A MULTIDISCIPLINARY, INTEGRATIVE APPROACH TO VALUING COASTAL ECOSYSTEM SERVICES FROM NATURAL INFRASTRUCTURE

2018 ADVISORY BOARD MEETING

Hatfield Marine Science Center – Newport, Oregon
Guin Library Seminar Room
April 12th and 13th, 2018

This research is supported by funding from the NOAA National Centers for Coastal Ocean Science Competitive Research Program through NOAA Cooperative Institutes Program award numbers NA11OAR4320091A and NA16OAR4320152 to the Cooperative Institute for Marine Resources Studies at Oregon State University.

Oregon State University CIMRS NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

WELCOME

- Welcome and thank you for you participation on our Advisory Board!
- 7 OSU faculty from 4 colleges working on an interdisciplinary research agenda
- Work is made possible by NOAA's National Centers for Coastal Ocean Science and their Competitive Research Program, and OSU's Cooperative Institute for Marine Resources Studies (CIMRS).
- **Funding Title:** Assessing the Benefits of Natural (Green) Infrastructure for Shoreline Stabilization: Ecosystem Service Valuation for Decision-making in Coastal Communities

MEETING OBJECTIVES

- Bring together stakeholders, decision makers, and experts on coastal issues in the Pacific Northwest.
- Provide context to these issues with site visits
- Provide updates on project objectives and research progress.
- Provide a structured setting for comments and input from the board.
- Plan future outreach and engagement with board members and the general public.

TODAY'S AGENDA

9:00	Welcome and Introductions
9:15	Estuary Pathway
10:45	Coffee break
11:00	Coastal Protection Pathway
12:30	Working Lunch

TODAY'S AGENDA

1:30 Dune Landscapes Survey
2:00 Dune Landscapes Projects
2:30 Outreach and Engagement
3 pm Adjourn

ESTUARY RESTORATION PATHWAY

Today's presenters:

David Lewis
Professor
Applied Economics

Sally Hacker
Professor
Integrative Biology

Caitlin Magel
Ph.D. Student
Integrative Biology

Cassie Finer
Ph.D. Student
Applied Economics

Oregon State University CIMRS NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

ESTUARY RESTORATION PATHWAY

Overall Goal: Understand the relationship between economic valuation of coho salmon and the production and restoration of salt marshes in Oregon

Objectives:

- Quantify the benefits of restoration:
  - Coho salmon choice experiment (research paper #1)
  - Factors important to salmon production and the role of estuarine restoration (research paper #2)
  - Linking salmon valuation with the production and restoration of salt marshes (research paper #3)
- Quantify the costs of restoration:
  - Land market impacts of restoration activities (research paper #4)

Coho Salmon Choice Experiment

David Lewis, Steven Dundas, David Kling – Oregon State Applied Economics
Daniel Lew – NOAA, Alaska Fisheries Science Center
Sally Hacker – Oregon State Integrative Biology

Oregon State University CIMRS NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

MOTIVATION

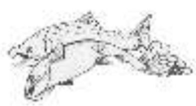
- Habitat loss has long been considered the central driver in the degraded condition of threatened and endangered species (Wilcove et al. 1998 BioScience).
- In response, most restoration programs aim to improve habitat conditions. E.g. NOAA's Recovery Plan for Oregon Coast Coho salmon.
  - Salt marsh restoration
  - Riparian zone conservation
  - Changes in upstream land management practices
  - Management of large wood in streams
- In terms of spending, 8 of the top 10 funded species listed in the U.S. ESA are Pacific salmon or steelhead.

MOTIVATION

- Conservation practitioners / managers make basic choices in regards to investing in natural capital.
  - How much to invest?
  - Where to invest?
  - How much to invest now versus in the future?
  - Efficient conservation requires estimates of the benefits of investment.
- Decades of research has shown that social benefits from restoring threatened and endangered species involves non-use values => stated preference methods needed.

OBJECTIVES OF THE COHO CHOICE EXPERIMENT

- Oregon Coast Coho are a primary beneficiary of investments in estuarine natural infrastructure.
- Estimate the public's demand (benefits) for restoring Oregon Coast Coho
- Survey a random sample of the population from OR, WA, ID, and northern CA
- Distinguish the public's willingness-to-pay for different attributes associated with restoring salmon (recovery, population, speed, recreation).



BACKGROUND

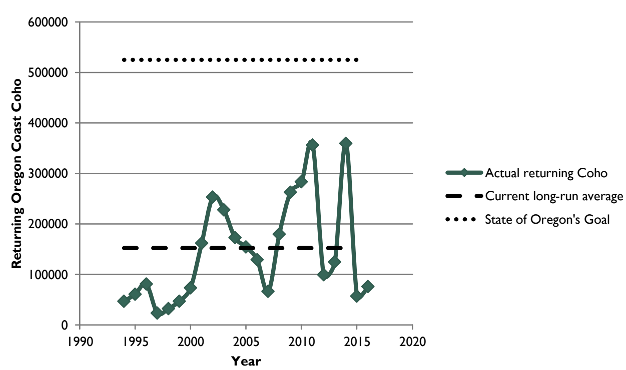
- Pacific salmon and steelhead migrate between freshwater and the Pacific Ocean.
- Major species of Pacific salmon and steelhead include Chinook, Chum, Pink, Sockeye, and Coho.
- Each of these species may be grouped into several **populations**, which are groups of individual fish of the same species living in the same place at a certain time.
- There are 28 different populations of salmon and steelhead that are listed as threatened or endangered under the Endangered Species Act (ESA). There are 24 other populations of salmon and steelhead that are not listed under the ESA.

BACKGROUND

- Some Coho salmon populations protected by the ESA include Coho that migrate to inland Oregon and Washington, and two populations in California.
- Other Coho salmon in the United States that are not listed under the ESA include three populations in Washington.
- Coho salmon are a popular fish to catch in both the ocean and freshwater streams and lakes.

BACKGROUND

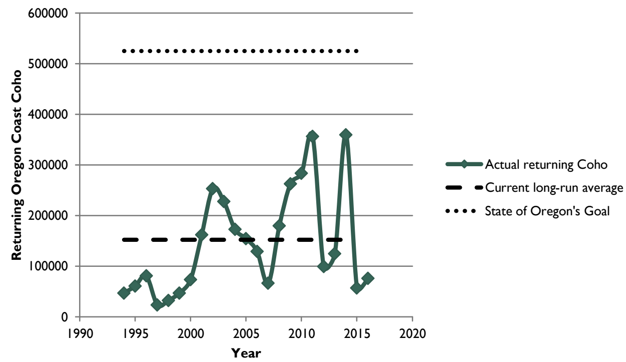
- Coho salmon survival is greatly affected by ocean conditions.
- During poor conditions, as few as 1% of fish survive to return to their home streams.
- During favorable conditions, as many as 15% of fish return.



14

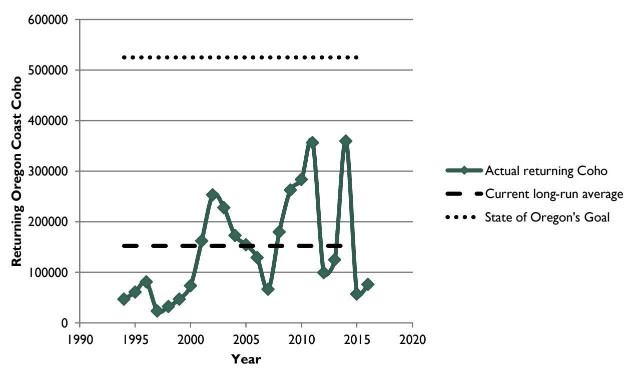
BACKGROUND

- The State of Oregon has found that historical (pre-development) Coho salmon numbered between 1 and 2 million fish.
- Primary threats to Oregon Coast Coho
  - Human activities, such as constructed barriers (dikes and tide gates) in estuaries and large pipes (culverts) in streams.
  - Streams and rivers lack large wood, pools, and connections to side channels that provide cover for juvenile Coho salmon.
  - Water quality problems, including high water temperatures, pollutants and sediment in streams.



BACKGROUND

- Current status of Oregon Coast Coho
  - Abundance is about 30% of the State of Oregon's conservation goal.
  - The U.S. government finds that stream habitat for Coho is not improving.
  - There is a very limited recreational freshwater fishery for wild Oregon Coast Coho salmon. Fishing is periodically closed when the numbers of returning fish are low. For example, the fishery was closed in 2016 because there were too few fish.



BACKGROUND

- New proposed restoration actions (NOAA Recovery Plan)
  - Increase Coho habitat and fish passage by removing constructed barriers in estuaries.
  - Conduct wetland planting projects to increase streamside vegetation and shade.
  - Increase large wood, boulders, or other beneficial structures in streams.
  - Develop strategies to reduce water pollution in estuaries and streams.

Source: NOAA Fisheries

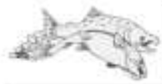
BACKGROUND – PAYMENT VEHICLE FOR SURVEY

- **If habitat restoration actions are taken for Oregon Coast Coho salmon, it will cost every household more money.**
  - Your household's annual federal or state taxes will increase, and you may pay higher prices for lumber and agricultural products.
  - The increase in annual taxes and prices is expected to last for a period of 10 years while the primary restoration activities take place.

Source: NOAA Fisheries

- Focus groups and pre-testing
- Experimental design
  - Three choice cards per survey and twenty versions of the survey => sixty different choice cards.
  - Design embeds correlation amongst population status, population size, and recreational fishing.

Figure S1. Example choice card - this is one of 60 unique choice cards used in the design, where the levels of attributes vary across the choice cards



	Results in 50 years		
	Status Quo	Alternative A	Alternative B
Population Status	Threatened	Recovered	Recovered
Population Size	150,000 fish	525,000 fish	375,000 fish
Population over Time	No Change	Slow Change	Quick Change
Recreational Fishing (# of fish that can be kept)	Periodically Closed 5 fish/year	Open Every Year 10 fish/year	Open Every Year 5 fish/year
Added cost to your household each year for 10 years	$0	$100/year	$350/year
Which alternative do you prefer? (Choose One)	Status Quo	Alternative A	Alternative B

- Focus groups and pre-testing
- Experimental design
  - Three choice cards per survey and twenty versions of the survey => sixty different choice cards.
  - Design embeds correlation amongst population status, population size, and recreational fishing.

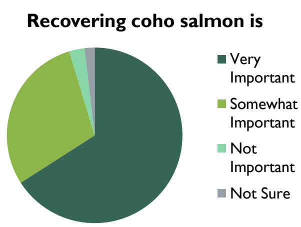
Figure S2. Example choice card – this is one of 60 unique choice cards used in the design, where the levels of attributes vary across the choice cards.

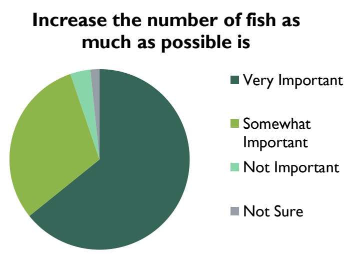
	Results in 50 years		
	Status Quo	Alternative A	Alternative B
Population Status	Threatened	Threatened	Threatened
Population Size	150,000 fish	325,000 fish	250,000 fish
Population over Time	No Change	Quick Change	Slow Change
Recreational Fishing (# of fish that can be kept)	Periodically Closed 5 fish/year	Periodically Closed 5 fish/year	Periodically Closed 5 fish/year
Added cost to your household each year for 10 years	$0	$250/year	$10/year
Which alternative do you prefer? (Choose One)	Status Quo	Alternative A	Alternative B

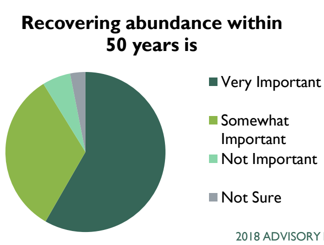
DATA COLLECTION

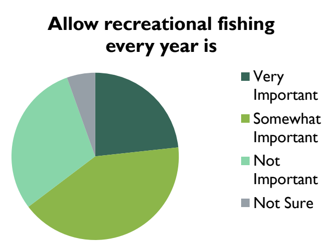
- Mail survey
  - Sent to 5,000 randomly selected households in Oregon, Washington, Idaho, and northern California (Fall 2017).
  - Used a Dillman approach with four mailings.
  - After throwing out undeliverable surveys, response rate was 21.5%.
  - We have 926 respondents, and 2,734 usable choice cards.

DATA ANALYSIS – QUALITATIVE EVIDENCE

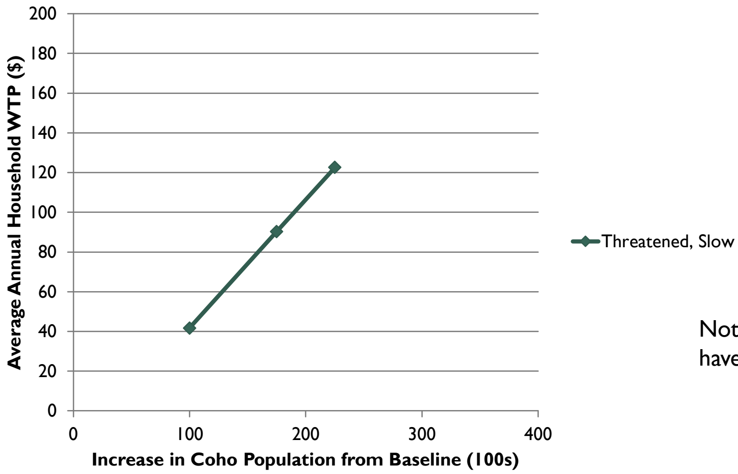






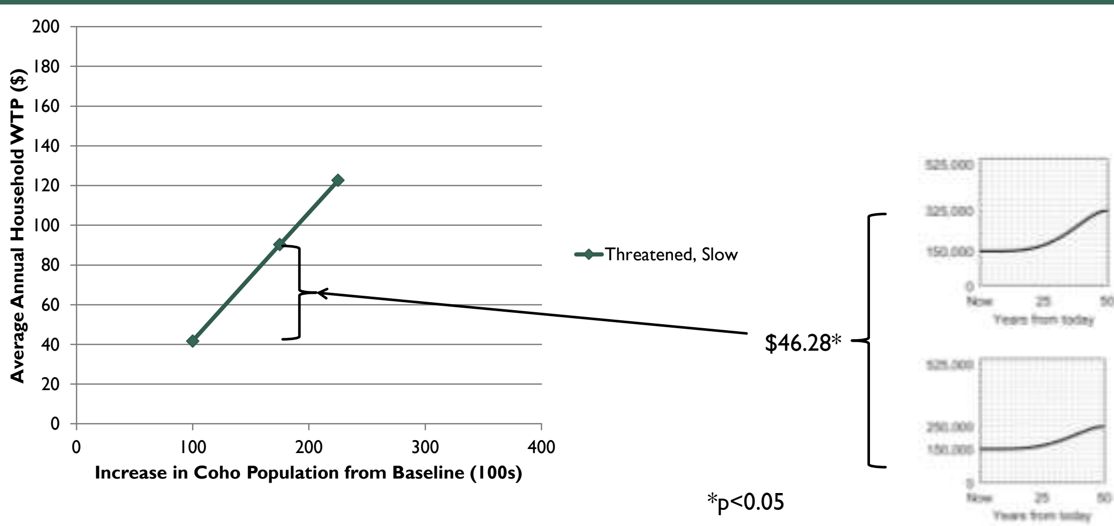


DATA ANALYSIS – HOUSEHOLD MEAN WTP ESTIMATION FOR ALTERNATIVE RESTORATION PROGRAMS



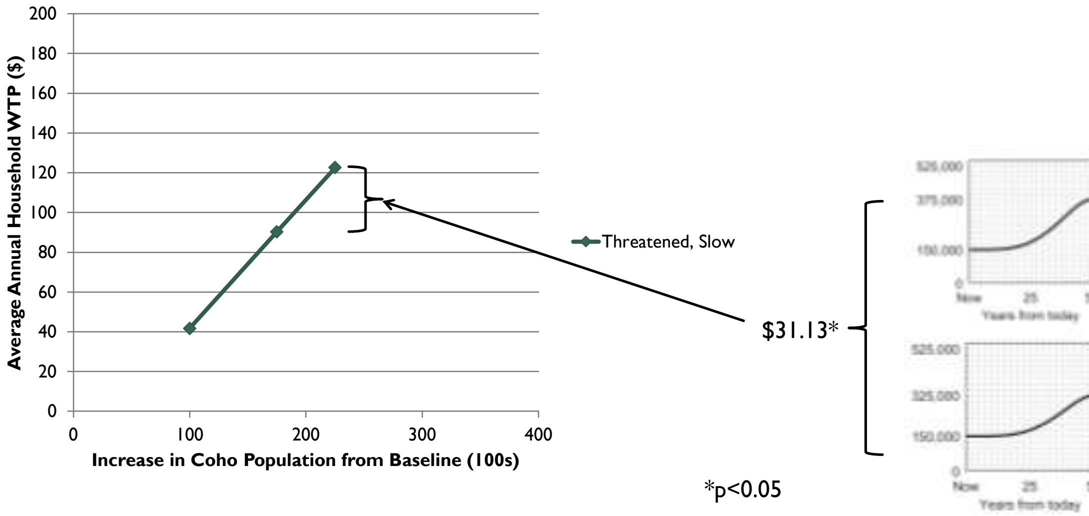
Note: these results are preliminary, and have not been published yet.

DATA ANALYSIS – HOUSEHOLD MEAN WTP ESTIMATION FOR ALTERNATIVE RESTORATION PROGRAMS



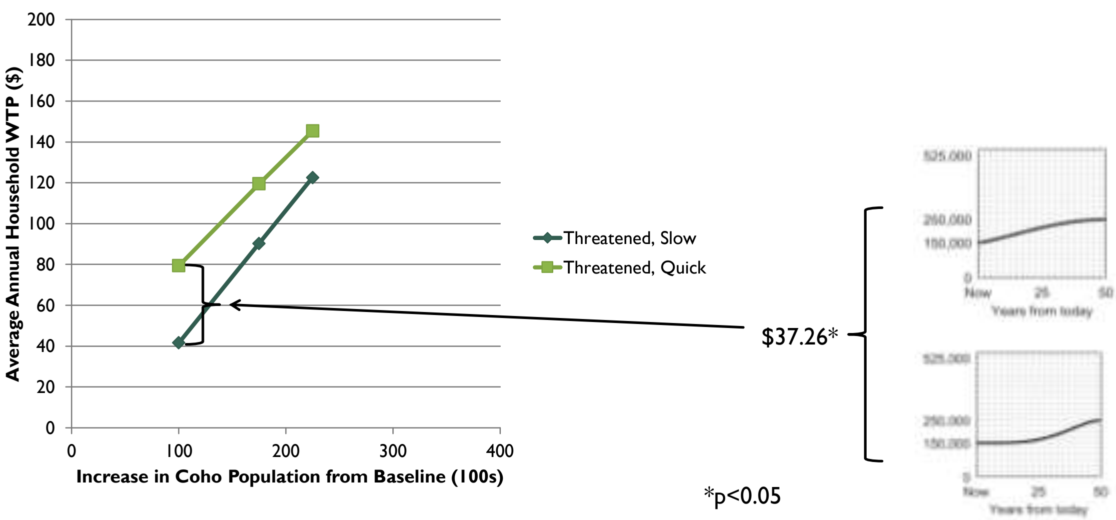
*p<0.05

DATA ANALYSIS – HOUSEHOLD MEAN WTP ESTIMATION FOR ALTERNATIVE RESTORATION PROGRAMS



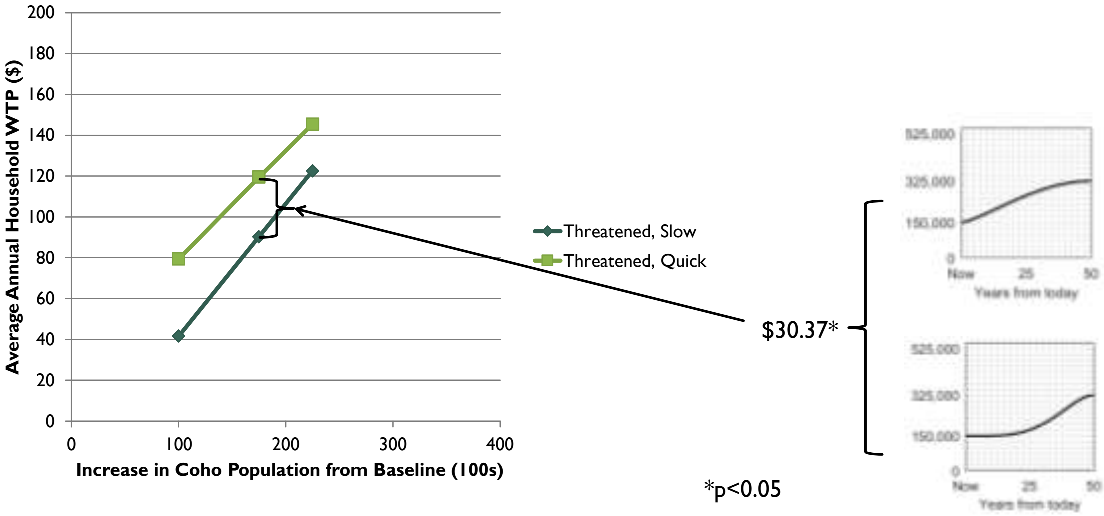
*p<0.05

DATA ANALYSIS – HOUSEHOLD MEAN WTP ESTIMATION FOR ALTERNATIVE RESTORATION PROGRAMS



*p<0.05

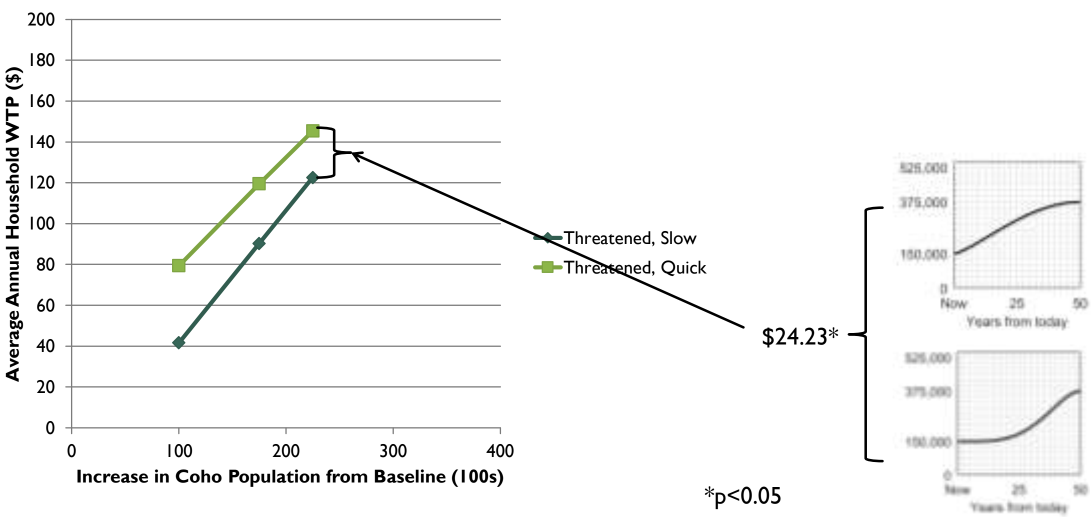
DATA ANALYSIS – HOUSEHOLD MEAN WTP ESTIMATION FOR ALTERNATIVE RESTORATION PROGRAMS



*p<0.05

27

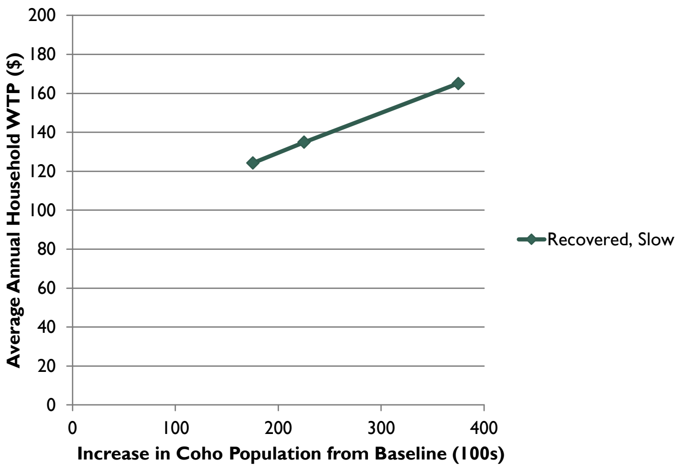
DATA ANALYSIS – HOUSEHOLD MEAN WTP ESTIMATION FOR ALTERNATIVE RESTORATION PROGRAMS



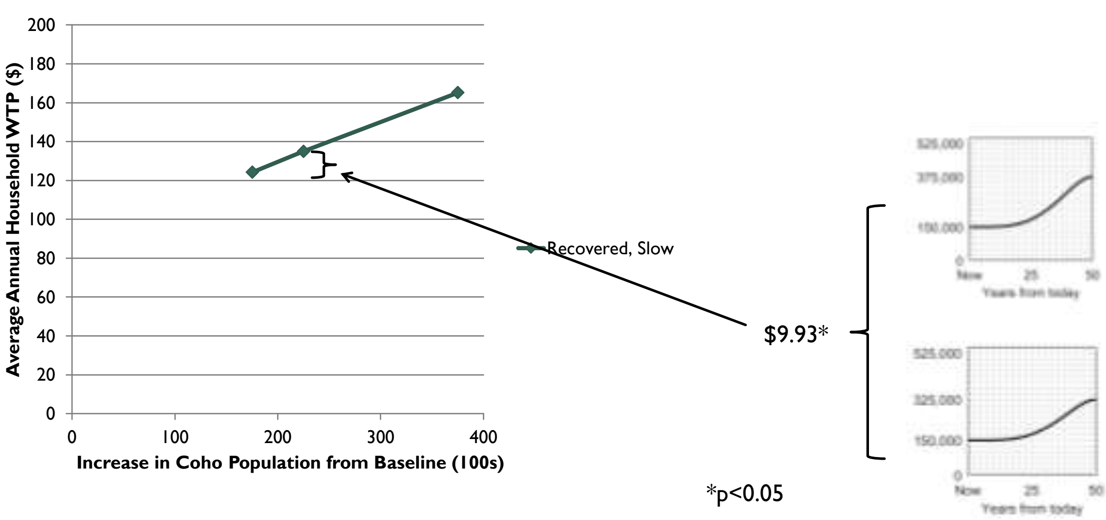
*p<0.05

28

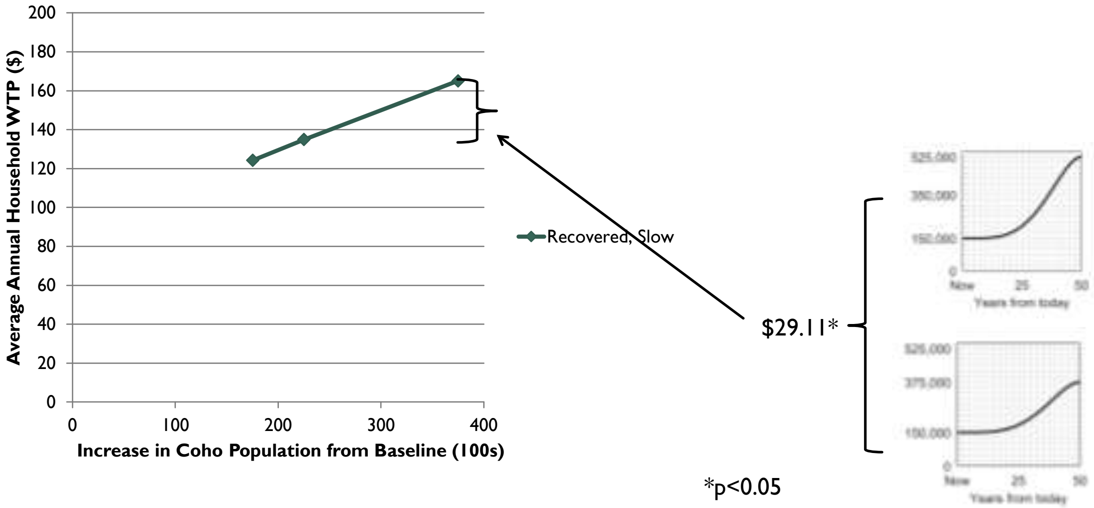
DATA ANALYSIS – HOUSEHOLD MEAN WTP ESTIMATION FOR ALTERNATIVE RESTORATION PROGRAMS



DATA ANALYSIS – HOUSEHOLD MEAN WTP ESTIMATION FOR ALTERNATIVE RESTORATION PROGRAMS

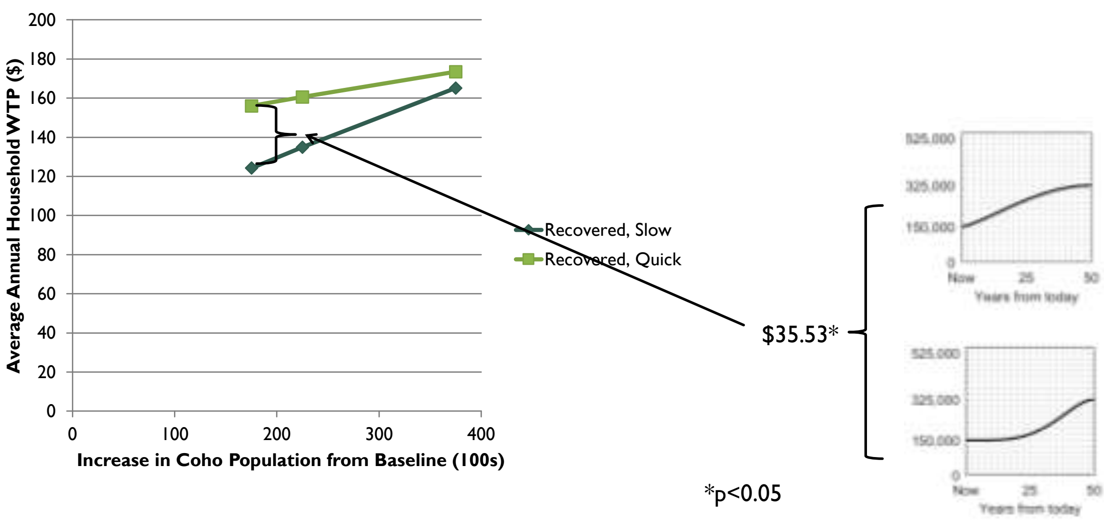


DATA ANALYSIS – HOUSEHOLD MEAN WTP ESTIMATION FOR ALTERNATIVE RESTORATION PROGRAMS



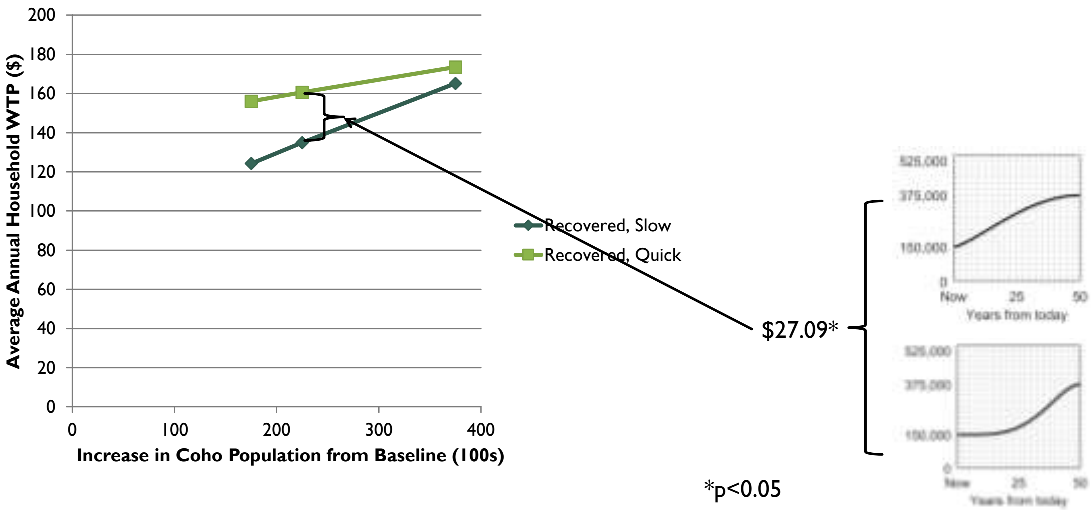
31

DATA ANALYSIS – HOUSEHOLD MEAN WTP ESTIMATION FOR ALTERNATIVE RESTORATION PROGRAMS



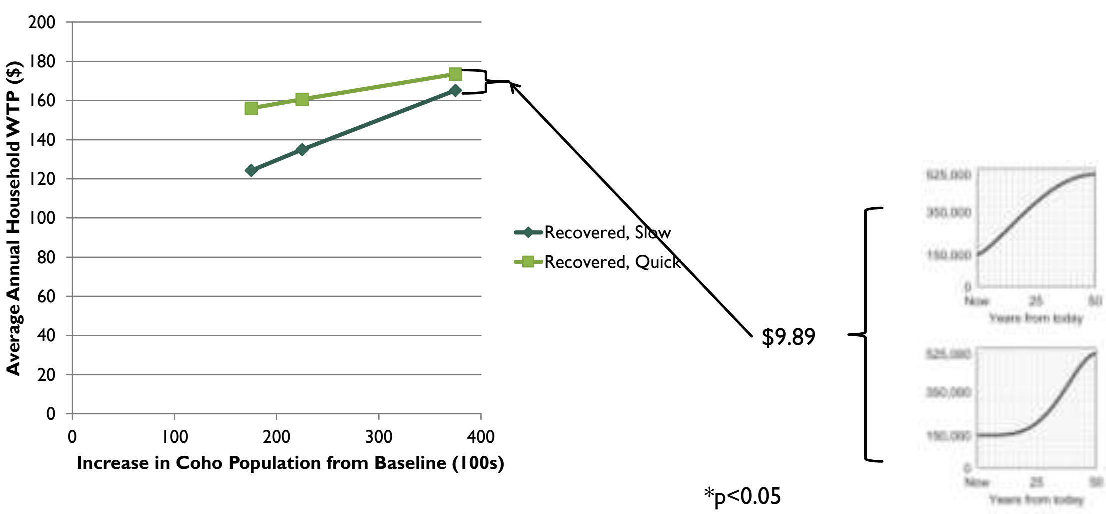
32

DATA ANALYSIS – HOUSEHOLD MEAN WTP ESTIMATION FOR ALTERNATIVE RESTORATION PROGRAMS



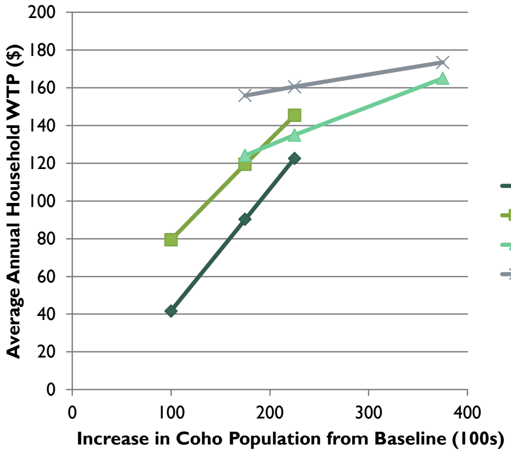
33

DATA ANALYSIS – HOUSEHOLD MEAN WTP ESTIMATION FOR ALTERNATIVE RESTORATION PROGRAMS

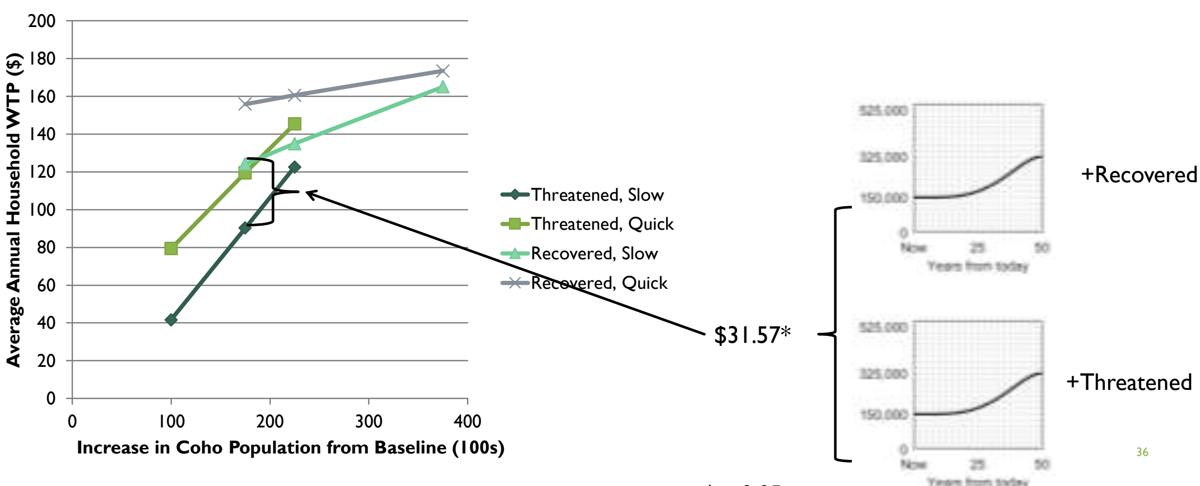


34

DATA ANALYSIS – HOUSEHOLD MEAN WTP ESTIMATION FOR ALTERNATIVE RESTORATION PROGRAMS

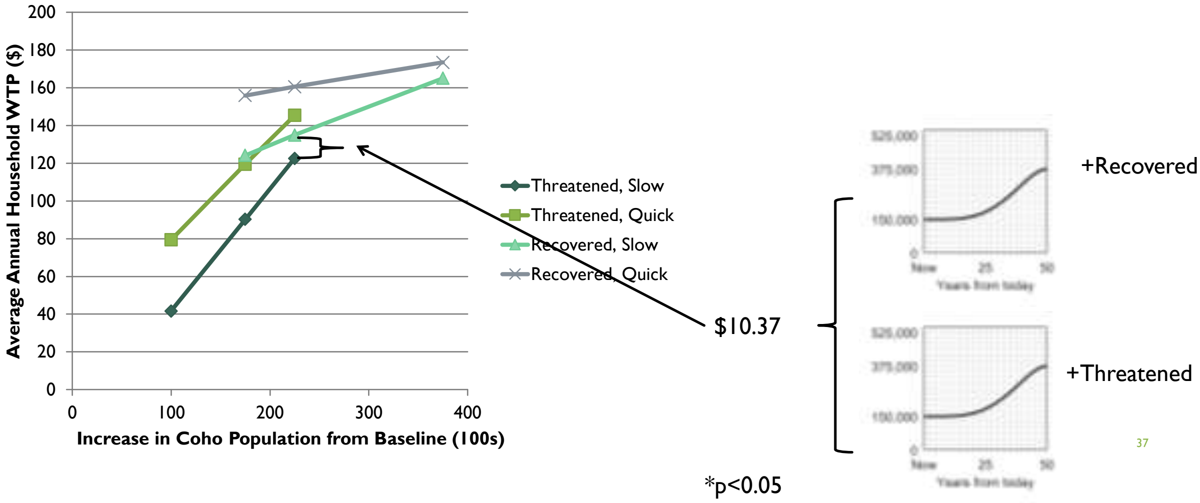


DATA ANALYSIS – HOUSEHOLD MEAN WTP ESTIMATION FOR ALTERNATIVE RESTORATION PROGRAMS



*p<0.05

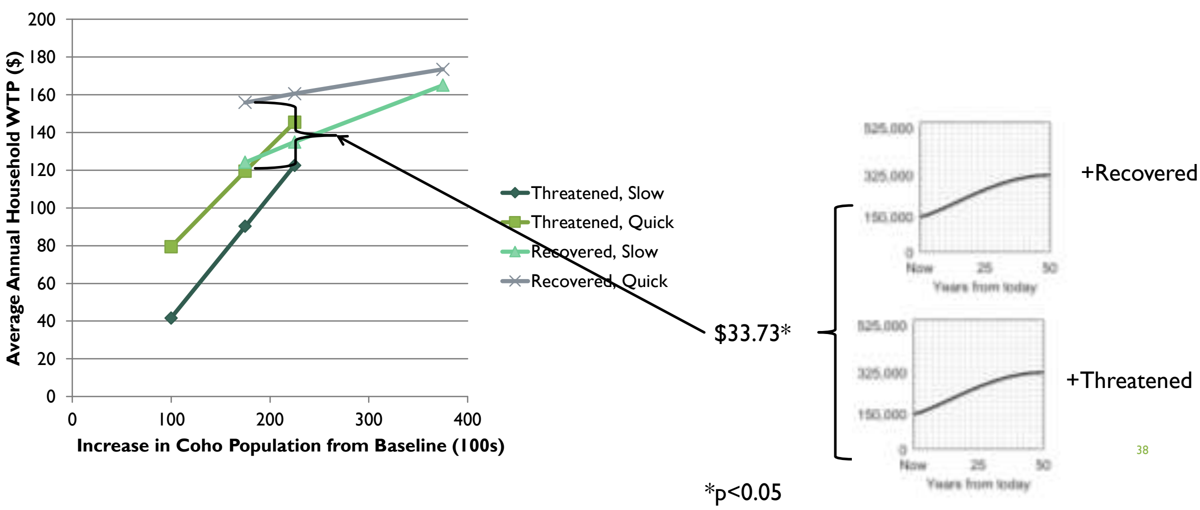
DATA ANALYSIS – HOUSEHOLD MEAN WTP ESTIMATION FOR ALTERNATIVE RESTORATION PROGRAMS



*p<0.05

37

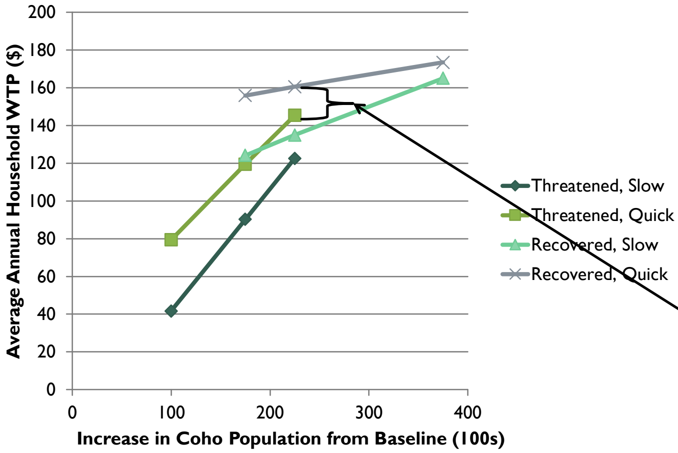
DATA ANALYSIS – HOUSEHOLD MEAN WTP ESTIMATION FOR ALTERNATIVE RESTORATION PROGRAMS



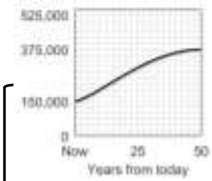
*p<0.05

38

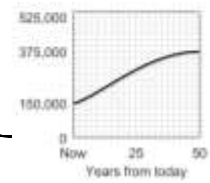
DATA ANALYSIS – HOUSEHOLD MEAN WTP ESTIMATION FOR ALTERNATIVE RESTORATION PROGRAMS



$13.23



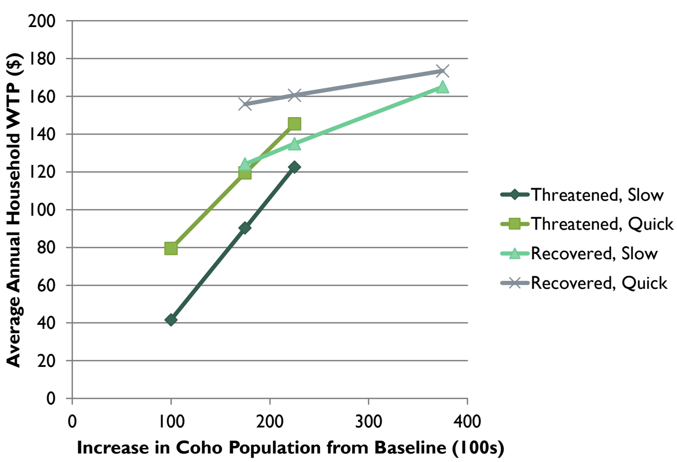
+Recovered



+Threatened

*p<0.05

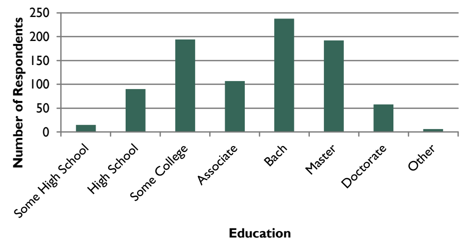
DATA ANALYSIS – HOUSEHOLD MEAN WTP ESTIMATION FOR ALTERNATIVE RESTORATION PROGRAMS

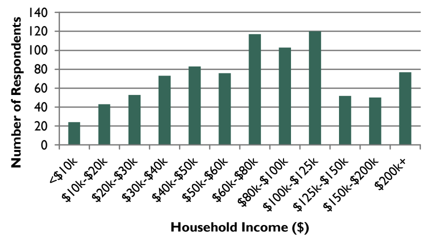


We fail to reject the null hypothesis that WTP = $0 for changes in coho fishing regulations. This is for the general population.

DATA ANALYSIS – VALUE AGGREGATION

- Issue: our sample is not representative of the broader population in observables.
  - The median respondent has a bachelor's degree (Census: 31%-34%).
  - The median respondent has household income between $60,000 and $80,000/year (Census: $53k - $63k).
  - 39% of respondents are age 65+ (Census: 14%-18%).
- Issue: our sample is almost surely not representative of the broader population in environmental preferences.

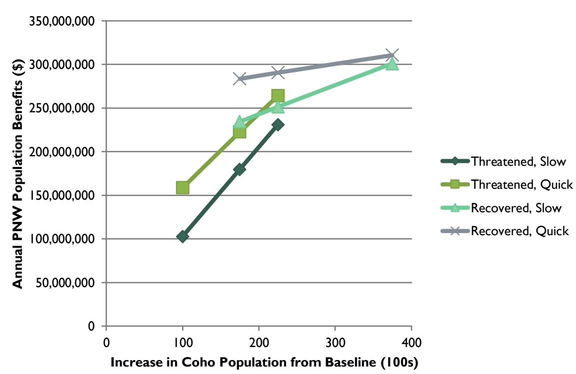




41

DATA ANALYSIS – VALUE AGGREGATION

- Lower-bound approach (Loomis 1987):
  - Use the survey response rate to indicate the portion of the population in which WTP is non-zero. The rest have assumed WTP of $0.
  - Response rate for Oregon is 25.4%, and for non-Oregon is 17.8%.
  - Multiply the mean household WTP by:
    - 398,889 Oregon households (0.254*1,570,430 households)
    - 1,395,098 non-Oregon PNW households (0.178*7,837,629 households)
    - 1,793,987 PNW households



Context: Federal spending on Oregon Coast Coho was just under $10,000,000 in FY 2016.

42

CONCLUSION

- Contributions of this research
  - New choice experiment evidence of WTP for marginal changes in populations of threatened species.
    - Public receives benefits from population increases, even if species is not "recovered" off the ESA.
    - Diminishing marginal WTP for higher long-run population changes.
    - WTP for higher long-run population changes is lower if the species is recovered.
  - New evidence that the general public is WTP for restoration that is quicker.
    - WTP for quick is highest at low ending population sizes.
  - New evidence of the general public's tradeoffs between ESA status changes, population, restoration speed, and fishing regulation changes for an iconic Pacific salmon species.

Coho Salmon Production Function

Caitlin Magel, Sally Hacker – Integrative Biology OSU
Mark Scheuerell – NOAA NWFSC NMFS Seattle
David Lewis, Cassie Finer – Applied Economics OSU

Oregon State University CIMRS NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

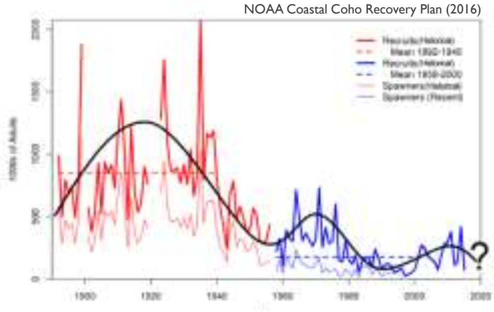
OUTPUT FROM CHOICE SURVEY

- What we will know from choice survey: willingness-to-pay for specific changes in coho salmon population size as a consequence of habitat restoration in estuarine watersheds in Oregon?

OREGON COAST COHO SALMON

- NOAA Recovery Plan: main goal is to protect and restore critical coho habitats
- Oregon estuaries have lost up to 94% of historic wetlands

NOAA Coastal Coho Recovery Plan (2016)



COHO SALMON PRODUCTION FUNCTION MODELS

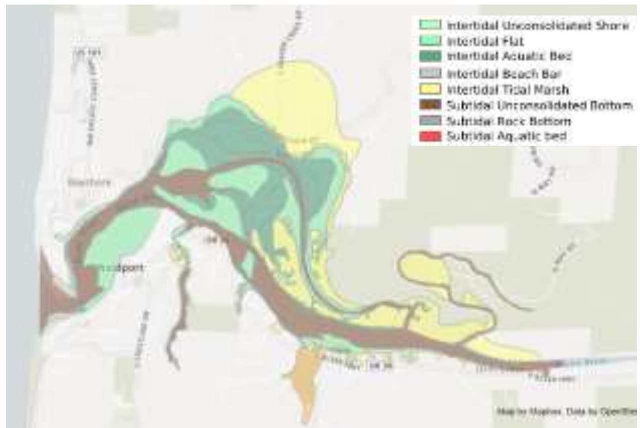
- Next, we asked an ecological question: how do we translate investments in natural infrastructure (estuary habitat and its restoration) to numbers of returning salmon?
- In other words, how many adult coho salmon might we expect to be produced by estuarine habitat and its restoration?

BAYESIAN APPROACH TO LINK HABITAT TO SALMON

- We are using a Bayesian statistical model to estimate the production function for estuarine habitat and coho salmon abundance.
  - Main partner: Mark Scheuerell, Fish Ecology Division, Northwest Fisheries Science Center, NMFS, NOAA
- Requirement was a time series dataset for coho salmon in multiple estuaries in Oregon:
  - Age structure and spawner abundance
  - Harvest rate
  - Ocean conditions (upwelling, climate variability)
  - Watershed conditions (river/stream characteristics)
  - Wetland marsh habitat in each estuary

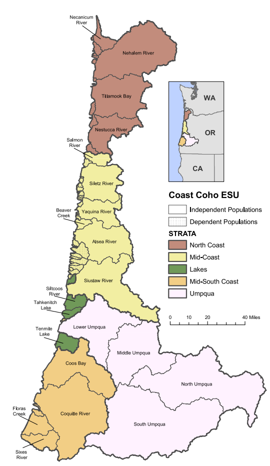
BAYESIAN APPROACH TO LINK HABITAT TO SALMON

- Delineate estuarine habitat appropriate for coho salmon along the Oregon coast using publically available GIS products
  - Main partner: Laura Brophy, Greenpoint Consulting, Corvallis, OR.
  - Graduate student: Caitlin Magel, OSU
- Calculate estuary habitat for coho salmon: existing unrestored, restored, and priority for restoration.

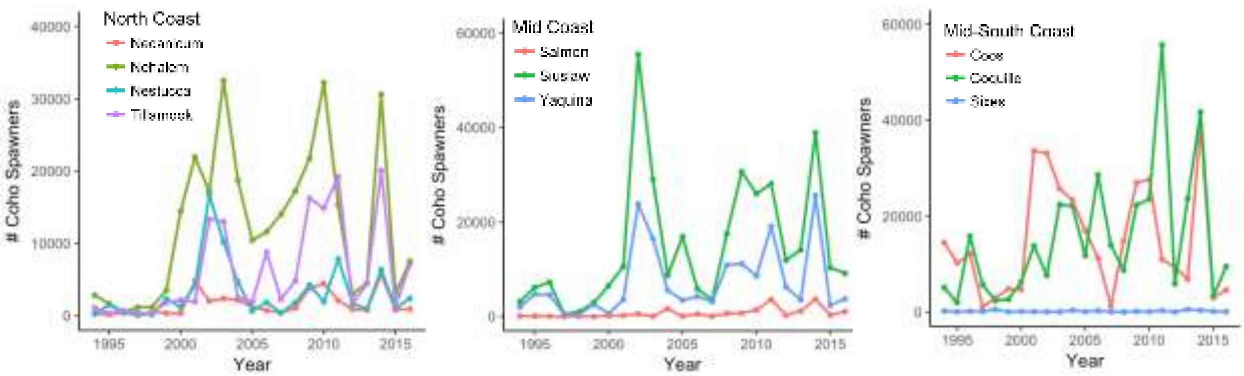


COHO SALMON DATA FOR BAYESIAN MODEL

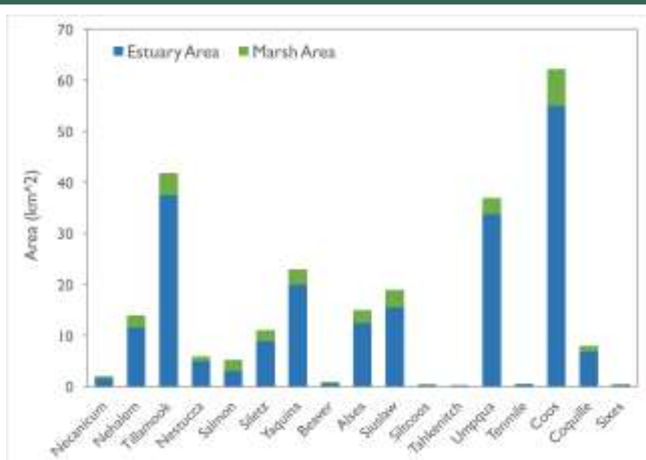
- 22 years of spawner data from 21 independent populations (ODFW)
  - Variation in space & time
- Covariates:
  - Hatchery releases
  - Harvest
  - Ocean conditions (PDO, upwelling, etc)
  - Watershed conditions (river/stream characteristics)
  - Area of marsh habitat in each estuary

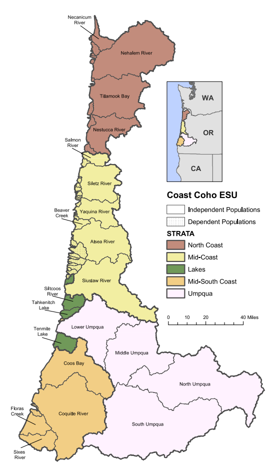


COHO SALMON DATA FOR BAYESIAN MODEL



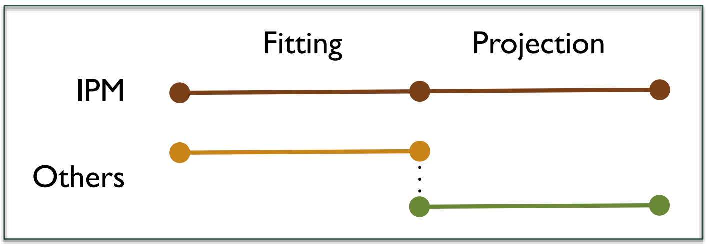
COHO SALMON DATA FOR BAYESIAN MODEL





INTEGRATED POPULATION MODEL (IPM)

- "The construction of a joint likelihood for the observed data… using all available data, in as raw a form as appropriate, in a single analysis" (Maunder & Punt 2013)
- Bayesian hierarchical models with distinct process and observation submodels
- Use the same procedure for both fitting and projection phases



INTEGRATED POPULATION MODEL (IPM)

- Use spawner–recruit models
- Incorporate stochasticity and uncertainty

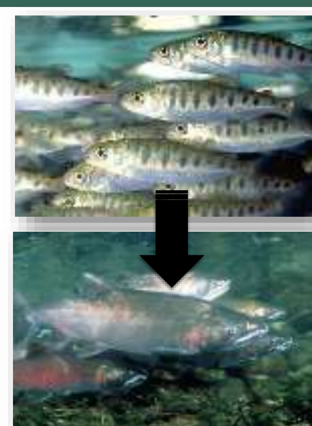
$Recruits_{t+k} = f(Spawners_t, Environment_t)$

Autocorrelated process

$e_t = \phi e_{t-1} + \varepsilon_t$

Covariates (e.g.,)

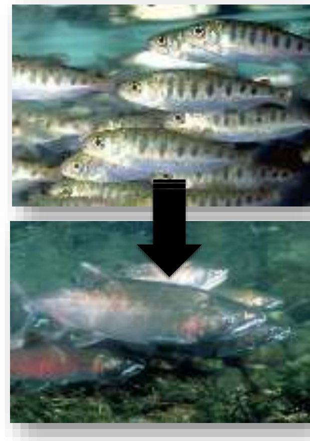
$e_t = \beta x_{t-h} + \varepsilon_t$



INTEGRATED POPULATION MODEL (IPM)

- Step 1: Create recruits

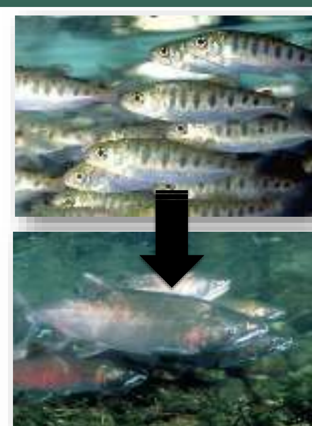
Year	Spawners	Recruits	Age 2	Age 3
1	S_1 →	R_1		
2	S_2 →	R_2		
3	S_3 →	R_3		
4	S_4 →	R_4		
5	S_5 →	R_5		
6				
7				
8				



INTEGRATED POPULATION MODEL (IPM)

- Step 2: Project recruits-by-age using proportion

Year	Spawners	Recruits	Age 2	Age 3
1	S_1 →	R_1		
2			$p_{2,1}$ ↓	$p_{3,1}$ ↓
3			$N_{3,2}$	
4				$N_{4,3}$
5				
6				
7				
8				



INTEGRATED POPULATION MODEL (IPM)

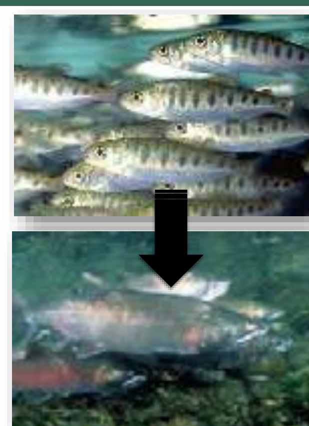
- Step 2: Project recruits-by-age using proportion

Year	Spawners	Recruits	Age 2	Age 3
1	S_1	R_1		
2	S_2	R_2		
3	S_3	R_3	$N_{3,2}$	
4	S_4	R_4	$N_{4,2}$	$N_{4,3}$
5	S_5	R_5	$N_{5,2}$	$N_{5,3}$
6			$N_{6,2}$	$N_{6,3}$
7			$N_{7,2}$	$N_{7,3}$
8				$N_{8,3}$

INTEGRATED POPULATION MODEL (IPM)

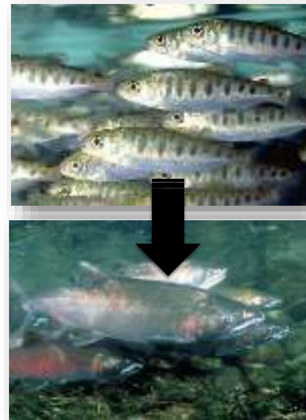
- Step 3: Estimate age composition

Year	Spawners	Recruits	Age 2	Age 3
1	S_1	R_1		
2	S_2	R_2		
3	S_3	R_3	$N_{3,2}$	
4	S_4	R_4	$N_{4,2}$	$N_{4,3}$
5	S_5	R_5	$N_{5,2}$	$N_{5,3}$
6	S_6	←	$N_{6,2}$	$N_{6,3}$
7			$N_{7,2}$	$N_{7,3}$
8				$N_{8,3}$



INTEGRATED POPULATION MODEL (IPM)

- Step 4: Calculate total spawners



True spawners

$Spawners_t = Returns_t - Harvest_t$

True spawners are difference between returns and harvest*

Observed spawners

$\log(Esc_t) = \log(Spawners_t) + Error_t$

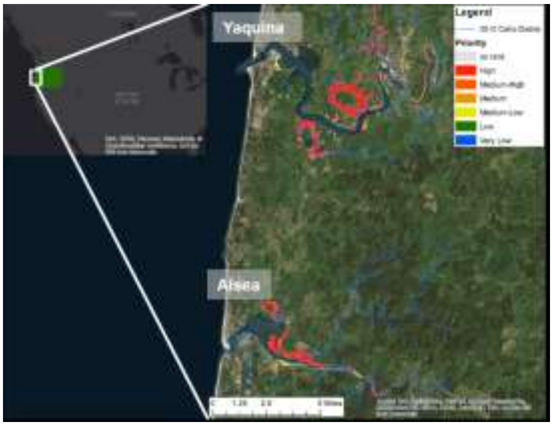
Measured escapement is estimate of true spawners

*Ignoring upstream mortality

BAYESIAN APPROACH TO LINK HABITAT TO SALMON

- IPM model will determine the variance explained by estuarine habitat area, ocean conditions, harvest, etc., on coho salmon production.
- Use production function of estuarine habitat to estimate the number of coho salmon produced under future estuarine habitat restoration efforts.

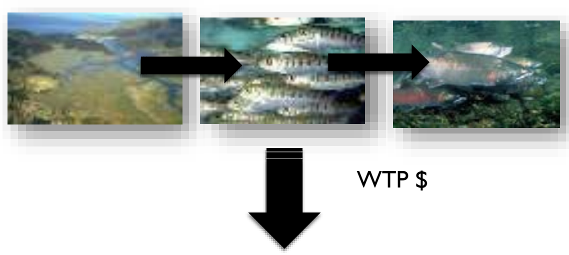
AN EXAMPLE RESTORATION SCENARIO



- An example restoration scenario would restore tidal flows and salt marshes (left), increasing habitat for coho salmon and thus production.
- Q: What are the economic benefits from this type of restoration in natural infrastructure?

AN EXAMPLE RESTORATION SCENARIO

- Bayesian Coho Model: Estimates how many additional coho return in each watershed under a restoration scenario.
  - This is a quantity. (e.g. 75,000 fish per restored watershed)
- Choice Experiment Model: Estimates the public's willingness-to-pay (WTP) for additional Coho salmon.
  - This is a price (e.g. WTP $46/year per household for 75,000 fish)
- Combining the Choice Experiment with the Bayesian coho salmon model:
  - Total economic benefits are the multiplication of the price the average public household is WTP for a given change in salmon by the number of households in the population.
  - For example, $46 x 1.8 million households (PNW) = $82,800,000 /year.

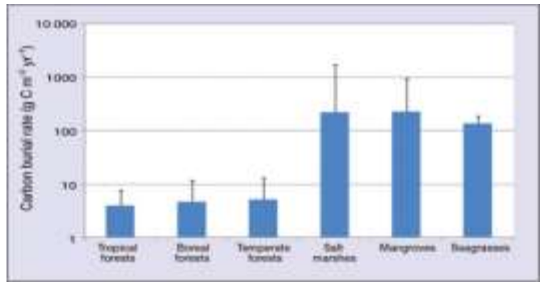


Total economic benefits of estuarine watershed restoration

We'll discuss the economic costs of restoration later.

OTHER ECOSYSTEM SERVICE PRODUCTION FUNCTIONS

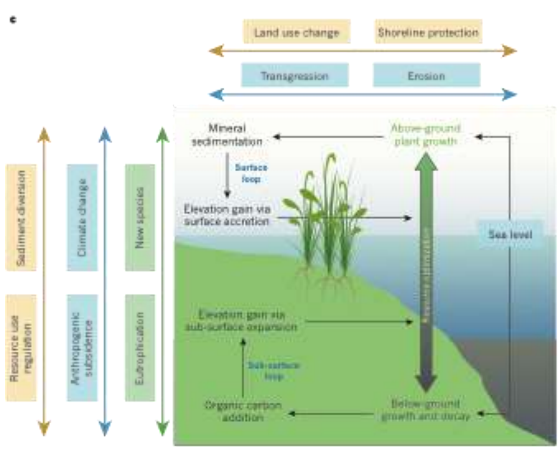
- Coastal blue carbon
  - Coastal salt marshes sequester very large amounts of carbon in sediments and other biomass.
  - Estuary restoration that increases salt marsh acreage and will sequester more carbon.
  - Q: How to model physical stock of blue carbon sequestration?
    - INVEST model from the Natural Capital Project.
    - Runs off spatial data (e.g., coastal habitat) and blue carbon estimates for PNW estuaries.
  - Q: How to measure price of carbon sequestration?
    - U.S. government's Social Cost of Carbon.
    - Easily available, unlike value of coho salmon.



- From Mcleod et al. (2011), *Frontiers in Ecology & Environment.*
- Mean long-term rates of C sequestration (g C m^{-2} yr^{-1}) in soils in terrestrial forests and sediments in vegetated coastal ecosystems. Note the logarithmic scale of the y axis.

OTHER ECOSYSTEM SERVICE PRODUCTION FUNCTIONS

- Coastal flood protection and sea level rise
  - Coastal salt marshes protect against flooding events and can mitigate sea level rise through sediment accretion.
  - Q: How to model the role of increased marsh area on coastal flood protection today and under SLR?
    - INVEST model from the Natural Capital Project.
    - Runs off spatial data (e.g., coastal habitat).
  - Q: How to estimate price of flood protection?
    - Prior studies have used the housing market.
    - Data is available (more later), but method is challenging.



From Kirwin Megonigal (2013), *Nature*

COHO HABITAT RESTORATION

ESTIMATING THE EFFECTS ON COASTAL LAND MARKETS

Cassie Finer
NMFS/Sea Grant Fellow
Ph.D. candidate, Applied Economics

Oregon State University CIMRS NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE Sea Grant

RESEARCH QUESTION

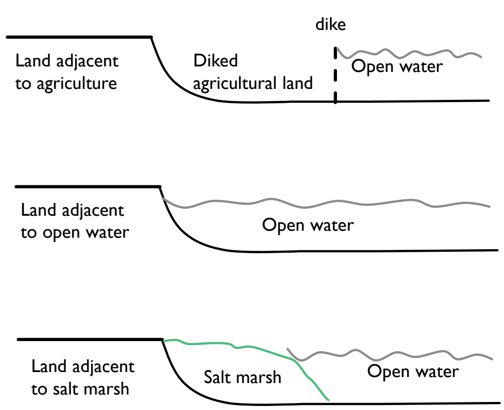
- How do land market impacts from Coho habitat restoration affect total restoration costs?
- Can better knowledge these impacts inform more efficient natural-infrastructure investment?

CONTRIBUTION

- *Local* private costs/benefits of habitat restoration
- Costs needed to determine optimal natural infrastructure investment

LAND MARKET EFFECTS

Dike Removal & Land Markets

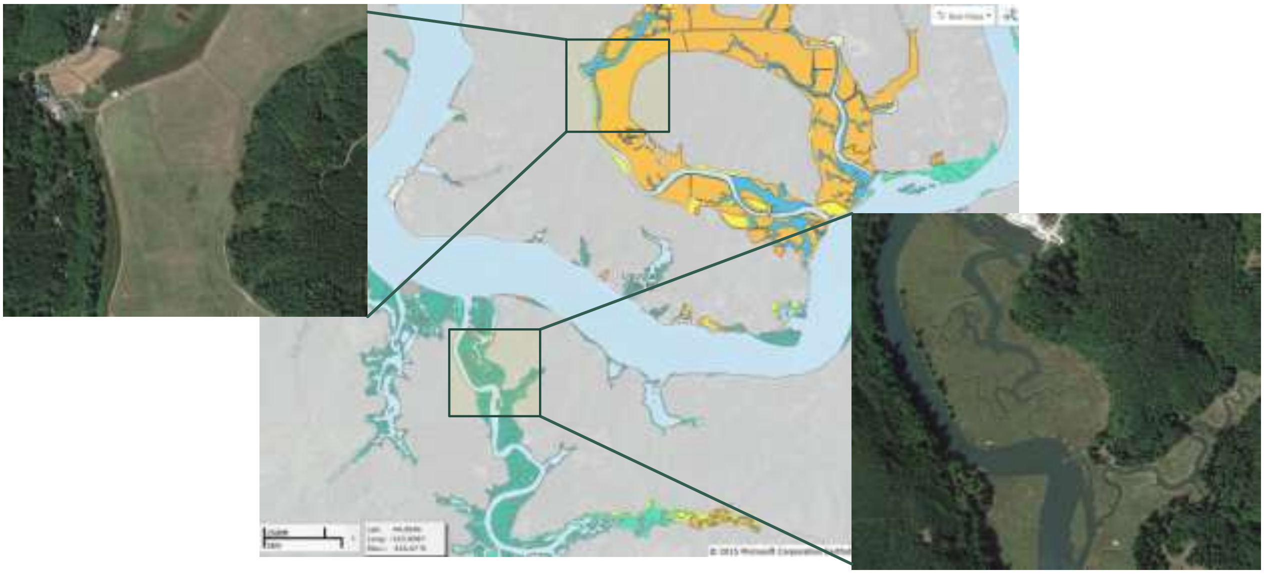


Current situation with dike

Short run without dike

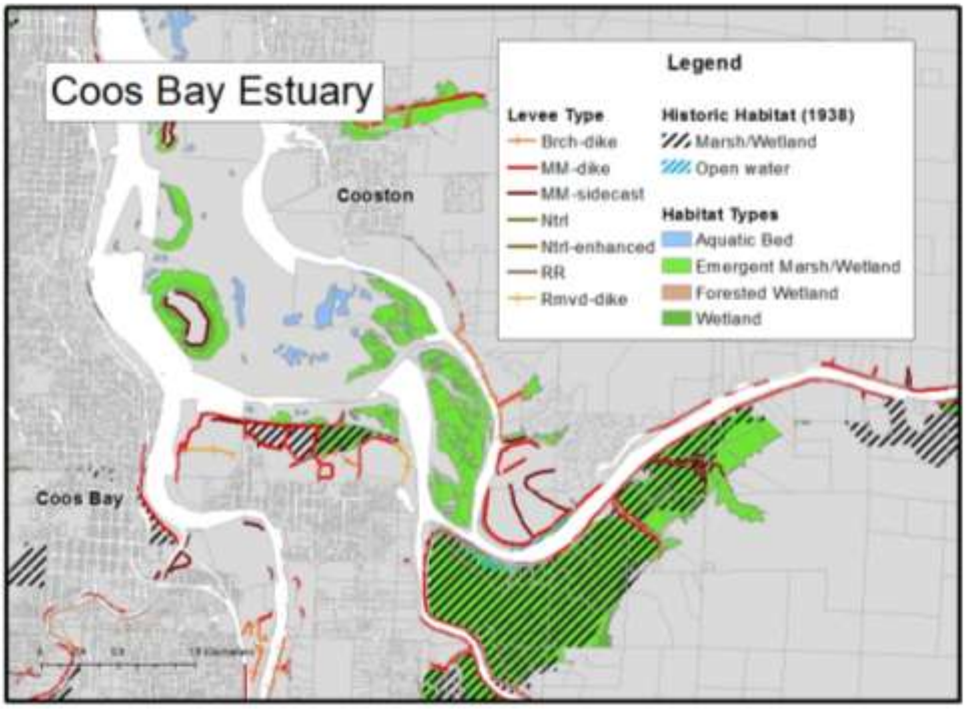
Long run without dike

Economics of the land market will change over time



DATA

- Land parcel data for entire Oregon Coast
  - RMV/Deed records for parcels adjacent to estuarine and forest habitat
- Estuarine and freshwater habitat location, quality, and human interference (dikes, culverts, clear-cut, etc.)
- Spatially explicit dataset allows for fine scale simulation of Coho habitat restoration costs



72

SUMMARY STATS – SINGLE FAMILY RESIDENCES

	Full	Clatsop	Coos	Douglas	Lane	Lincoln	Tillamook
Sale Price	$238,000 *(244,000)*	$373,000 *(401,000)*	$154,000 *(178,000)*	$153,000 *(210,000)*	$307,000 *(331,000)*	$232,000 *(197,000)*	$236,000 *(227,000)*
Natural - Enhanced	8%	-	12%	-	14%	8%	6%
Manmade Dike	7%	5%	15%	-	11%	4%	4%
Riprap	3%	-	6%	-	10%	1%	2%
Natural	2%	-	3%	-	-	-	20%
Breached Dike	1%	-	1%	25%	2%	1%	1%
Manmade Sidecast	1%	1%	-	-	-	1%	-
Removed Dike	1%	6%	-	-	-	4%	1%
Observations	1,296	127	270	4	111	681	103

INTEGRATING ALL PARTS TO VALUE NATURAL INFRASTRUCTURE INVESTMENT (NATURAL CAPITAL)

$$\text{Unit price of capital} = \frac{\text{Ecosystem service flows} + \text{Capital gains}}{\text{Discount rate} - \text{Growth rate of capital stock (Net appreciation)}}$$

Q: How does the value of an acre of restored salt marsh compare to the value of an acre of diked agricultural land?

From Fenichel et al. (2015 PNAS)

ESTUARY RESTORATION PATHWAY

Objectives:

- Non-market benefits from alternative restoration scenarios on Oregon Coast Coho salmon (research paper #1).
- A biophysical production function for coho (research paper #2)
- Linking salmon valuation with the production function to value a salt marsh as a natural capital stock in comparison to the value of alternative land-uses (research paper #3)
- Analysis of the economic costs to the land market from restoration (research paper #4)

OUTREACH DISCUSSION AND FEEDBACK

- Who are the consumers of this research?
- How should we reach those that will not read our scientific papers?
- When should we reach out to those that will not read our scientific papers?

A MULTIDISCIPLINARY, INTEGRATIVE APPROACH TO VALUING COASTAL ECOSYSTEM SERVICES FROM NATURAL INFRASTRUCTURE

2018 ADVISORY BOARD MEETING

COFFEE BREAK

Oregon State University CIMRS NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

COASTAL PROTECTION PATHWAY

Today's presenters:

Steven Dundas
Assistant Professor
Applied Economics, COMES

W. Jason Beasley
Ph.D. Student
Applied Economics

Oregon State University · CIMRS · NCCOS National Centers for Coastal Ocean Science

COASTAL PROTECTION PATHWAY

Research Questions

- How do coastal housing markets respond to the ability to invest in coastal protection?
- Do parcel-level options for protective structures generate spillover effects?
- What socioeconomic and geomorphological factors impact coastal landowner's land use decisions?

COASTAL PROTECTION PATHWAY

Research Questions

- Does the general public value investments in coastline stabilization?
- If so, does that value differ based on type and location of investment?

COASTAL PROTECTION PATHWAY

Research Questions

- How can natural infrastructure be optimally allocated within coastal communities, accounting for the value of life safety (via tsunami evacuation facilitation)?
- Given the current suite of risks, what land use policy decisions in the area of natural infrastructure can make coastal communities more resilient against those risks?

COASTAL PROTECTION PATHWAY

Overview of Projects

- *Estimating Option Values and Spillover Damages from Coastal Protection*
- *Hold the Line: Identifying Determinants of the Decision to Install Beachfront Protective Structures*
- *Public Preferences for Coastal Protection Options*
- *Life Safety and Natural infrastructure: An Economic Perspective*

ESTIMATING OPTION VALUES AND SPILLOVER DAMAGES FROM COASTAL PROTECTION

Steven Dundas
Assistant Professor
Applied Economics & COMES

David Lewis
Professor
Applied Economics

Oregon State University
CIMRS
NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

MOTIVATION

- Insurance programs, public investments, and regulations can influence protection levels from various coastal risks.



SO WHAT? WHY SHOULD WE CARE?

Economic value of capital stock located in areas vulnerable to coastal erosion: $1.2 Trillion (Nordhaus 2006)

Sea levels are rising (NOAA 2017)

From 2011-2013, disaster recovery cost each household in the U.S. more than $400 annually ($136 billion total)

SO WHAT? WHY SHOULD WE CARE?

USACE spends billions on coastline stabilization

- $5 billion in Mid-Atlantic alone post-Sandy

Estimating economic values for coastal protection can help inform better decision-making, policy, & funding mechanisms

RESEARCH QUESTIONS

- How do housing markets value the private option to invest in protection from coastal erosion?
- Does a parcel-level option for protective structures have spillover effects to neighboring parcels?
- Does the presence of spillover effects negate an otherwise beneficial policy?

OPTION VALUES FOR COASTAL PROTECTION

Hedonic models of Oregon oceanfront properties

- State Planning Goal 18 provides variation in protection option
  - That is, some homes can install beachfront protective structures, others cannot
- Results suggest a significant premium (13 – 24 %) for having the option to protect property, but only for vulnerable parcels.

SPILLOVER DAMAGES

Private coastal protection choices may generate private benefits to the individuals making the choice, but external costs to neighbors from altered erosion dynamics.

We run an additional suite of models that suggest spillover damages are present (7 – 16 % negative impact on ineligible parcels)

Spatial configuration of Goal 18 policy may generate externalities on ineligible parcels and perverse incentives for eligible parcels.

SETTING

- Oregon oceanfront parcels from 2004 - 2015
- State Planning Goal 18: Eligibility for beachfront protective structures restricted to lots platted prior to Jan. 1st, 1977.



Sherwood RV Park
Rockaway Beach, OR

1994

Google Earth Historic Imagery

Sherwood RV Park
Rockaway Beach, OR

2000

Google Earth Historic Imagery

Sherwood RV Park
Rockaway Beach, OR

2005

Google Earth Historic Imagery

Sherwood RV Park
Rockaway Beach, OR

2017

Google Earth Current Imagery

TRANSACTION DATA

- Universe of transactions in Oregon's seven coastal counties 2004 – 2015 (1,519 oceanfront SFR sales)
- Tax data geocoded into GIS parcel maps
- Geospatial data generated from LiDAR and other sources including parcel elevation, erosion/accretion rates, structure setback from statutory vegetation line

SUMMARY STATISTICS

Eligible (N=1,101)	Mean	Std. Dev	Not Eligible (N=418)	Mean	Std. Dev.
Price (US 2015$)	$589,666	$375,973		$622,667	$421,994
Market Improvement Value	$221,482	$184,634		$327,888	$230,327
Erosion Rate (m/yr)	0.38	0.83		0.85	1.22
Minimum Elevation (ft)	21.03	26.63		42.2	59.9
Structure Setback (ft)	158	194		345	333
Age	42.1	25.0		20.1	12.7
Square Footage	2,144	1,076		2,642	1,105
Lot Size (ft^2)	19,254	27,404		32,067	50,450
Dist. to Mean High Water (ft)	102	104		173	162
100-Year Floodplain	0.71	0.46		0.46	0.50

Post-Match Data

866 observations
- 448 treated
- 418 control

	Eligible Mean *(N=448)*	Ineligible Mean *(N=418)*	% Reduction in Standardized Bias
Price (US 2015$)	$613,848	$622,667	74.9
Market Improvement Value (US 2012$)	$316,497	$327,888	88.9
Erosion Rate (m/yr)	0.58	0.85	49.4
Minimum Elevation (feet)	29.7	42.2	41.0
Structure Setback (feet)	323	345	92.0
Age	17.3	20.1	82.7
Bedrooms	2.91	2.95	62.9
Bathrooms	2.57	2.61	85.6
Square Footage	2,383	2,642	45.4
Lot Size (ft^2)	33,429	32,067	91.4
Distance to Lighthouse (feet)	43,489	40,886	17.1
Landslide zone	0.17	0.17	100
Bluff location	0.21	0.21	100
Distance to mean high water (feet)	151	173	75.7
100-Year floodplain	0.58	0.46	53.5
Tsunami zone	0.67	0.62	78.4
Year	2008.29	2008.36	60.1
County	3.80	3.77	94.4
Latitude	44.23	44.24	98.3
Longitude	-124.14	-124.13	87.1

98

HEDONIC MODEL

$$\ln P_{it} = \alpha + \beta Goal18_i + Elev_i\left[\delta_1 + \delta_2 Goal18_{it}\right] + SC_i\left[\omega_1 + \omega_2 Goal18_{it}\right] + \mathbf{X}_{it}\sigma + \eta_{jt} + \nu_t + \varepsilon_{ijt}$$

Vector of parcel-specific structure and land attributes

County by year fixed effect

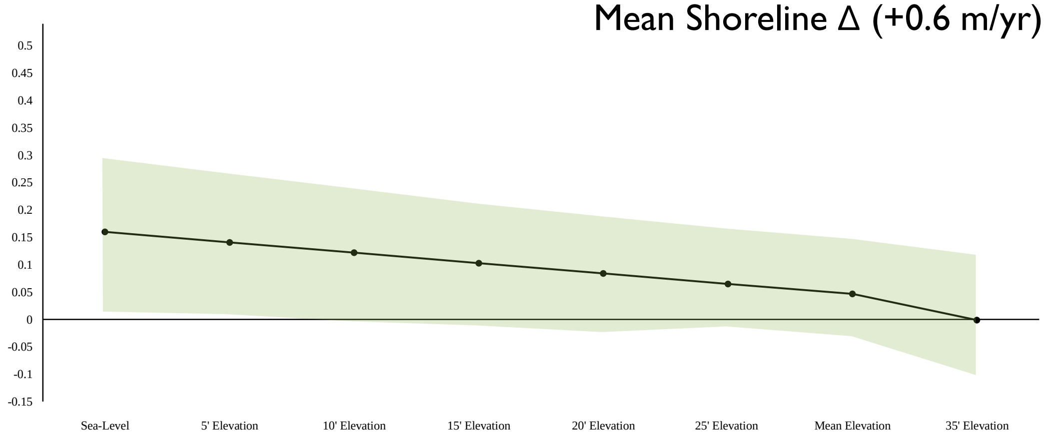
Quarter of sale fixed effect

GOAL 18 ELIGIBILITY RESULTS

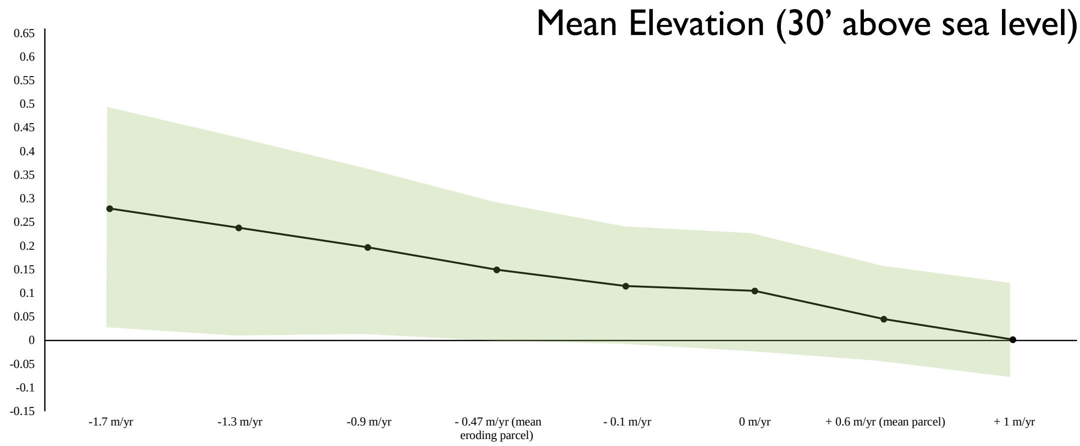
	Estimate	Std. Error
Discrete Change Effect of Goal 18 Eligibility		
All parcels (N=866)	0.045	0.059
Eroding parcels (N=245)	0.149*	0.083
Low Elev. <= 30' (N=534)	0.127*	0.071
Eroding, Low Elev. (N=155)	0.236**	0.095

GOAL 18 ELIGIBILITY EFFECTS: ALL PARCELS
(N=866)

Mean Shoreline Δ (+0.6 m/yr)

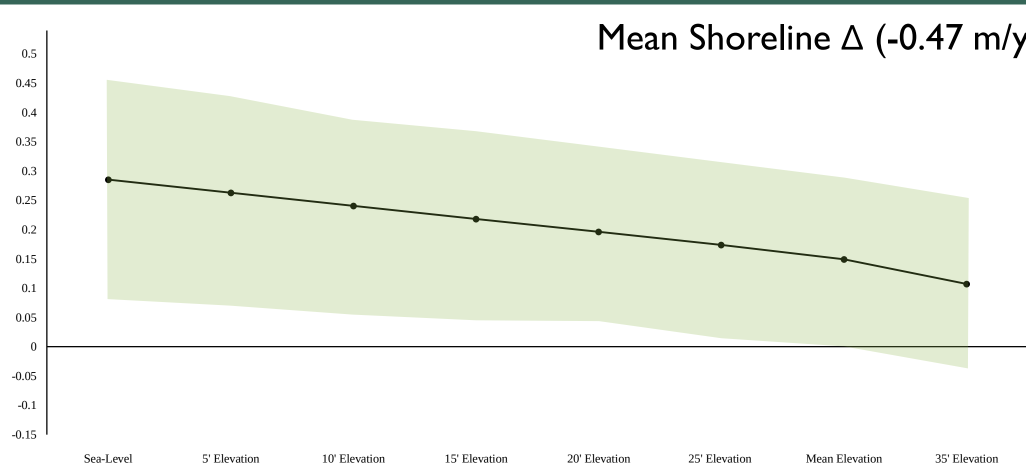


GOAL 18 ELIGIBILITY EFFECTS: ALL PARCELS
(N=866)



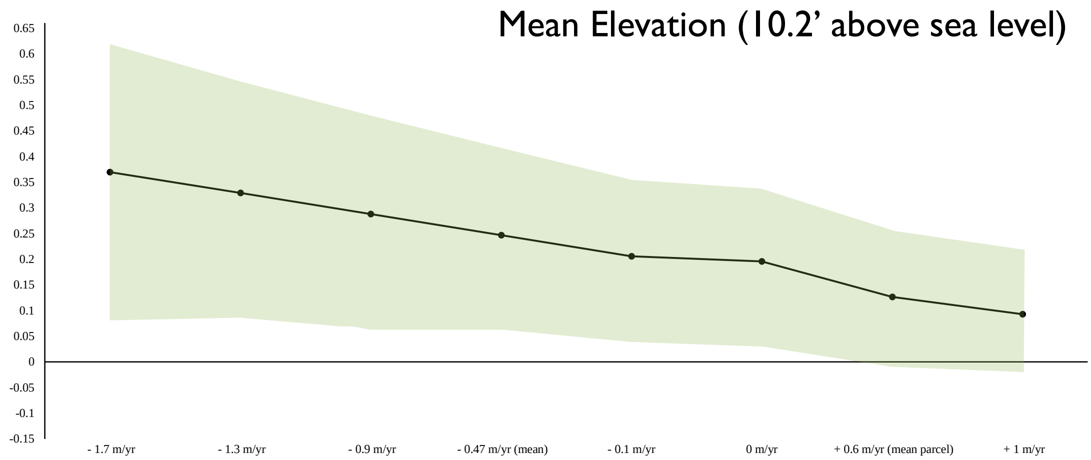
102

GOAL 18 ELIGIBILITY EFFECTS: ERODING PARCELS
(N=245, 28% OF SAMPLE)



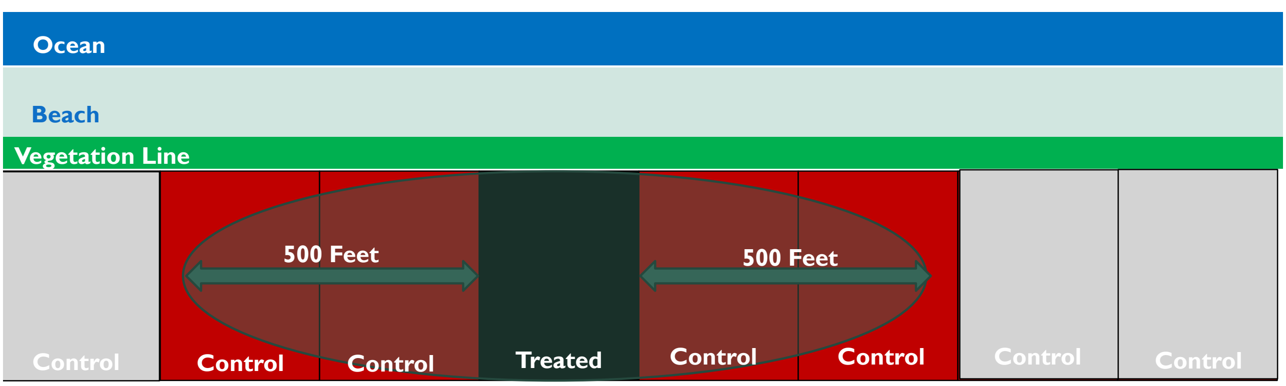
103

GOAL 18 ELIGIBILITY EFFECTS: LOW ELEVATION PARCELS
(N=534, 62% OF SAMPLE)



104

REGRESSION WITH SPATIAL BUFFERS



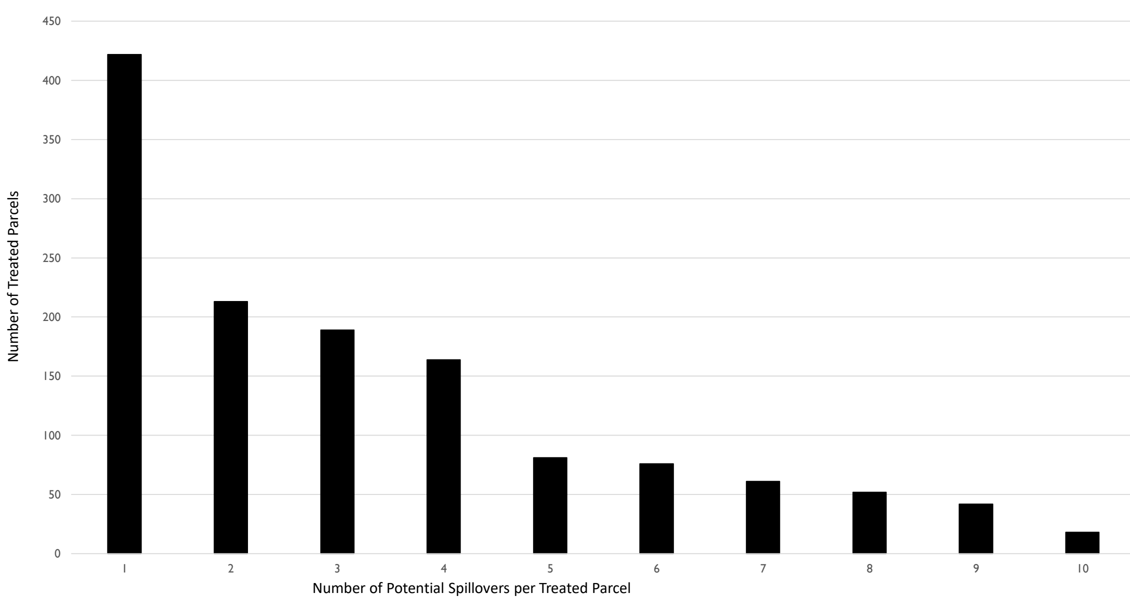
105

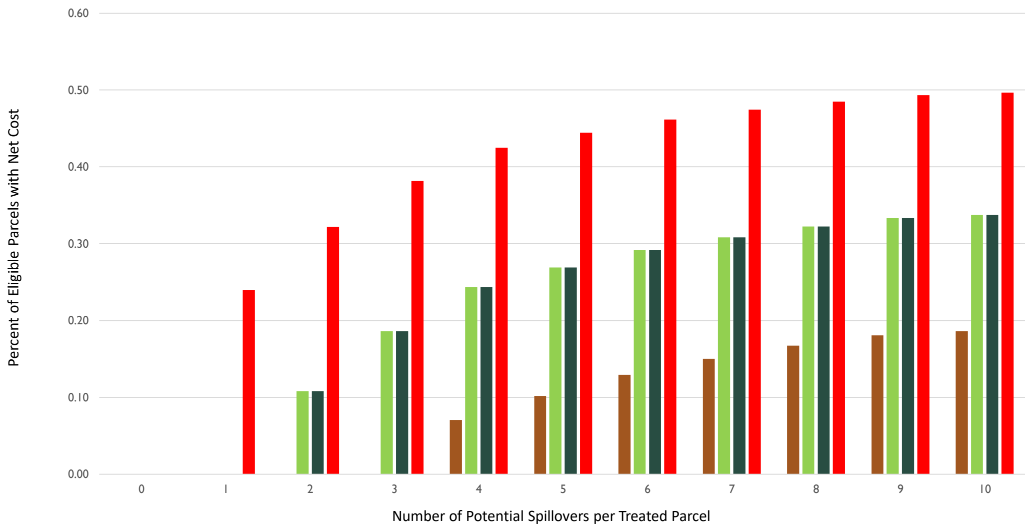
GOAL 18 ELIGIBILITY EFFECTS

	(1) Preferred Model		(2) 100' buffer		(3) 200' buffer		(4) 500' buffer	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
All parcels (N=866)	0.045	0.059	0.011	0.051	0.017	0.051	0.011	0.066

$$\%C_{NI} * \beta_{NI} + \%C_{SPE} * \beta_{SPE} = \beta_{full}$$

$$SPE = \beta_{SPE} - \beta_{NI}$$





108

Surf Pines – Clatsop County

- 118 parcels with a Goal 18 determination
  - 35 eligible (blue)
  - 83 ineligible (yellow)

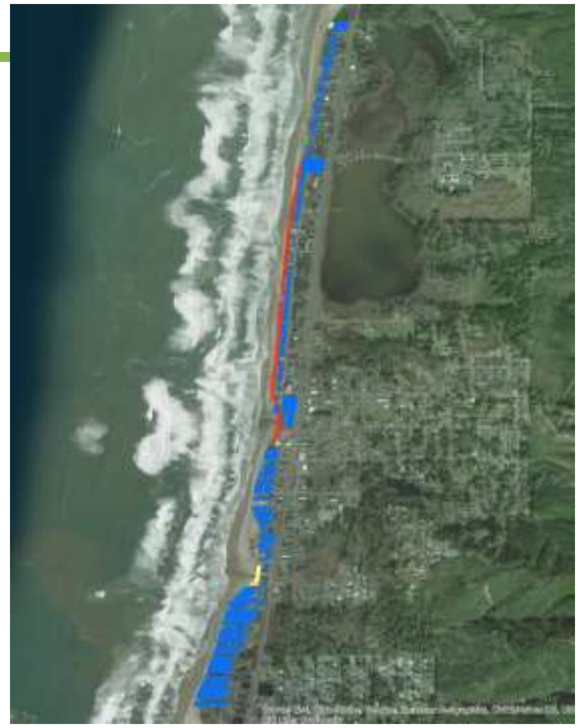
- With 500' buffer, 86% of ineligible parcels subject to potential spillover damages

- Goal 18 is a net cost in this community under a most scenario assumptions

109

Rockaway Beach – Tillamook County

- 233 parcels with a Goal 18 determination
  - Nearly all eligible (blue)
  - 85 already armored (red)
- All existing armoring is nearly continuous
- Suggestive evidence of cascading effect of shoreline armoring decisions to avoid spillover damages



SUMMARY OF FINDINGS

- The option value for coastal protection is positive but not significant for the average Oregon oceanfront home (30' elevation, 0.6 m/year accretion)
- For eroding parcels, effect is + and significant (~ 15%)
- For low elevation parcels, effect is + and significant (~ 13%)
  - These are not small effects, implying premiums of ~ $88,000 and $77,000 respectively

SUMMARY OF FINDINGS

- Estimation with spatial buffers suggests a 7 – 16 % negative spillover effect on ineligible parcels in close proximity to eligible parcels.

CONCLUSION & POLICY IMPLICATIONS

- Option values for coastal protection have the potential to be large, depending on the risk profile of the parcel
- Spillover effects are real and potentially economically significant for spatially-varying coastal policies
- Goal 18 is going to be tested in the near-term.
  - Legal cases are on the horizon

HOLD THE LINE:
IDENTIFYING DETERMINANTS OF THE DECISION TO INSTALL BEACHFRONT PROTECTIVE STRUCTURES

W. Jason Beasley
Ph.D. Student
Applied Economics

Steven Dundas
Assistant Professor
Applied Economics & COMES

Oregon State University CIMRS NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

RESEARCH QUESTIONS

- What factors matter in the decision to install coastal armoring?
  - Socioeconomic or other Controls?
  - Neighboring Spillovers?
  - Coalitions?
- What will the future coastal landscape look like under current Goal 18 laws?
  - Where and when?
- How might changes to policy alter the future coastal landscape?

IMPORTANCE

- Homeowners are limited in their options to combat coastal erosion
  - Do Nothing
  - Move Away
  - Hold the Line

IMPORTANCE

- Armoring, Seawalls, Other Options?
  - Scyphers et al (2015) - Gulf Coast survey respondents prefer riprap revetments for the "perceived durability and cost effectiveness"
  - Neumann et al (2015) - By 2100, the US cost of storm surge and sea-level rise net of adaptation >$990B
    - Majority of the expenditure will be in coastal armoring

IMPORTANCE

- Spillovers
  - What is a spillover?
    - When the decision from landowner A effects landowner B
  - We know the installation of armoring alters erosion patterns of neighboring parcels
    - Gopalakrishnan et al (2016) suggest the effects could extend as far as 10km
    - But, does this impact decision making?
      - Concerns over the "domino effect"

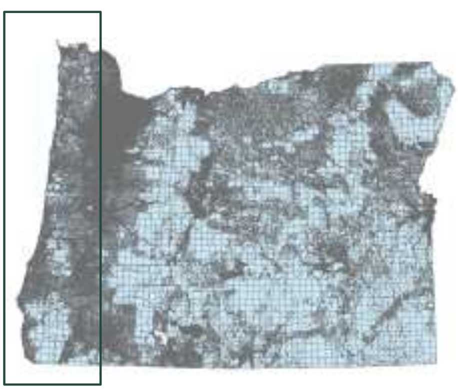
IMPORTANCE

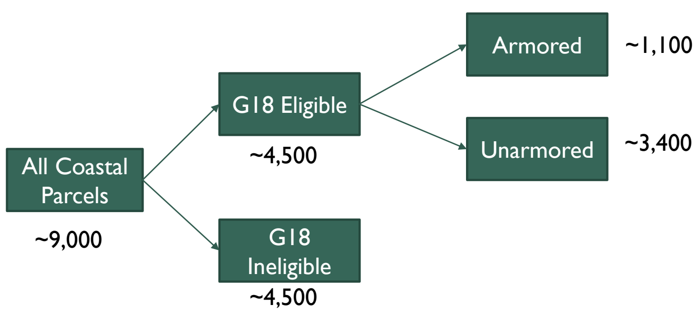
- Environmental Concerns
  - Limits beach access
  - Alters the natural landscape
  - Breaks the link between terrestrial and aquatic ecosystems
  - Disrupts the sediment cycles

IMPORTANCE

- We anticipate continuing erosion on the coast, increased storm surges and sea level rise
- Our largest expense to combat these problems will be in MORE coastal armoring, yet there are large gaps in our understanding of:
  - The way factors beyond geomorphological characteristics alter the installation decision
  - The way neighbors influence one another in the installation decision
  - The way different policies produce different coastlines

DATA





Variable	Description	WITH BPS Mean	WITH BPS Std. Dev.	WITH BPS Obs	WITHOUT BPS Mean	WITHOUT BPS Std. Dev.	WITHOUT BPS Obs
yearbuilt	Year of House Construction	1968	24	919	1965	25	2,650
universalbldgsqft	Square Footage	1,945	3,171	1,118	1,644	2,321	3,343
bedrooms	# of Bedrooms	2.45975	1.557518	1,118	2.168711	1.583772	3,343
impr_rmv_2015	RMV Improvement Value (2015)	67,498	134,725	1,131	50,360	129,284	3,373
lnd_rmv_2015	RMV Land Value (2015)	155,058	198,145	1,131	95,730	193,698	3,373
calc_ac	Acreage	0.741	6.180	1,131	0.698	5.119	3,373
min	Minimum Bare Earth Elevation	10.722	10.415	1,131	24.188	26.845	3,373
mean	Mean Bare Earth Elevation	18.754	20.053	1,131	35.031	30.993	3,373
epr_st	Short Term (50 yr) Erosion Rate	-0.786	0.955	1,131	0.180	1.296	3,373
lrr_lt	Long Term (100 yr) Erosion Rate	0.189	0.585	1,131	0.511	0.899	3,373
d_beach	Distance to Nearest Beach	0.066	0.032	1,131	0.103	0.073	3,373
d_posssps	Setback Distance for Structures	0.024	0.025	1,131	0.052	0.058	3,373
d_light	Distance to a Lighthouse	13.237	6.211	1,131	9.407	7.629	3,373
tsunami_SMALL		0.760	0.428	1,131	0.619	0.486	3,373
tsunami_MED		0.212	0.409	1,131	0.150	0.357	3,373
tsunami_LAR	Tsunami Classification Zones	0.014	0.118	1,131	0.084	0.278	3,373
tsunami_XLAR		0.009	0.094	1,131	0.074	0.262	3,373
tsunami_XX		0.000	0.000	1,131	0.009	0.094	3,373
tsunami_NONE		0.005	0.073	1,131	0.063	0.243	3,373
narrow	Beach Width Classification	0.035	0.185	1,131	0.024	0.154	3,373
inclined	Beach Incline Classification	0.060	0.238	1,131	0.039	0.193	3,373
gravel	Gravel Beach Classification	0.034	0.183	1,131	0.018	0.134	3,373
gravel_sand	Gravel and Sand Mixture Classification	0.036	0.187	1,131	0.129	0.335	3,373
sand	Sandy Beach Classification	0.016	0.125	1,131	0.033	0.178	3,373
sand_mud	Sand and Mud Mixture Classification	0.844	0.363	1,131	0.781	0.414	3,373

122

DATA

- Cross-Sectional [All Eligible Parcels]
  - We gather information on all parcels, at a single point in time
    - Analyze who has installed riprap and who has not installed riprap
- Panel [Lincoln & Tillamook County Parcels]
  - For the last 15 years, we collect information on parcels and characteristics that have changed over time and analyze against who armors and when
    - How many neighbors were armored in 2000? 2005? 2010?
    - What is the land value in 2000? 2005? 2010?
    - What is my setback distance in 2000? 2005? 2010?

MODELS & RESULTS

	(1) OLS	(2) OLS FE	(3) SAR	(4) SAR w FE	(5) SAR FE	(6) SARAR FE
main						
Acres	0.0035	0.0025	0.0029**	0.0019	0.0021	0.0021
Improv. RMV 2015	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
Land RMV 2015	0.0000***	0.0000	0.0000***	0.0000	0.0000*	0.0000*
Min Elev (ft)	-0.0012	-0.0015**	-0.0012*	-0.0014**	-0.0013**	-0.0013*
Mean Elev (ft)	-0.0025***	-0.0008	-0.0021***	-0.0005	-0.0001	-0.0001
Dist. Beach (m)	-1.3390***	-0.9981***	-1.1949***	-0.8906***	-0.7237***	-0.7104***
Erosion Rate (m)	-0.0937***	-0.0488***	-0.0844***	-0.0432***	-0.0228***	-0.0248**
Dist. SPS (m)	-0.7113***	-0.9405***	-0.6503***	-0.8461***	-0.6533***	-0.7160***
Dist. Shoreline (m)	0.7973**	0.6416**	0.7212**	0.5684*	0.4325*	0.4754*
gravel_sand	-0.2883***	-0.2004***	-0.2581***	-0.1763***	-0.1422***	-0.1489***
sand	-0.2759***	-0.1713***	-0.2451***	-0.1476***	-0.1032**	-0.1096**
sand_mud	-0.1683***	-0.1438***	-0.1485***	-0.1234***	-0.0964***	-0.0989***
narrow	0.1320*	0.0583	0.1215**	0.0576	0.0814*	0.0723
inclined	0.0518	0.1178***	0.0416	0.1022***	0.1156***	0.1138***
Constant	0.6140***	0.5408***	0.5342***	0.4582***	0.2849***	0.3017***
lambda						
Constant			0.0488***	0.0487**	2.3956***	2.2320**
rho						
Constant						1.1947

IMPACTS

- Example Marginal Effects:
  - A 1 ft increase in the parcel average elevation reduces the likelihood of armoring by 6.5%
  - A 1 ft increase in the distance from the structure on a parcel to SPS location reduces the likelihood of armoring by 0.2%
  - A 1 ft increase in erosion rate leads to a greater likelihood of armoring by 1.8%

LPM vs Logit ME

	LPM	ME-Logit	ME-TimeDum-t
Acres	0.0026	-0.0128	0.0041***
	(0.0014)	(0.0079)	(0.0009)
Improv. RMV (000s)	0.0001	0.0001	0.0001
	(0.0001)	(0.0001)	(0.0001)
Land RMV (000s)	0.0001*	0.0001	0.0002***
	(0.0000)	(0.0001)	(0.0000)
Min Elev (ft)	0.0014*	0.0015	-0.0010
	(0.0006)	(0.0010)	(0.0014)
Mean Elev (ft)	-0.0035***	-0.0046***	-0.0065***
	(0.0006)	(0.0008)	(0.0010)
Dist. Beach (ft)	-0.0002***	-0.0013***	-0.0003***
	(0.0000)	(0.0002)	(0.0001)
Dist. SPS (ft)	-0.0002***	-0.0004***	-0.0002***
	(0.0000)	(0.0001)	(0.0000)
Dist. Shore (ft)	-0.0002**	0.0008***	0.0003**
	(0.0001)	(0.0002)	(0.0001)
ST Erosion (ft)	-0.0182***	-0.0210***	-0.0181***
	(0.0021)	(0.0026)	(0.0021)

NEXT STEPS - COALITION

- What if the actual process consists of neighbors getting together and sharing the installation cost across multiple parcels?
  - Examples include establishing LLCs
  - ~50% of all permits > 1 parcel
  - ~85% of all permits < 4 parcels

NEXT STEPS - COALITION

Simplified Coastline:

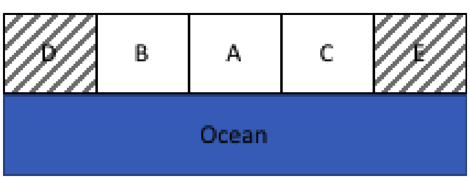
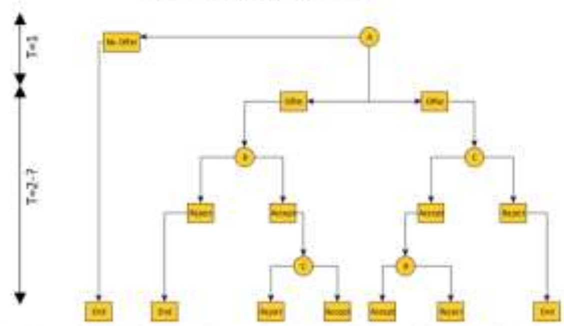


Figure 4: Extensive Game Tree



Installation A:	R=1	R=1	R=1	R=1	R=1	R=1	R=1
Installation B:	R=0	R=0	R=1	R=1	R=1	R=0	R=0
Installation C:	R=0	R=0	R=0	R=1	R=1	R=1	R=0
Coalition:	A	A	AB	ABC	ABC	AC	A

NEXT STEPS - SIMULATION

- Three major goals
  - 1) Simulate future landscape and identify timing and location of anticipated armoring along the Oregon Coast
  - 2) Test varying modifications to G18 eligibility and quantify coastline changes in terms of preserved or lost natural beach landscape
  - 3) Understand how climate change may impact the armoring patterns under future policy scenarios

PUBLIC PREFERENCES FOR COASTAL PROTECTION OPTIONS



Oregon State University CIMRS NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

CURRENT STATE OF KNOWLEDGE

- There are a number of economic estimates of the value of storm protection services for coastal property owners.
- Much less is known about public preferences for shoreline management options
  - Only prior valuation study asked North Carolina residents a single valuation question about management options
    - 46% of survey respondents indicated some positive WTP for any management ($37 per year/household)
    - Managed retreat was most preferred ($61 per year/household)

EXISTING PROGRAMS

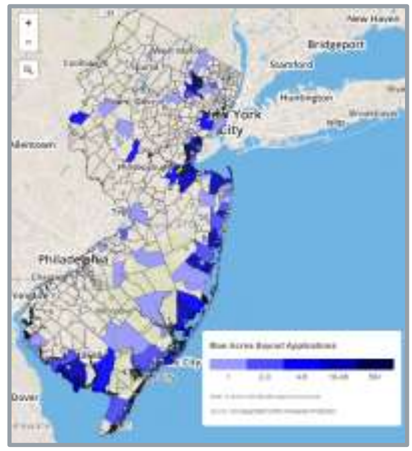
YES on AA

CLEAN AND HEALTHY BAY

- Watershed-level - Measure AA (CA):
- $12 annual parcel tax in all nine Bay Area counties to fund wetlands restoration and flood control projects around San Francisco Bay's shoreline.
- Measure AA will raise roughly $500 million over the next 20 years.
- Provides a local source of funding toward the estimated $1.5 billion job of restoring thousands of acres of tidal marshlands around the bay.
- Dual purpose of bringing back wildlife and giving the Bay Area a strategy to deal with rising sea levels.

EXISTING PROGRAMS

- State-level - The Blue Acres Program (NJ):
  - Part of New Jersey's Green Acres Program that purchases flood-prone properties.
  - State buys homes that were flooded in Sandy or previous storms.
  - Land permanently preserved as open space, accessible to the public, for recreation or conservation.
  - Natural buffers against future storms and floods.
  - 600+ properties purchased so far



OUR GOAL

- Estimate willingness-to-pay (WTP) for coastal protection based on the type of investment used (natural, grey, retreat) and the ecosystem services provided by such investments.
- Value attributes of restoration and protection that are critical inputs to both conceptual and empirical models of coastal management options.

CURRENT QUESTIONS

What are the attributes of a coastal infrastructure investment that matter to the general public?

CURRENT QUESTIONS

How can we accurately and simply describe changes in attributes that matter from a policy intervention?

Attributes and Levels

Habitat Construction Program Attribute	Levels
Increased water quality	(No, 10%, or 20%) reduction in nitrogen and phosphorus
Improved flood protection	(5%, 10%, or 15%) increase in the number of homes protected
Increased commercial fisheries support	(10%, 20%, or 30%) increase in annual seafood catch
Increased wading bird population	(No, 5%, or 10%) increase in wading bird population
Total one-time cost to your household	($5, $10, $25, $50, $75, $100, $150, $200)

Interis & Petrollia. 2016. *Land Economics*

135

CURRENT QUESTIONS

How can we accurately and simply describe changes in attributes that matter from a policy intervention?

- Example: storm buffer
  - Reduction in annual flooding events (# of events or percentage)?
  - Count of number of homes/pieces of critical infrastructure protected?

TIMELINE

Summer 2018

- Finalize attributes and plausible changes to those attributes from a policy intervention

Fall 2018

- Initial focus groups
- Experimental design

Winter 2018/19

- Final focus groups
- Pre-test

Spring 2019

- Survey implementation

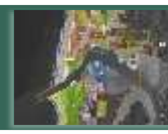
LIFE SAFETY AND NATURAL INFRASTRUCTURE

AN ECONOMIC PERSPECTIVE

W. Jason Beasley
Steven Dundas
David Kling
Ali Mostafizi
Dan Cox
Haizhong Wang

Oregon State University
CIMRS
NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

OVERVIEW

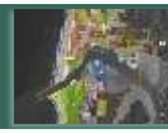


Strategies for mitigating tsunami risk have generally involved evacuating to naturally occurring high ground

However, tsunamis triggered by local events may not allow sufficient warning time to evacuate.

Vertical evacuation is a potential solution for communities subject to these risks.

OVERVIEW



Oregon's coastal communities are at high risk Cascadia subduction zone (CSZ) earthquakes and tsunamis

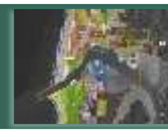
We are modeling Seaside as the community has a very high risk from a local CSZ tsunami

OVERVIEW

Vertical evacuation from tsunamis is gaining traction in US as an investment in life safety and coastal resilience

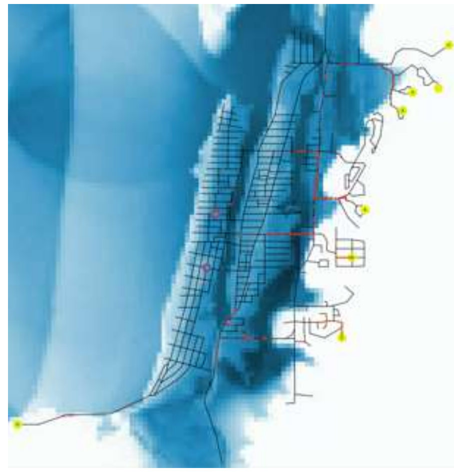
- 2009 FEMA/NOAA report for community planners
- 1st vertical evacuation center breaks ground in 2015 (WA)
- New MSI building here at HMSC

OVERVIEW

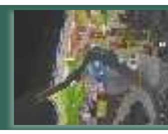


Existing Models
- Tsunami inundation model
  - Where the water goes

- Built Infrastructure and transportation system model
  - Where and how people can evacuate

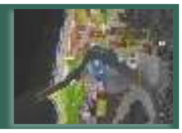


OVERVIEW



Existing Models
- Agent-based Model of Human Behavior Event Response

OVERVIEW



New Inputs

- Agent placement
- New infrastructure

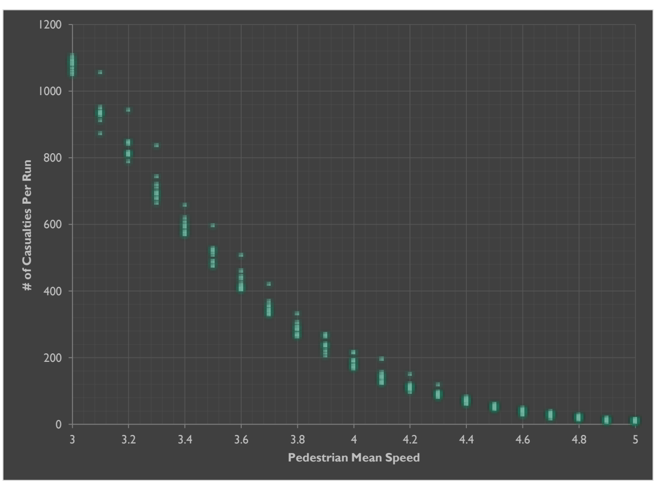
MODEL DEVELOPMENT

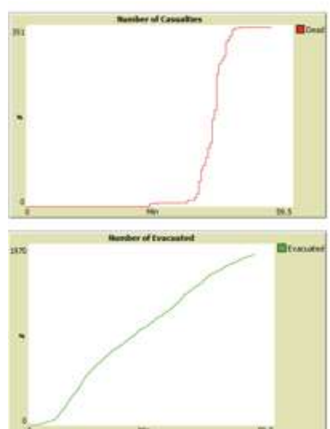
- Agent-based Model Updates
  - Enhanced real-world actions of agents
    - ”Herd mentality”
    - Updates to route decision making
  - Enhanced parameterization of agents
    - Type - resident / tourist
    - Physical Capabilities - Family / Solo;Young / Elderly

PROCEDURE

- Parameterize Model
  - Determine # of "agents" by type (tourist / resident)
  - Determine placement of agents
  - Determine distribution of parameters by agent type (speed, evacuation method, panic time, evacuation route)
- Simulations (thousands)
  - Each simulation will produce different outcomes in mortality rates
- Aggregate results / ranges of results

IMPLICATIONS / RESULTS





IMPLICATIONS / RESULTS

- Benefit Cost analysis
  - VE with grey infrastructure → life safety
  - VE with natural infrastructure → life safety AND ancillary benefits assoc. with parks, trails, open space
- Life Safety Measures
  - Identify best escapement infrastructure type
  - Identify value of reduction in tourist uncertainty
  - Identify equity of life safety benefit across population parameters

A MULTIDISCIPLINARY, INTEGRATIVE APPROACH TO VALUING COASTAL ECOSYSTEM SERVICES FROM NATURAL INFRASTRUCTURE

2018 ADVISORY BOARD MEETING

WORKING LUNCH

Oregon State University CIMRS NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

A MULTIDISCIPLINARY, INTEGRATIVE APPROACH TO VALUING COASTAL ECOSYSTEM SERVICES FROM NATURAL INFRASTRUCTURE

2018 ADVISORY BOARD MEETING

DUNE HABITAT SURVEY

Oregon State University | CIMRS | NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

DUNE LANDSCAPES PATHWAY

Today's presenters:

Sally Hacker
Professor
Integrative Biology

Paige Hovenga
Ph.D. Student
CEOAS

David Kling
Assistant Professor
Applied Economics

Oregon State University | CIMRS | NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE



Steve Dundas, Assistant Professor, Applied Economics
Sally Hacker, Professor, Integrative Biology
Paige Hovenga, PhD Student, CEOAS
Katya Jay, PhD Student, Integrative Biology
David Kling, Assistant Professor, Applied Economics
Tu Nguyen, PhD Student, Applied Economics
Peter Ruggiero, Professor, CEOAS

DUNE LANDSCAPE PATHWAY

Overall Goal: Understand the relationship between beach and dune management and their ecosystem services and values

Projects:

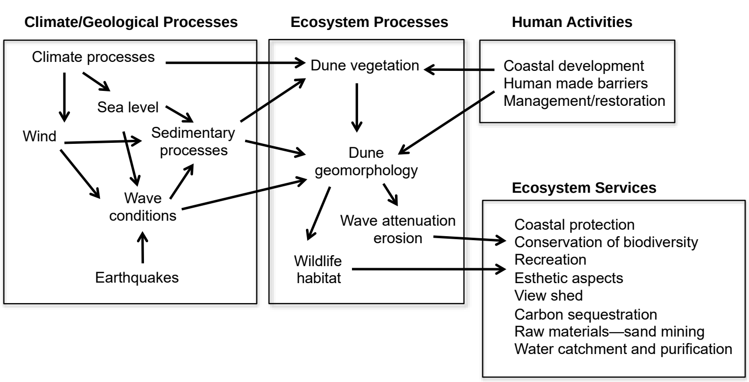
- Dune landscape choice experiment (earlier presentation)
- Conceptual model of beach and dune ecosystem services
- Case study: empirical model of beach and dune ecosystems
- Stylized optimization

Conceptual model of beach and dune ecosystem services

Oregon State University CIMRS NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

CONCEPTUAL MODEL OF BEACH AND DUNE ECOSYSTEM SERVICES

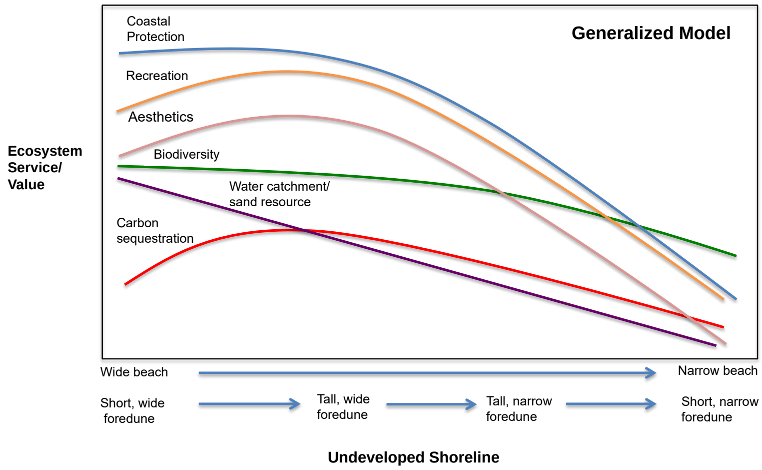
Explore the ecosystem services delivered by coastal beaches and dunes as a function of geomorphology, ecology, and management



CONCEPTUAL MODEL OF BEACH AND DUNE ECOSYSTEM SERVICES

Generalized model of undeveloped shoreline

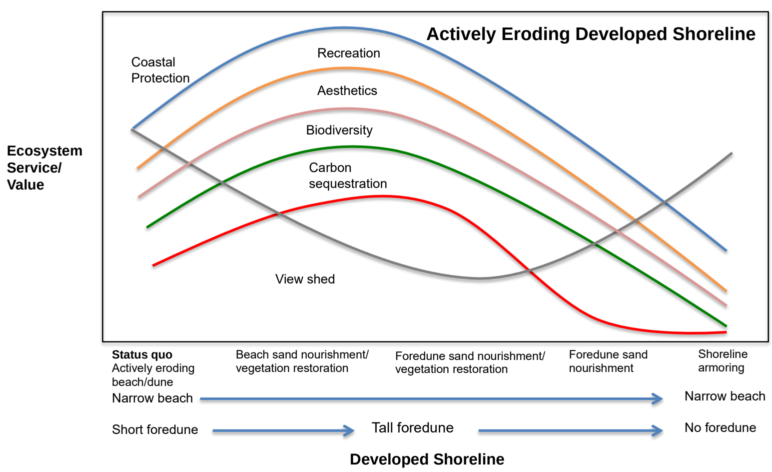
Role of beach width and foredune height for a variety of ecosystem services



CONCEPTUAL MODEL OF BEACH AND DUNE ECOSYSTEM SERVICES

Actively eroding developed shoreline

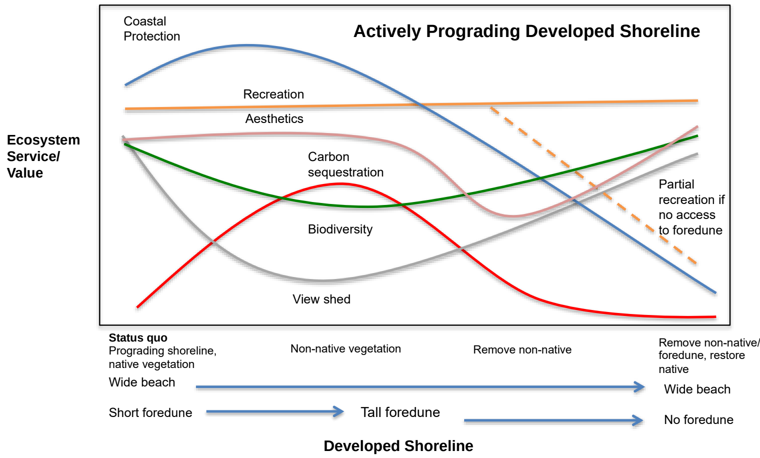
Role of management actions for a variety of ecosystem services



CONCEPTUAL MODEL OF BEACH AND DUNE ECOSYSTEM SERVICES

Actively prograding developed shoreline

Role of management actions for a variety of ecosystem services



CONCEPTUAL MODEL OF BEACH AND DUNE ECOSYSTEM SERVICES

Next steps:

Finalize the model and write a synthesis paper

Test the model using empirical data from the Oregon coast



Spatially-Explicit Dune Landscape Model

Oregon State University · CIMRS · NCCOS National Centers for Coastal Ocean Science

SPATIALLY EXPLICIT LANDSCAPE MODEL

Research Question:

How do we enhance a suite of beach and dune ecosystem services along a stretch of coastline while minimizing costs?

Approach:

1. Develop and implement a spatially explicit empirical model using field measurements (topographic and ecological), economic data sets (willingness to pay and housing market), and expert knowledge to target a set of management options.
2. Polasky et. al (2008) Where to put things? Spatial land management to sustain biodiversity and economic returns

BACKGROUND: INTRODUCTION OF BEACHGRASSES TO PACIFIC COAST

Adapted from Zarnetske et. al 2012
Photo Credit: Katya Jay

Ammophila arenaria (AMAR)

- High sand capture
- Tall, densely vegetated dunes

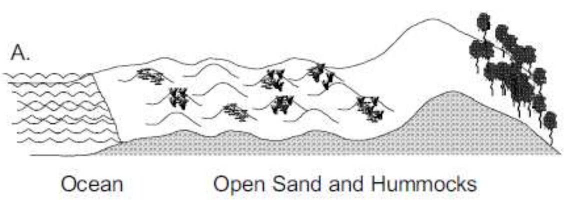
Ammophila breviligulata (AMBR)

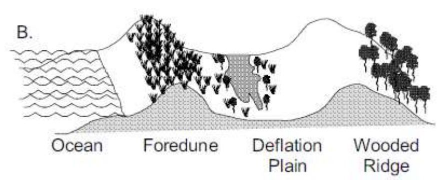
- Moderate sand capture
- Low, wide dunes

Elymus mollis (ELMO)

- Low sand capture
- Low, hummocky dunes

BACKGROUND: INTRODUCTION OF BEACHGRASSES TO PACIFIC COAST





BACKGROUND: INTRODUCTION OF BEACHGRASSES TO PACIFIC COAST

Beachgrass invasion caused:

- Increase in coastal protection services
- Sand stabilization for development behind dun
- Wetlands behind dunes (deflation plains)
- Forested and shrub habitat
- Invasion of other plant species

But also created a decline in:

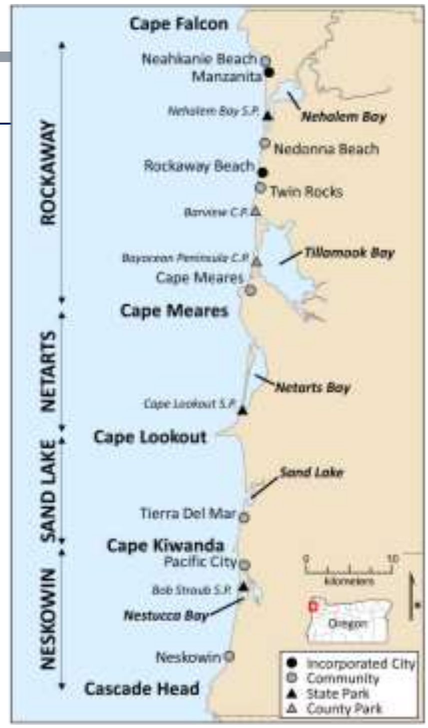
- Open dune habitat
- Some species of native plants and animals

BACKGROUND: BEACH / DUNE MANAGEMENT STRATEGIES

- Backshore armoring
- Restoration for plovers
- Dune grading

STUDY AREA: TILLAMOOK COUNTY

- Population: 25,653 (2015)
- ~104 km of coastline
- 4 littoral cells
- Geomorphology ranges from broad, low-sloped dune-backed beaches to cliff-backed and armored
- Majority of sediment sourced from erosion of the backshore



STUDY AREA: TILLAMOOK COUNTY

Dune-backed (Yellow)

Cliff-backed & Armored (Red/Brown)

Rockaway North

Rockaway South

Netarts

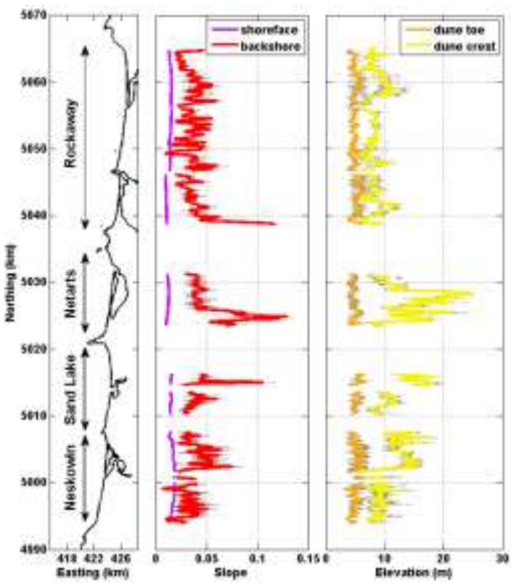
Sand Lake

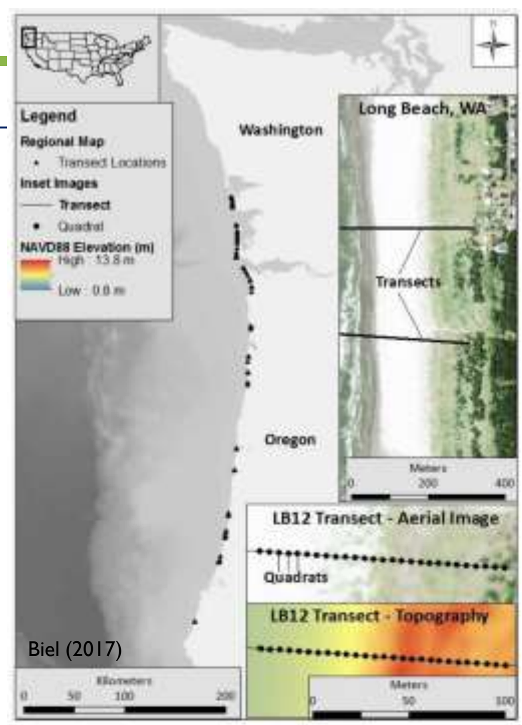
Neskowin

DATASETS AVAILABLE

- Lidar – 2011 (foredune height, short-term shoreline change rate, beach width)
- Grasses – (stem density, grass cover, dominant species, species diversity)
- Land use land cover - development patterns
- Distance from development
- Cliff-backed and armoring
- Viewsheds
- Water level impacts (overtopping days per year)
- Recreation patterns / beach access data
- Housing market data

LIDAR AND GRASS DATASETS





ECOSYSTEM SERVICES

Significance or value of each service is spatially explicit.

- Coastal protection
  - Foredune / riprap overtopping days per year
  - Impact hours per year
- Viewshed
- Recreation (beach accessibility / walking on the beach)
- Aesthetics
- Habitat (biodiversity)

MANAGEMENT ACTIONS

Management actions will be implemented in a spatially explicit manner.

- Dune scraping
- Dune mowing
- Beach nourishment
- Dune construction
- Grass species alteration
  - Removal / planting

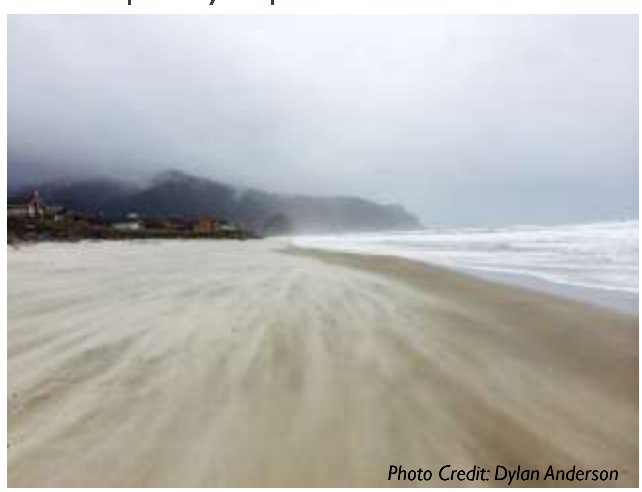


Photo Credit: Dylan Anderson

MODEL FLOWCHART

Determine Current Land Use
(developed vs undeveloped)

Quantify Present Day Ecosystem Service Metrics
(weight according to developed or undeveloped)

Willingness to Pay
For each ecosystem service (surveys)

Identify Relevant Management Actions
(e.g., dune grading, grass alteration)

Value Present Day Ecosystem Services
(dune landscape survey, literature, Steve's work)

Model Output:
Maximize N km space with n% of each ecosystem service
Total value of ecosystem services

QUESTIONS?



General Dune Management Model

Oregon State University

CIMRS

NCCOS | NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

MANAGING COASTAL DUNES AS NATURAL INFRASTRUCTURE

- How can an area of coastal dunes be managed to maximize net benefits to the general public?
  - Are there areas where coastal dunes can be:
    - Built-up to increase protection to built infrastructure?
    - Restored to their original (uninvaded) state?
  - If so, how might the cost of these different management approaches compare to potential benefits?

GENERAL FRAMEWORK FOR PLANNING INVESTMENT

$$\underset{\text{from time } t \text{ to } T}{\textbf{maximize}} \begin{pmatrix} \text{discounted} \\ \text{sum} \\ \text{of} \ldots \end{pmatrix} \begin{bmatrix} \text{expected value of} \\ \textbf{goods} \text{ and } \textbf{services} \\ \text{at time } t \end{bmatrix}$$

Subject to:

$$\begin{bmatrix} \textbf{goods} \text{ and } \textbf{services} \\ \text{at time } t+1 \end{bmatrix} = \begin{matrix} \text{Production} \\ \text{Funtion} \end{matrix} \left(\begin{bmatrix} \textbf{goods} \text{ and } \textbf{services} \\ \text{at time } t \end{bmatrix} \right)$$

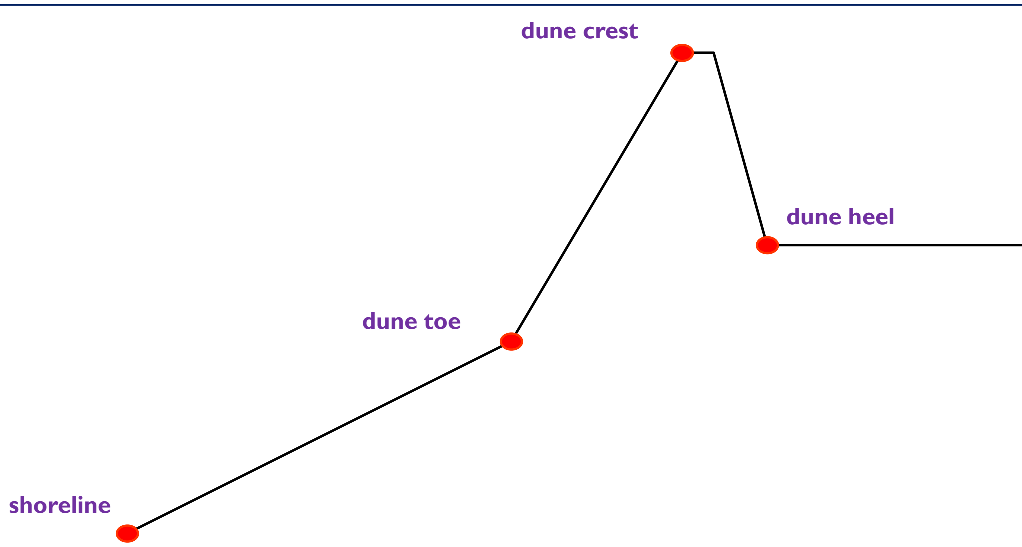
MANAGING COASTAL DUNES AS NATURAL INFRASTRUCTURE

- How can an area of coastal dunes be managed to maximize net benefits to the general public?
  - Are there areas where coastal dunes can be:
    - Built-up to increase protection to built infrastructure?
    - Restored to their original (uninvaded) state?
  - If so, how might the cost of these different management approaches compare to potential benefits?
- **These questions are important for natural infrastructure management in the PNW and around the world.**

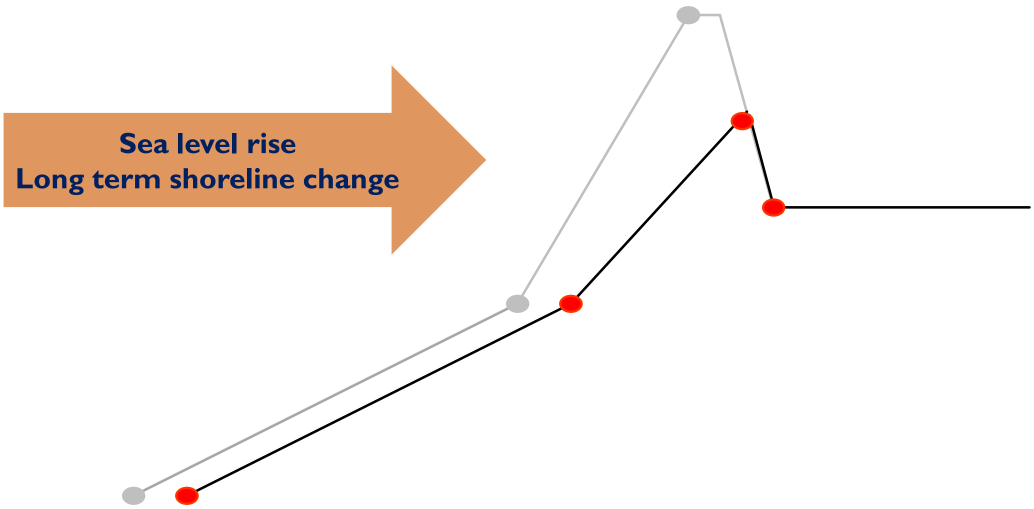
SEEKING INSIGHTS WITH A GENERAL MODEL

- To understand the trade-offs in this system, need a model of coastal dune morphodynamics that can be optimized to represent investment in dune management. **This doesn't exist yet.**
- **Goal**: develop a stylized economic-morphodynamic model of optimal coastal dune management. Desired features:
  1. Simple enough to thoroughly explore using optimization. This is a novel approach in the study of dune morphodynamics to the best of our knowledge.
  2. Calibrated using information from past research on PNW coastal dunes.
  3. Aim for conclusions that are likely to be generalizable to sandy beach and coastal dune landscapes inside *and* outside the PNW.

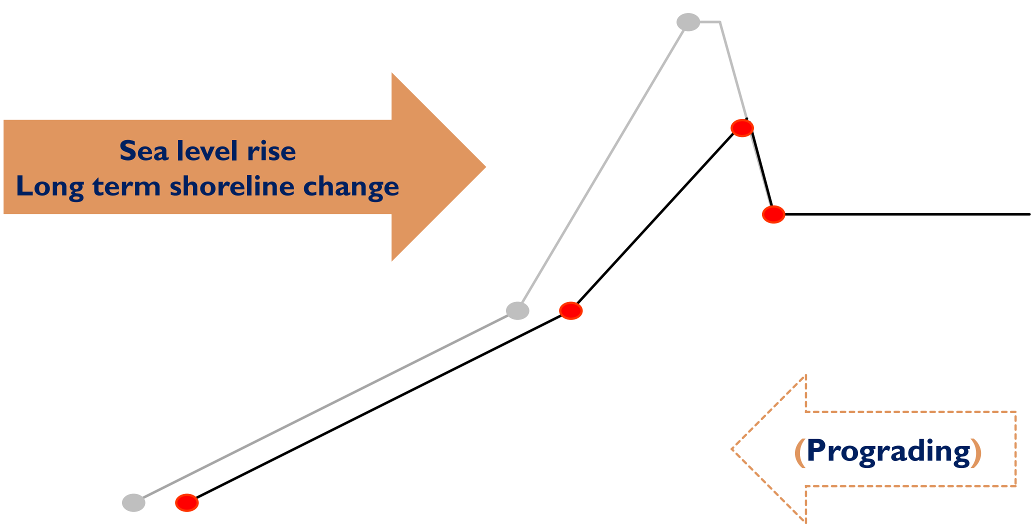
GENERAL DUNE MANAGEMENT MODEL



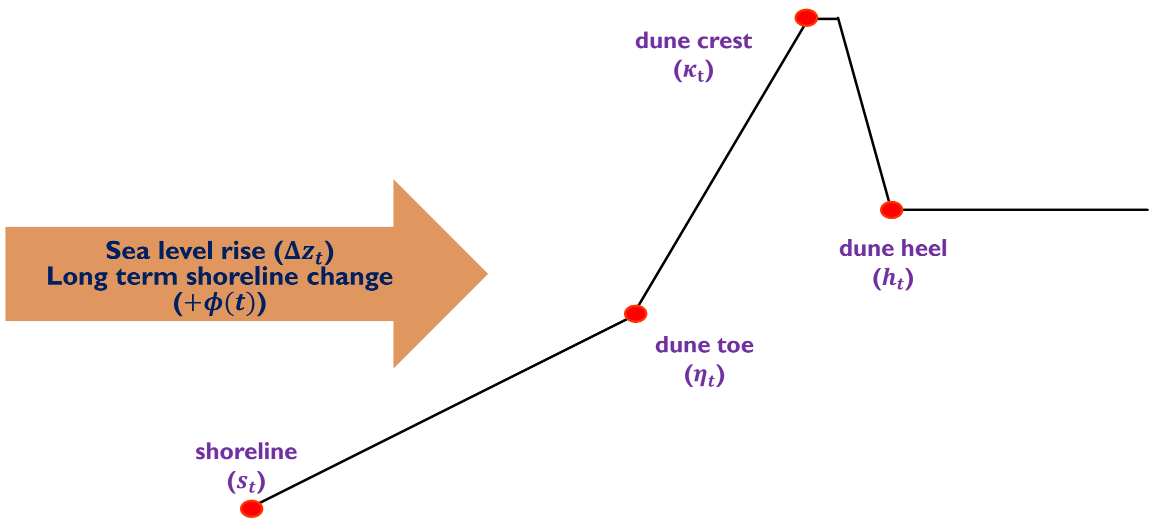
GENERAL DUNE MANAGEMENT MODEL



GENERAL DUNE MANAGEMENT MODEL



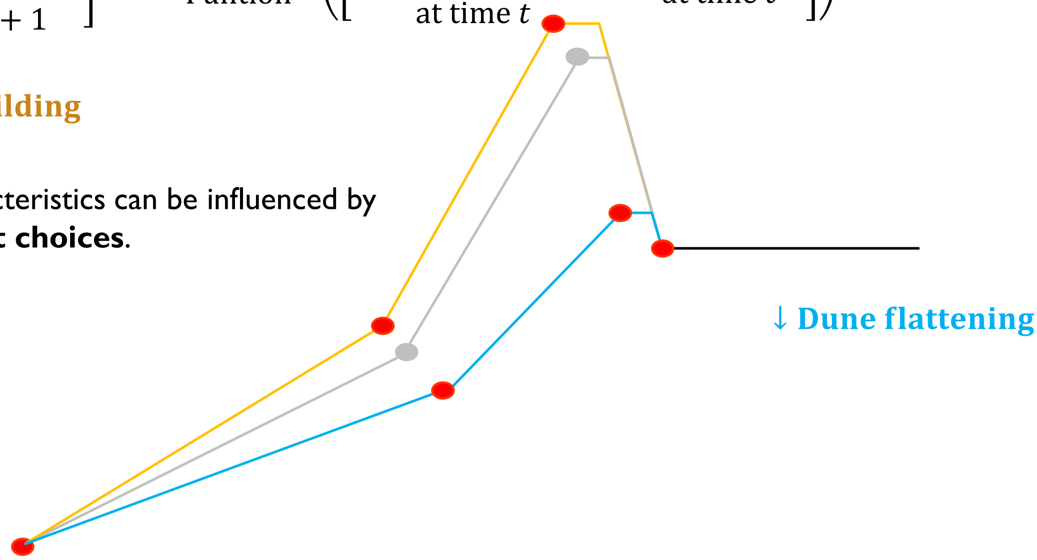
Metrics that represent (average) characteristics of coastal dune and sandy shore landscape become dynamic **state variables** that are tracked over time.



[dune/shoreline characteristics at time $t+1$] = Production Funtion ([dune/shoreline characteristics at time t , Investment at time t])

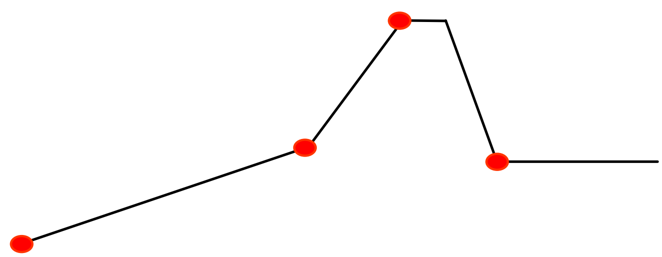
↑ **Dune building**

Dune characteristics can be influenced by **investment choices**.



Objective of optimization model:

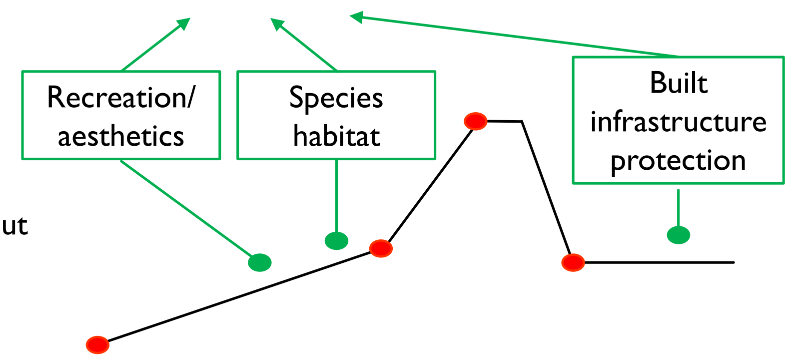
maximize from time t to T (discounted sum of … [Value of **dune/shoreline characteristics** at time t − Cost of **investment choices** at time t])



Objective of optimization model:

maximize from time t to T (discounted sum of … [Value of **dune/shoreline characteristics** at time t − Cost of **investment choices** at time t])

- Different coastal dune landscape states generate different types of benefits.
- **Example**: tall foredunes provide more protection, but deprive some species of habitat.



RESEARCH QUESTIONS

- How is economically-optimal (i.e., cost-effective) sandy beach and coastal dune landscape management influenced by various benefit/cost profiles?
- How do managed beach-dune morphodynamics compare to the expected status-quo trend?
- How do different expected sea level rise/storm regime predictions influence optimal management?
- How do representative optimal dune management plans from one part of the world (e.g., the PNW) compare to other parts of the world involved in active sandy beach/ coastal dune management.

NEXT STEPS

- Complete morphodynamic sub-model.
- Calibrate model
- Use numerical optimization methods to characterize economically-optimal sandy beach and coastal dune landscape management for different benefit/cost profiles.
  - Survey results will ultimately integrate with this analysis.

A MULTIDISCIPLINARY, INTEGRATIVE APPROACH TO VALUING COASTAL ECOSYSTEM SERVICES FROM NATURAL INFRASTRUCTURE

2018 ADVISORY BOARD MEETING

OUTREACH & ENGAGEMENT

Oregon State University

CIMRS

NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE