Accounting for Outcome Uncertainty in Ecosystem Service Valuation: The Case of Coastal Adaptation

Christos Makriyannis

Department of Economics, Clark University, Worcester, MA, USA

Robert J. Johnston

George Perkins Marsh Institute and Department of Economics, Clark University, Worcester, MA, USA

Introduction

- Coastal communities face hard choices – know they need to adapt but do not know how
- Without guidance on social benefits, decisions are based on unverified assumptions (e.g., protecting homes and infrastructure is most important).

Tradeoffs

- Natural systems vs. built infrastructure

Uncertainty

- Future climatic conditions
- And which homes to protect?

These make adapting to coastal storms & flooding a subject of debate

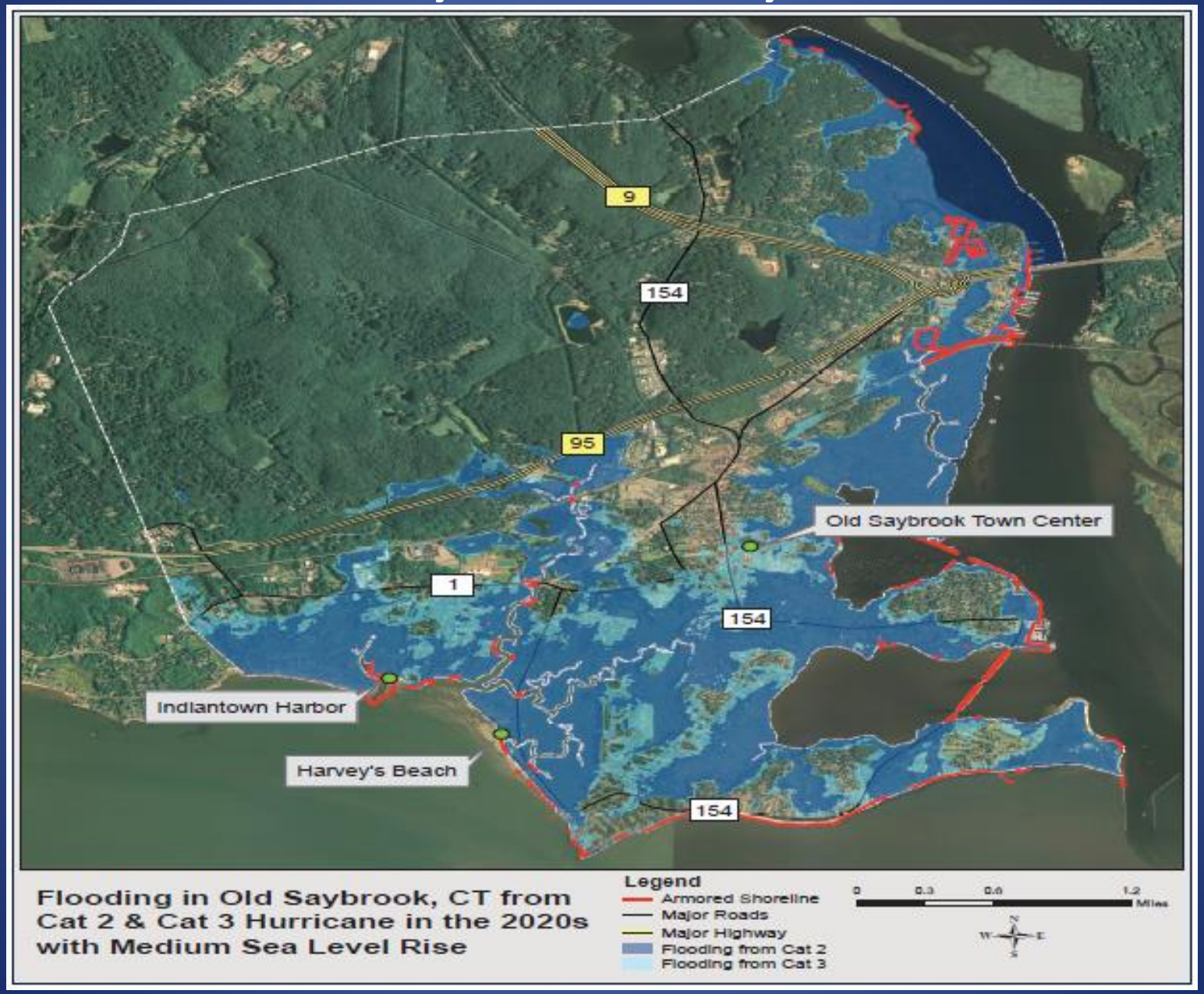
Why Value Ecosystem Services (ES) and Associated Tradeoffs?

- To *quantify tradeoffs* based public's values and preferences
- Value of what is gained and lost – expressed in common monetary metric
- *Ignoring uncertainty distorts values*
- Quantifying tradeoffs while accounting for uncertainties: At the heart of adaptation efforts that seek to maximize social welfare
- Current studies focus largely on estimating damage costs and inadequately account for uncertainty

How to Value Ecosystem Services and Associated Tradeoffs?

- The choice experiment survey method
- Specialized survey depicting hypothetical but realistic market
- Presents relevant, concise information
- Asks respondents to “vote” or choose from alternative adaptation options
- Reported choices analyzed to estimate values

Case Study – Old Saybrook, CT



Key Research Questions

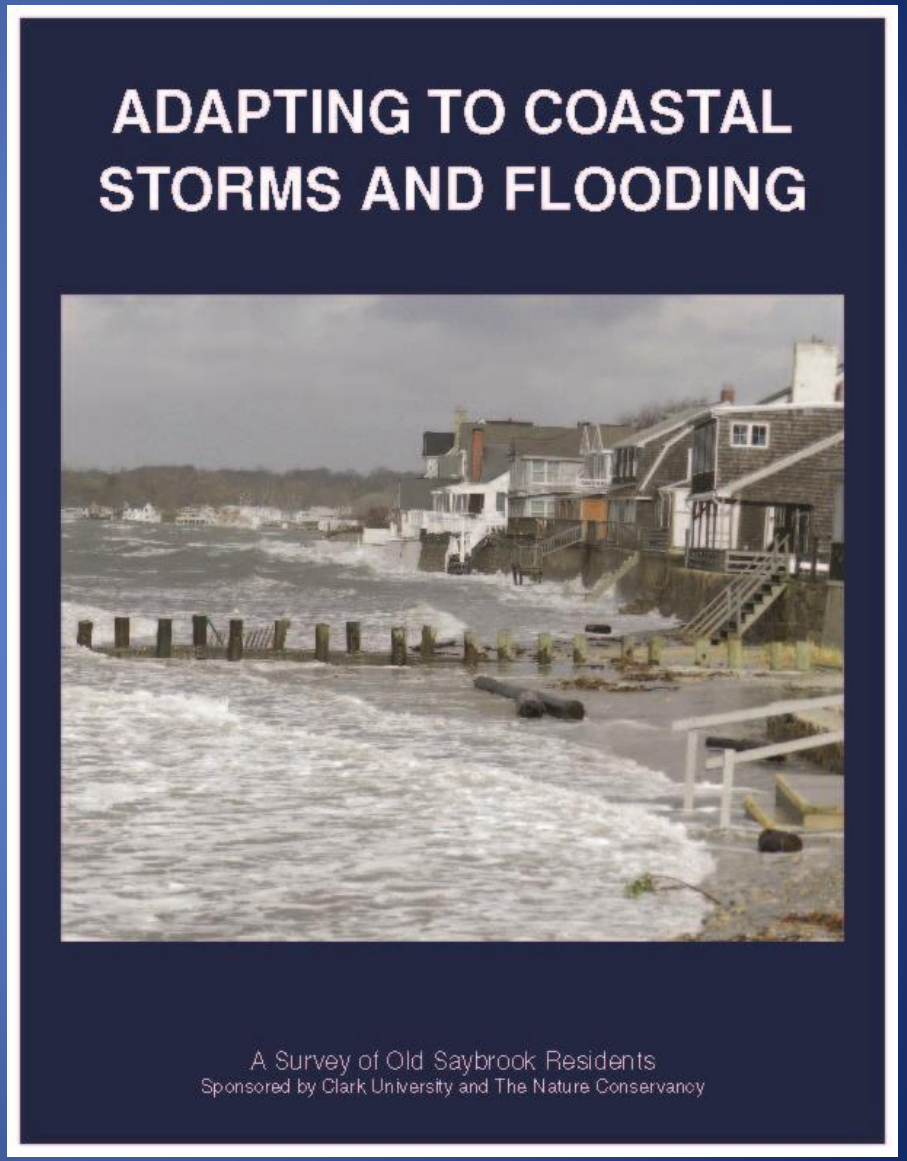
1. How does uncertainty influence Old Saybrook residents' adaptation values?

2. What are residents' values for ecosystems vs built infrastructure ?

3. What kind of adaptation strategy would residents most likely vote for?

Survey Development and Testing

- Developed over two years
- All information pretested in 13 focus groups with residents and meetings with town planners and stakeholder groups
- Prior to choice questions survey provided a combination text, graphics, GIS maps and photographs to convey information.



Information Sources

- Nature Conservancy's Coastal Resilience program (along with other sources) - data layers, inundation scenario projections, photographs
- NOAA Coastal Services Center – graphics

Advantages/disadvantages of hard and natural defenses

HARD DEFENSES

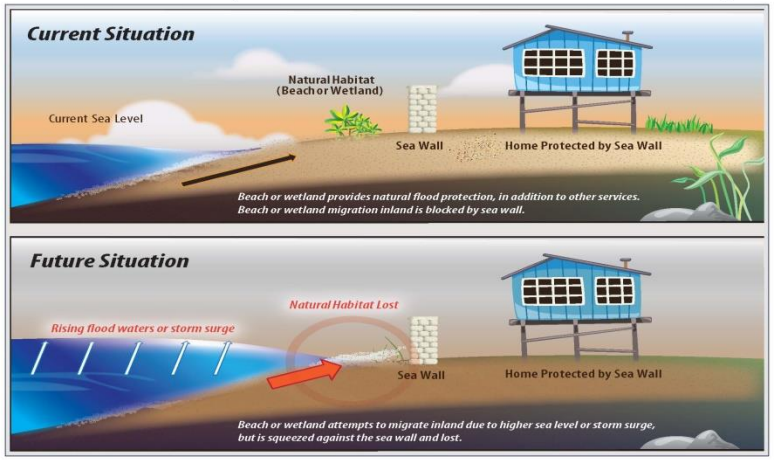
Hard defenses include the **use of coastal armoring such as seawalls and bulkheads** to hold back the sea. Roads and bridges can be raised to prevent flooding. Buildings can be retrofit, for example by raising them on pilings.

Advantages: Compared to other approaches, hard defenses often provide the most effective protection for homes, facilities and transportation.

Disadvantages: Hard defenses can be costly to build and maintain. Extreme floods can breach these defenses. While hard defenses can sometimes be used to maintain beaches, wetlands and other natural areas, they can also cause natural areas to be lost.

Example of Hard Defenses in Connecticut

How can hard defenses cause the loss of natural areas? As waters rise, natural areas can be squeezed between the water and hard defenses. Hard defenses can also deflect wave energy onto other natural or developed areas. So natural areas can be flooded or washed away:



SOFT OR NATURAL DEFENSES

Soft defenses include beaches, dunes, wetlands and other natural areas that have the ability to absorb and slow floodwaters. Increasing soft defenses requires preservation and restoration of natural areas. It can also require restrictions on coastal development.

Advantages: Soft defenses can provide effective protection for homes, facilities and transportation. They also preserve beaches, wetlands and other natural areas as habitat and public amenities.

Disadvantages: Compared to hard defenses, soft defenses often provide less effective protection for homes, facilities and transportation. Some flooding can still occur in severe storms.

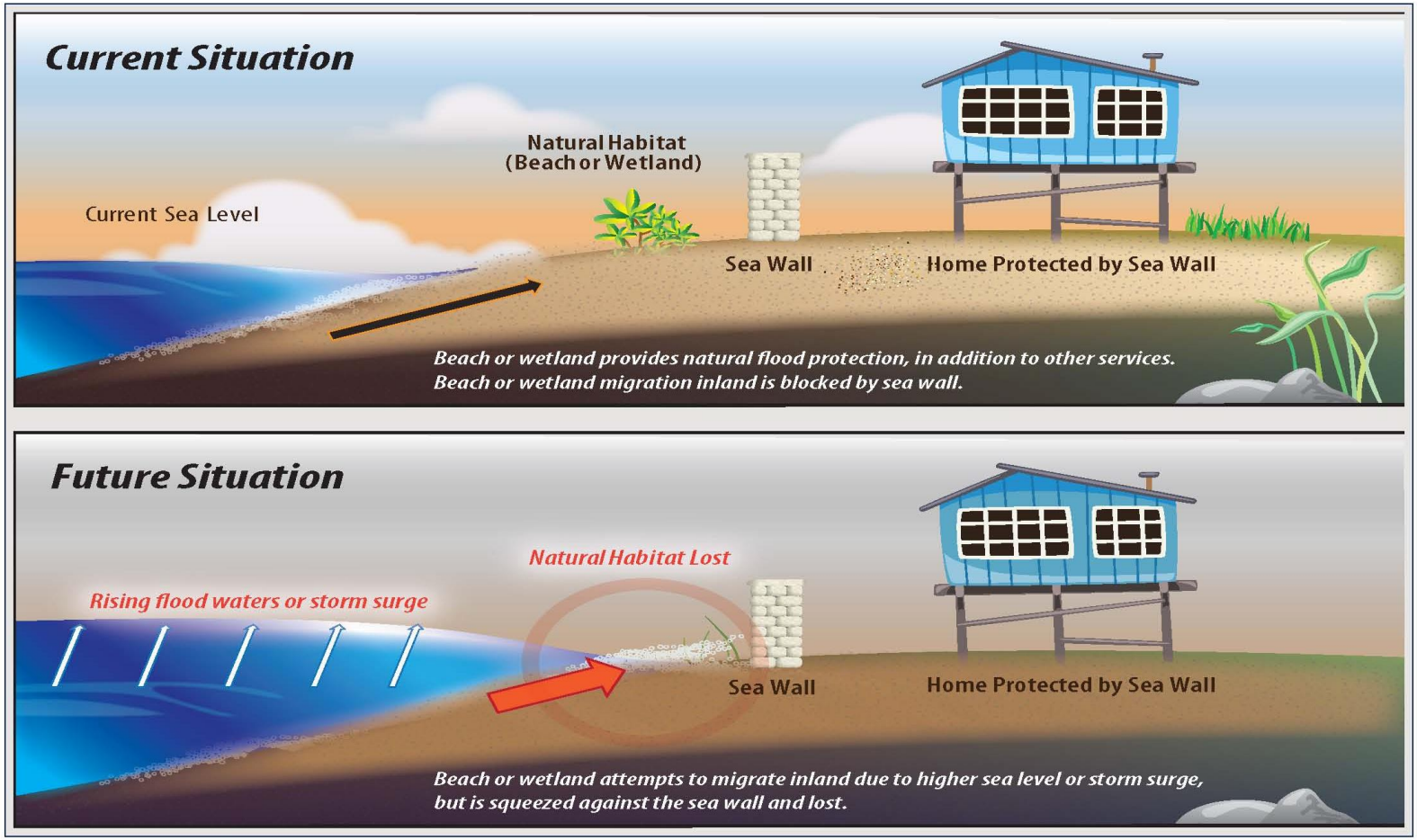
Example of Soft Defenses in Connecticut

In addition to flood protection, coastal wetlands and beaches in Connecticut provide natural services. Examples include:

- Coastal wetlands host an average of 19 to 24 bird species per acre
- Highly productive coastal marshes can produce up to 300 pounds of fish and shellfish per acre annually
- Coastal wetlands filter, clean and store water
- Beaches and coastal marshes provide natural views and recreation

Associated tradeoffs

How can hard defenses cause the loss of natural areas? As waters rise, natural areas can be squeezed between the water and hard defenses. Hard defenses can also deflect wave energy onto other natural or developed areas. So natural areas can be flooded or washed away:



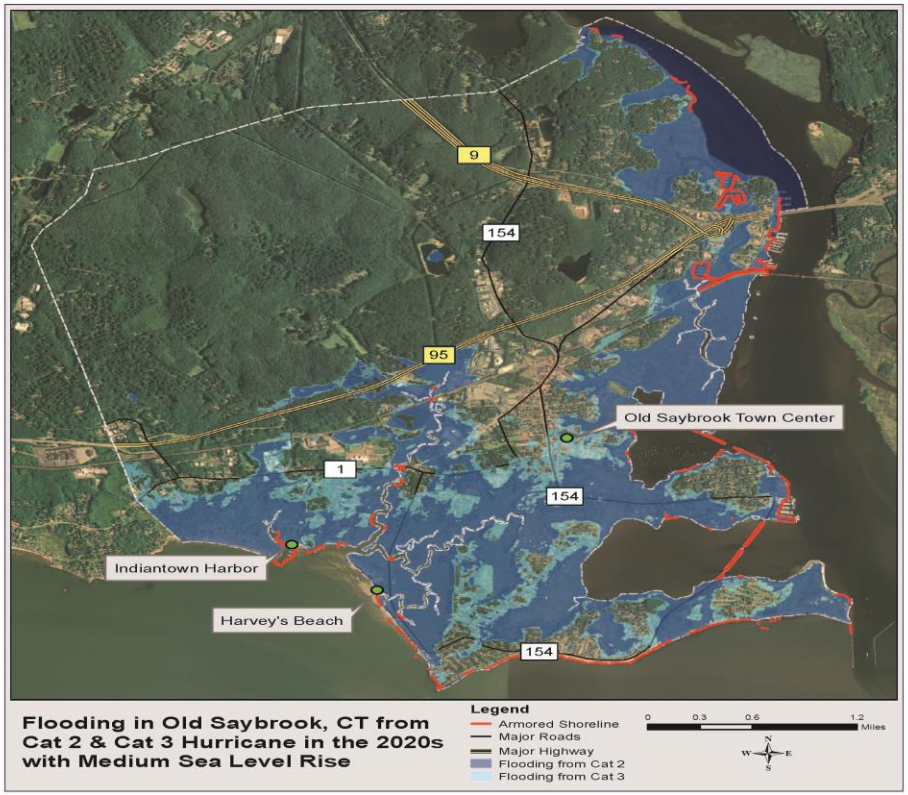
Flood scenarios in mid-2020s

PREDICTING THE FUTURE RISK

This survey asks you to consider different options that Old Saybrook might use to protect against coastal storms and flooding, and choose the ones you prefer.

To help make choices such as these, scientists have developed forecasts of the type of flooding that would occur in the mid-2020s, under different scenarios.

For example, the map below shows the expected flooding in Old Saybrook under moderate intensity (Category 2) and high intensity (Category 3) hurricanes in the mid-2020s. Conditions would approach these scenarios gradually. The Category 2 scenario is similar to the flooding caused by Hurricane Sandy in 2012, while the Category 3 scenario is slightly more extensive.



Flooding in Old Saybrook, CT from Cat 2 & Cat 3 Hurricane in the 2020s with Medium Sea Level Rise

Storm Event Uncertainty

WHAT IS THE RISK?

Scientists categorize hurricane intensity by wind speed. Hurricanes that rank higher are more intense and pose greater risks.

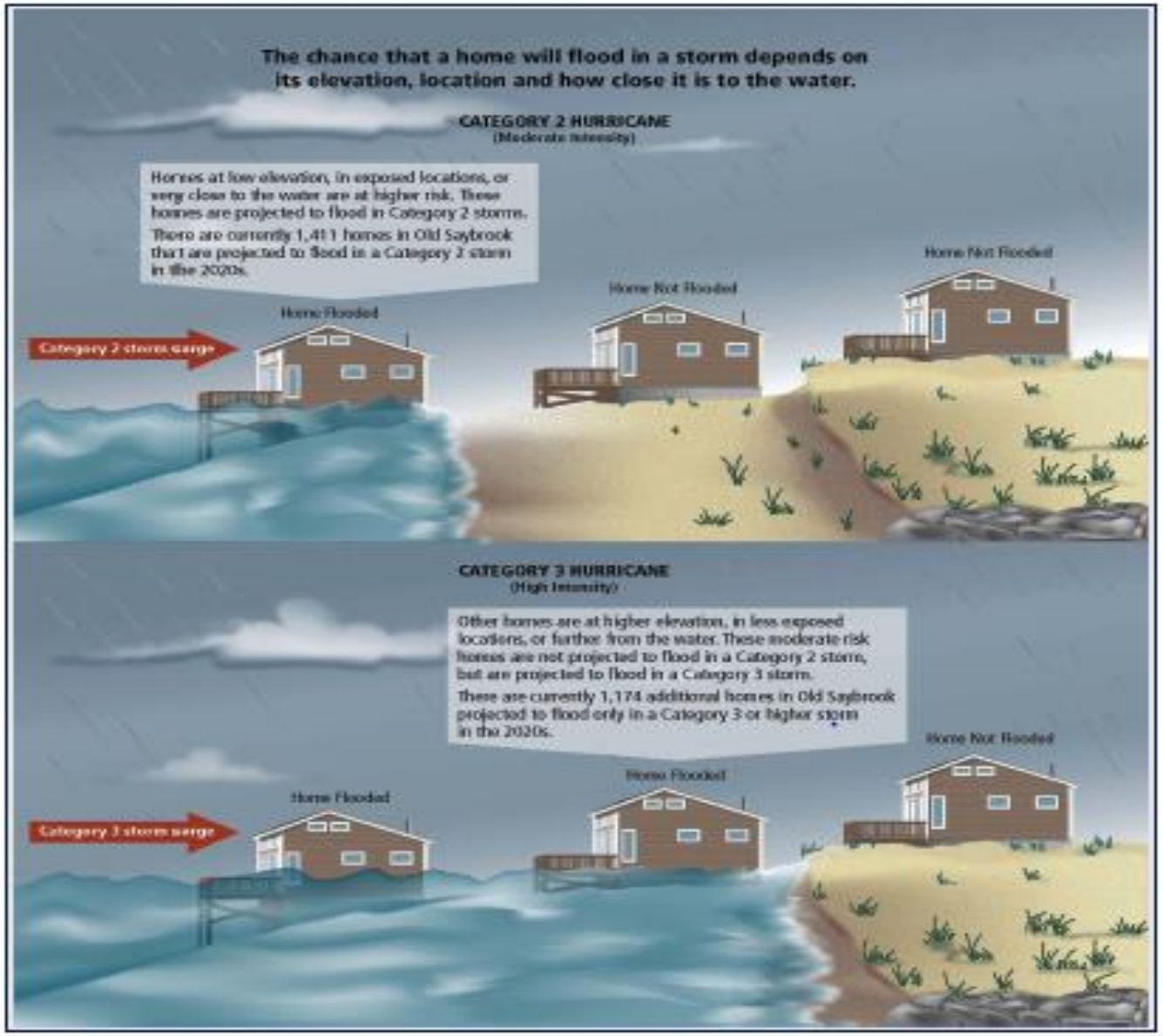
Category	Wind Speed	Hurricane Intensity
Category 1	74 - 95 miles per hour (mph)	Low
Category 2	96 - 110 mph	Moderate
Category 3	111 - 130 mph	High
Category 4	131 - 155 mph	Very High
Category 5	156 mph or higher	Extremely High

Over the last 75 years, Old Saybrook has been struck by a **Category 2 storm in 1960, 1985 and 1991**, and by a **Category 3 storm in 1938 and 1954**. There have been no Category 4 or Category 5 storms. Although Hurricane Sandy was a Category 2 storm off the New Jersey coast, it weakened to below hurricane intensity before it reached Connecticut.

Based on past storm events, scientists estimate that there is approximately a **55% (or about one in two) chance that a Category 2 storm will strike Old Saybrook at least once by the mid-2020s** (0% would mean there is no chance and 100% would mean it is absolutely certain).

In contrast, scientists estimate that there is approximately a **20% (or one in five) chance that a Category 3 or higher storm will strike Old Saybrook at least once by the mid-2020s**.

HOMES AT DIFFERENT FLOOD RISK



Adaptation Outcomes

Methods and Effects of Protection	What it Means
 **Homes Flooded in Category 2 Storm**	The percentage of Old Saybrook homes at relatively high risk of flooding. These homes are expected to flood in a **Category 2 or higher** storm in the mid-2020s. With no new action, **28%** of homes (1,411 of the current 5,034 homes in Old Saybrook) will be in this higher risk category by the mid-2020s.
 **Homes Flooded Only in Category 3+ Storm**	The percentage of Old Saybrook homes at moderate risk of flooding. These homes are expected to flood **ONLY** in a **Category 3 or higher** storm in the mid-2020s. They are not expected to flood in a Category 2 storm. With no new action, **23%** of homes (1,174 of the current 5,034 homes in Old Saybrook) will be in this moderate risk category by the mid-2020s.
 **Wetlands Lost**	The percentage of Old Saybrook's coastal marshes expected to be lost by the mid-2020s due to flooding or erosion. With no new action, **5%** of Old Saybrook's coastal marshes (25 of 497 acres that exist today) are expected to be lost.
 **Beaches and Dunes Lost**	The percentage of Old Saybrook's beaches and dunes expected to be lost by the mid-2020s due to flooding or erosion. With no new action, **10%** of Old Saybrook's beaches and dunes (about 3 of 30 acres that exist today) are expected to be lost.
 **Seawalls and Coastal Armoring**	The percentage of Old Saybrook's coast shielded by hard defenses. With no new action, **24%** of Old Saybrook's coastline (12 of 50 miles) will have hard defenses by the mid-2020s. This is the same level as today.
$ **Cost to Your Household per Year**	How much the option will cost your household per year, in unavoidable taxes and fees. Assume that these funds are legally guaranteed to be spent only on the coastal protection option that you vote for.

Sample Question

Methods and Effects of Protection	Result in 2020s with NO NEW ACTION	Result in 2020s with PROTECTION OPTION A	Result in 2020s with PROTECTION OPTION B
	No Change in Existing Defenses	More Emphasis on SOFT Defenses	More Emphasis on SOFT Defenses
 **Homes Flooded in Category 2 Storm**	**28%** 1,411 of 5,034 homes expected to flood in a Category 2 storm	**32%** 1,611 of 5,034 homes expected to flood in a Category 2 storm	**28%** 1,411 of 5,034 homes expected to flood in a Category 2 storm
 **Homes Flooded Only in Category 3+ Storm**	**23%** 1,174 of 5,034 homes expected to flood only in a Category 3+ storm	**23%** 1,174 of 5,034 homes expected to flood only in a Category 3+ storm	**27%** 1,359 of 5,034 homes expected to flood only in a Category 3+ storm
 **Wetlands Lost**	**5%** 25 of 497 wetland acres expected to be lost	**2%** 10 of 497 wetland acres expected to be lost	**2%** 10 of 497 wetland acres expected to be lost
 **Beaches and Dunes Lost**	**10%** 3 of 30 beach acres expected to be lost	**16%** 5 of 30 beach acres expected to be lost	**16%** 5 of 30 beach acres expected to be lost
 **Seawalls and Coastal Armoring**	**24%** 12 of 50 miles of coast armored	**24%** 12 of 50 miles of coast armored	**24%** 12 of 50 miles of coast armored
$ **Cost to Your Household per Year**	**$0** Increase in annual taxes or fees	**$125** Increase in annual taxes or fees	**$95** Increase in annual taxes or fees
HOW WOULD YOU VOTE? (CHOOSE ONLY ONE) I vote for	☐ I vote for **NO NEW ACTION**	☐ I vote for **PROTECTION OPTION A**	☐ I vote for **PROTECTION OPTION B**

Data Analysis

- 1,152 risk surveys mailed to Old Saybrook residents with a 32.59% response rate
- CE with 3 choice sets, each with 3 policy options (No New Action, Option A, Option B)
- 368 observations
- Models estimated using Mixed Logit with 500 Halton draws

Someone has To Pay for Coastal Adaptation

- When it comes down to it…how much of their money are people willing to put down?
- And for what?

Willingness-to-Pay (WTP)
(Per %, per household, per year)

Choice Attribute	RISK Model WTP
Homes2 Flooded	- $41.68**
Homes3 Flooded	- $50.45**
Wetlands Lost	- $54.13**
Beaches Lost	- $33.92***
Seawalls	- $26.60

Note: ***, **, * ==> Significance at 1%, 5%, 10% level

Willingness-to-Pay
(Per *unit*, per household, per year)*

Choice Attribute	Risk Model WTP
Homes2 Flooded	- $0.83** / home2
Homes3 Flooded	- $1.00** / home3
Wetlands Lost	- $10.89** / acre
Beaches Lost	- $113.07*** / acre
Seawalls	- $53.20 / mile

What Would be Residents' Value of Protecting a Home if They Were Certain a Cat. 2 or 3 Storm Would Occur?

Choice Attribute	Risk (Expected) Value	"Certainty Equivalent" Value
Homes2 Flooded	- $0.83 / home2	- $1.51 / home2
Homes3 Flooded	- $1.00 / home3	- $5.00 / home3

* p-values suppressed

- Accounting for uncertainty in ecosystem valuation affects estimated values
- If uncertainty were ignored, values for homes would be exaggerated

Key Finding I

- Residents appear to know **“ when to hold them and when to fold them ”**
- Risk plays critical role in how people value assets: All else equal, risk makes homes less valuable to protect. Why?

1. People feel that HR infrastructure may be lost anyway
2. People feel that protecting HR homes is responsibility of property owner and not the public’s

Key Finding II

- **Values for protecting natural systems are relatively high compared for values for protecting built infrastructure.**
- **Common assumptions do not appear to match actual public values.**

Policy Implications

- Residents have higher values for *community* assets and resources
- Adaptation strategies should prioritize *first* the preservation of natural systems and the community's natural character, and *then* the protection of *lower*-risk built infrastructure
- Strategy more likely to be consistent with public values and expectations

Thank You!!!
Questions?

Christos Makriyannis
cmakriyannis@clarku.edu
Department of Economics, Clark University, Worcester, MA, USA

Robert J. Johnston
rjohnston@clarku.edu
George Perkins Marsh Institute and Department of Economics, Clark University, Worcester, MA, USA

CLARK UNIVERSITY
1887
CHALLENGE CONVENTION
CHANGE OUR WORLD™

ACES
A Community on Ecosystem Services

Attribute Levels Across Choice Sets

Variable Noted	Levels for Options
Homes2	28%; 20%; 24%; 32%
Homes3	23%; 16%; 19%; 27%
Wetlands	5%; 2%; 10%
Beaches	10%; 4%; 16%
Seawalls	24%; 35%; 15%
Cost	$0; $35; $65; $95; $125; $155
Hard	0 (emphasis on soft); 1(emphasis on hard)
Soft	0 (emphasis on hard); 1(emphasis on soft)

Mixed Logit Results

(Standard errors suppressed for conciseness)

Choice Attribute	Coefficient Mean Estimates	Standard Deviations of RPs.
Ne	-2.98887***	7.07239***
Homes2 Flooded	-0.04297*	----------
Homes3 Flooded	-0.06474**	----------
Wetlands Lost	-0.05697*	----------
Beaches Lost	-0.05285***	----------
Neg_Cost	0.00495*	0.00495*
Seawalls	-0.01989	----------
χ^2 (8 d.f.) / Significance Level	**172.235/ 0.0000**	
Pseudo - R^2	**0.213**	

Note: ***, **, * ==> Significance at 1%, 5%, 10% level