe crabs and Project Limulus? Visit www.projectlimulus.org

Spawning adult horseshoe crabs at Great Salt Pond, Block Island, RI. Photo: J. Mattei

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