Integrating spatially dynamic ocean acidification on recreational values of coral reefs for the Main Hawaiian Islands

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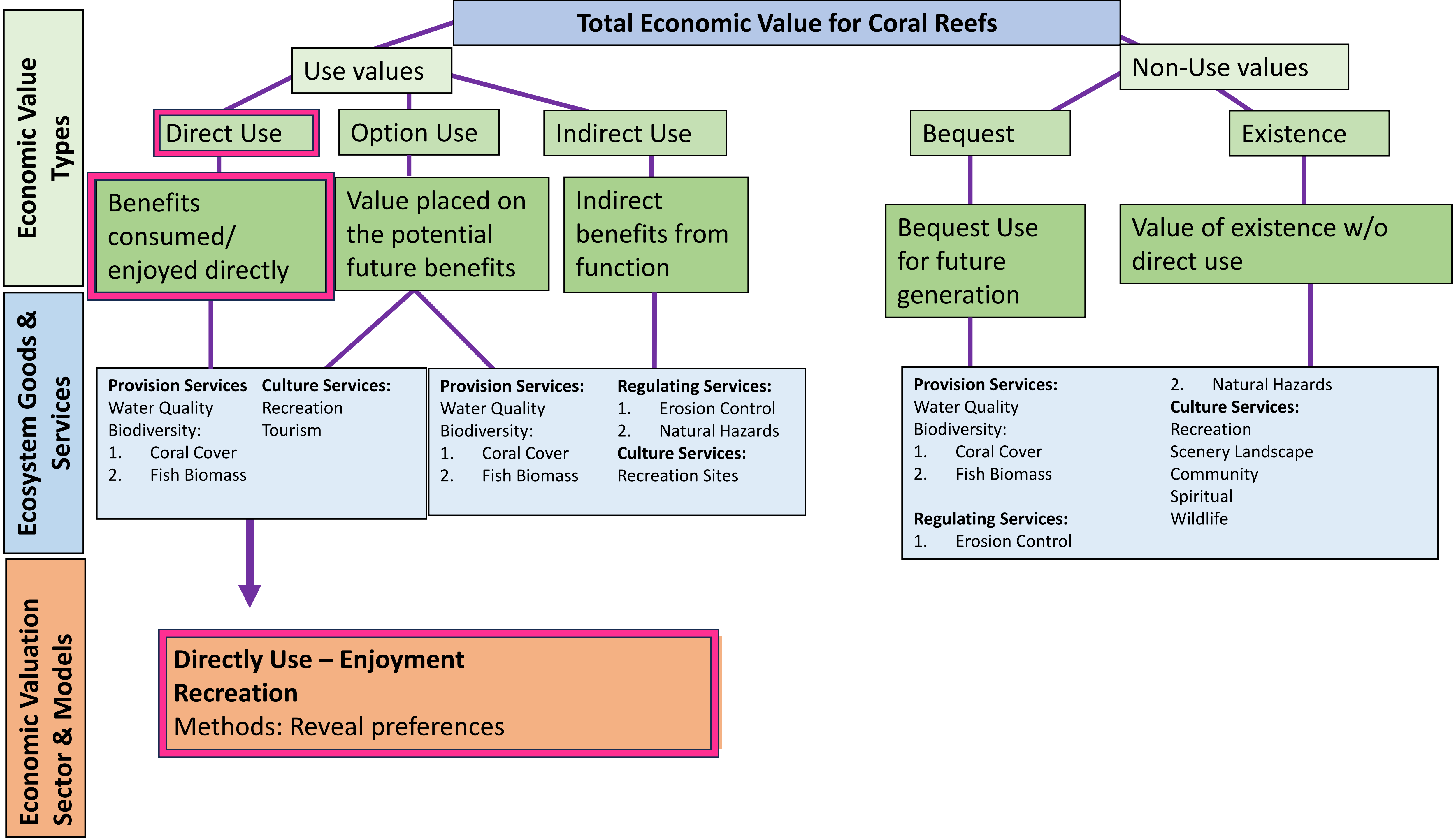
Motivations

- Coral reefs provide numerous ecosystem services supporting life of more 1/2billion people (UN Envir. 2018)
- Calls for valuation ecosystem services for Capital Accounts, BCA, Assessments (NCAVES, Frontiers of BCA, NNA)
- Calculating economic value is tedious but important understand full impacts of our choices.


Total Economic Value for Coral Reefs
Economic Value Types
Use values
Non-Use values
Direct Use
Option Use
Indirect Use
Bequest
Existence
Benefits consumed/ enjoyed directly
Value placed on the potential future benefits
Indirect benefits from function
Bequest Use for future generation
Value of existence w/o direct use
Ecosystem Goods & Services
Provision Services
Water Quality
Biodiversity:
1. Coral Cover
2. Fish Biomass
Culture Services:
Recreation
Tourism
Provision Services:
Water Quality
Biodiversity:
1. Coral Cover
2. Fish Biomass
Regulating Services:
1. Erosion Control
2. Natural Hazards
Culture Services:
Recreation Sites
Provision Services:
Water Quality
Biodiversity:
1. Coral Cover
2. Fish Biomass
Regulating Services:
1. Erosion Control
2. Natural Hazards
Culture Services:
Recreation
Scenery Landscape
Community
Spiritual
Wildlife
Economic Valuation Sector & Models
Directly Use – Enjoyment
Recreation
Methods: Reveal preferences

Previous EV Hawaii Coral Reefs

- Cesar, H.S. et al(2004). Economic valuation of the coral reefs of Hawai'i. *Pac. Sci.*
  - ➢ Most Comprehensive Hawaii Based Valuation study over 20yrs old (Cesar et 2004)
  - ➢ Estimates Total Economic value ~$600million (2024 $) with $23.7 Mil from Resident Recreational Value

TABLE 3

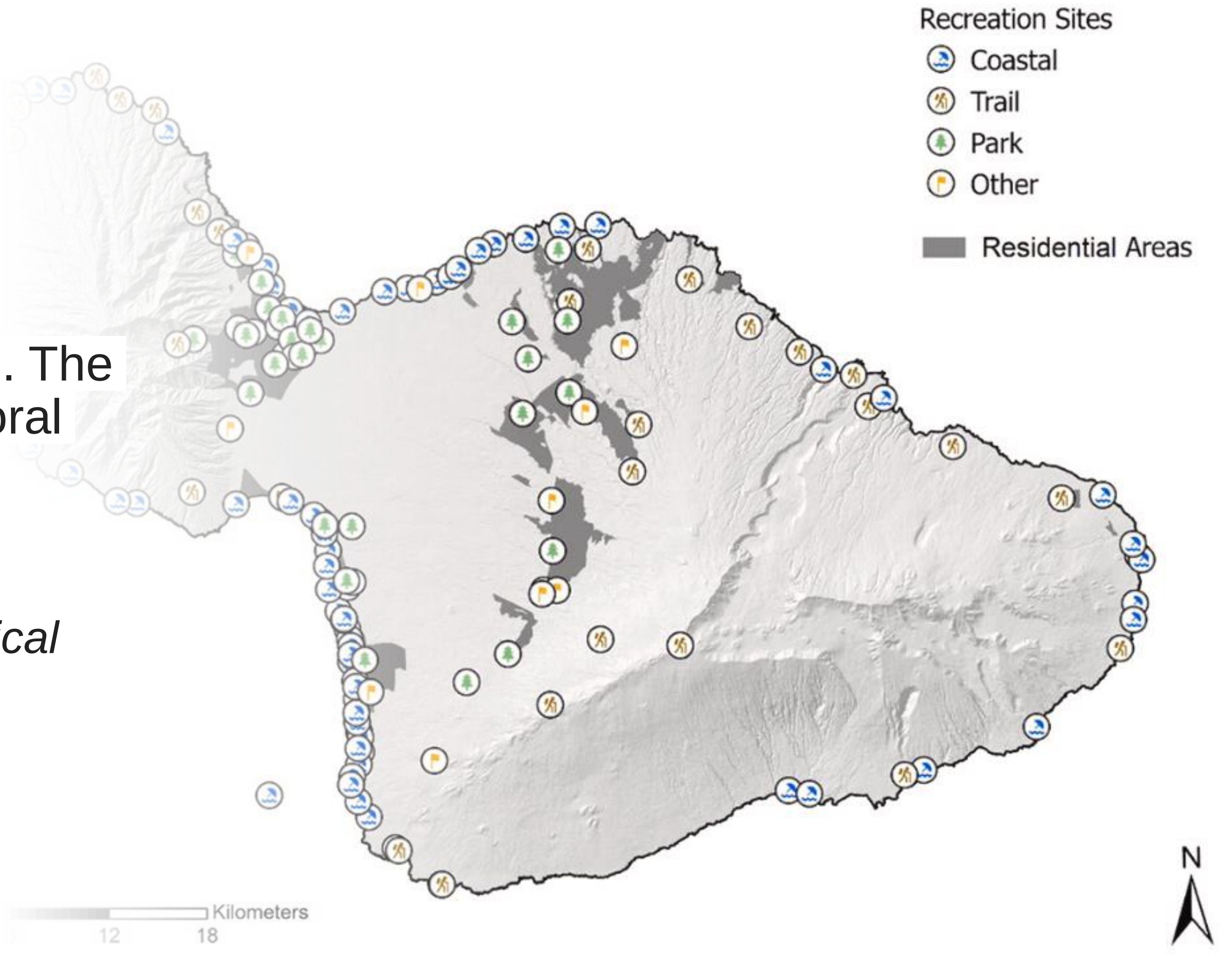
Recreational Value of Coral Reefs in Hawai'i in 2001 (in Million $)

	Consumer Surplus	Value Added of Direct Expenditure	Value Added of Indirect Expenditure	Multiplier Effect	Total Value Added
Snorkelers					
Residents	10.1	2.3	—	0.6	13.0
U.S. West	47.8	20.9	23.1	11.0	102.9
U.S. East	33.2	14.5	20.4	8.7	76.8
Japan	13.3	5.8	2.2	2.0	23.4
Canada	5.2	2.3	3.6	1.5	12.6
Europe	3.8	1.7	2.2	1.0	8.7
Other	11.8	5.1	6.8	3.0	26.7
Subtotal	125.2	52.6	58.4	27.8	264.0
Divers					
Residents	3.4	5.1	—	1.3	9.9
U.S. West	1.6	3.1	3.5	1.7	10.0
U.S. East	1.1	2.2	3.1	1.3	7.7
Japan	1.3	2.5	2.7	1.3	7.8
Canada	0.2	0.3	0.5	0.2	1.3
Europe	0.1	0.3	0.3	0.1	0.9
Other	0.4	0.8	1.0	0.5	2.7
Subtotal	8.1	14.3	11.3	6.4	40.2
Total recreational value					
Residents	13.5	7.5	—	1.9	22.8
U.S. West	49.4	24.0	26.7	12.7	112.8
U.S. East	34.3	16.7	23.6	10.1	84.6
Japan	14.6	8.3	4.9	3.3	31.1
Canada	5.4	2.6	4.1	1.7	13.9
Europe	3.9	1.9	2.6	1.1	9.6
Other	12.2	5.9	7.8	3.4	29.4
Total	133.3	66.9	69.7	34.2	304.2

Our Team

Updating studies

- Fezzi, C., et al(2023). The economic value of coral reefs…. *Eco. Econ.*
  - ➢*Residents all users (direct use)*
  - ➢*Spatial tied Ecological Conditions*



Theoretical Framework

Random Utility Model:

$$U_{ij} = V_{ij} + e_{ij}$$

Assume maximizes income, m, over exogenous x_j that influence demand for recreational trip

$$U_j^*\left(z_1\left(x_j, m\right), z_2\left(x_j, m, y\right), y\right) = U_j^*\left(x_j, m, y\right)$$

Where z_1 & z_2, $set\ of\ goods$, m = income, $y\ ecosystem$

Changes Ecosystem => Calculate Compensating Variation

Recreation Values

- Coral Reefs increases utility when snorkeling available

Table 3
Random utility recreation model estimates.

	Model 3	
Variable	Coef.	Std. error
travel cost	−0.076 ***	0.002
NOR	5.666 ***	0.129
Site types:		
-coastal	−0.668 ***	0.193
-city park	−0.780 ***	0.163
-trail	0.703 ***	0.150
-Haleakala	4.652 ***	0.247
-olokini	4.489 ***	0.531
site attributes:		
-parking	1.178 ***	0.074
-showers	0.591 ***	0.062
coastal site attributes:		
-lifeguard	0.086	0.067
-pebbles	−1.266 ***	0.153
-manmade	−0.970 ***	0.185
-length = medium	0.117 *	0.070
-length = large	0.322 ***	0.075
-surf	−0.289 ***	0.057
-swim	0.131 *	0.078
-snorkeling	0.272 **	0.119
-fish	0.037 ***	0.004
-coral	0.008	0.007
-snorkeling * fish	0.006	0.004
-snorkeling * coral	0.020 **	0.008
city park attributes:		
-playground	0.723 ***	0.061
-sport fields	0.390 ***	0.071
Log-likelihood	−17,021.25	
Pseudo-R^2	0.651	

Assumptions Resident Recreational Value

Original WTP for sites:

$$\widehat{WTP}_{js} = f(z_{js}, \hat{\beta}_s)$$

Where $j = site\ \&\ s = population$

Transfering to *New sites*, i, & *Population*, r

where i $\neq$ j & r $\neq$ s:

$$\widehat{WTP}_{ir}^{BT} = f([z_{ir}^{1} z_{js}^{2}], \hat{\beta}_s)$$

Annual Value :

where m $=$ $county\ income$:

$$\widehat{WTP}_{ir}^{BT} * \frac{m_r}{m_{s=Maui}} * Pop18_r * 365$$

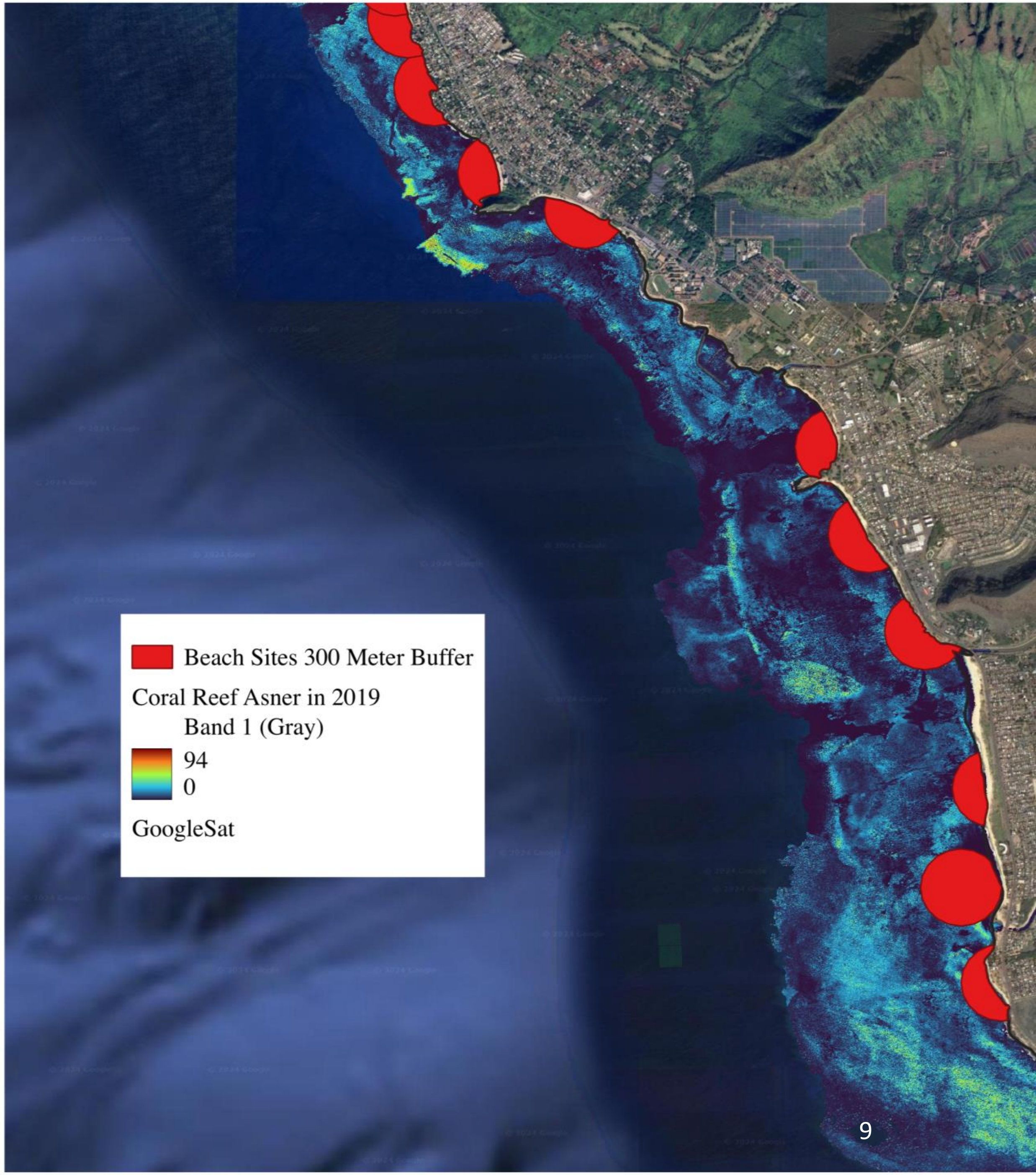
Define Sites & Ecosystem Condition

Recreation Site:

- Google API & Tour Guides

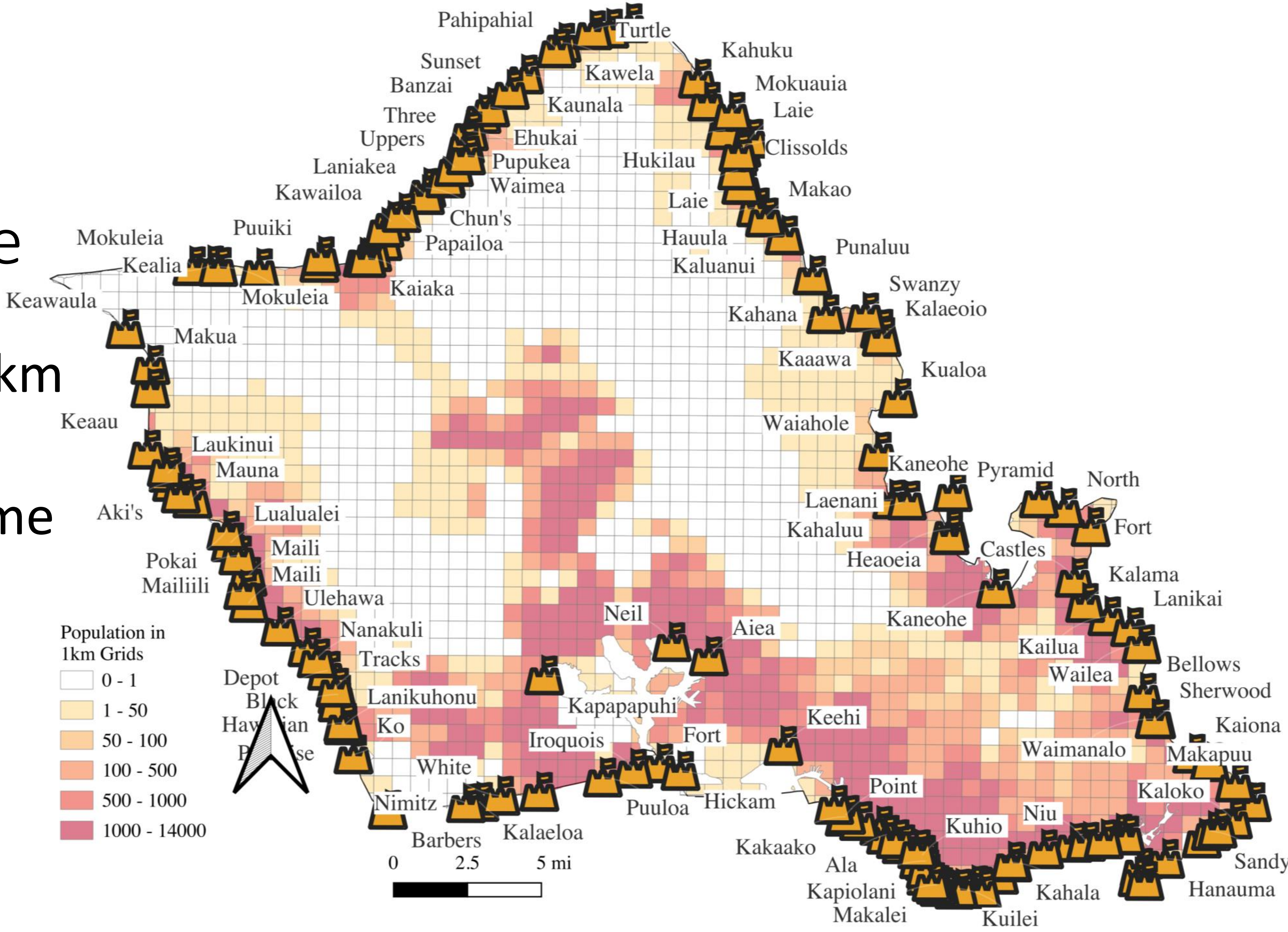
300-meter buffer:

- Coral Reef(Asner et al 2020)
- Resource Fish Biomass (NOAA 2017)



Define population & distance/time

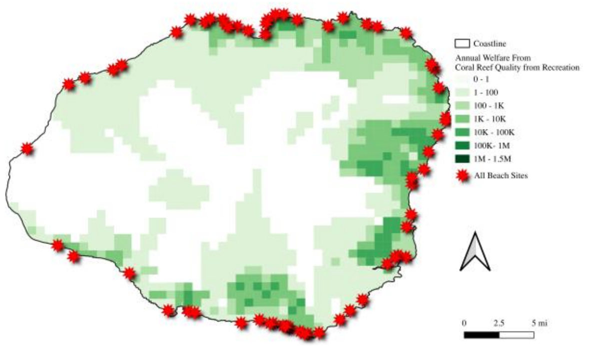
- Population km square
- Distance/time to site

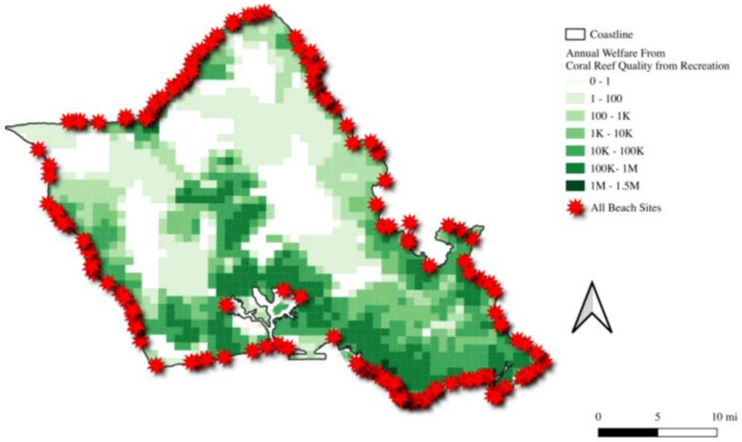


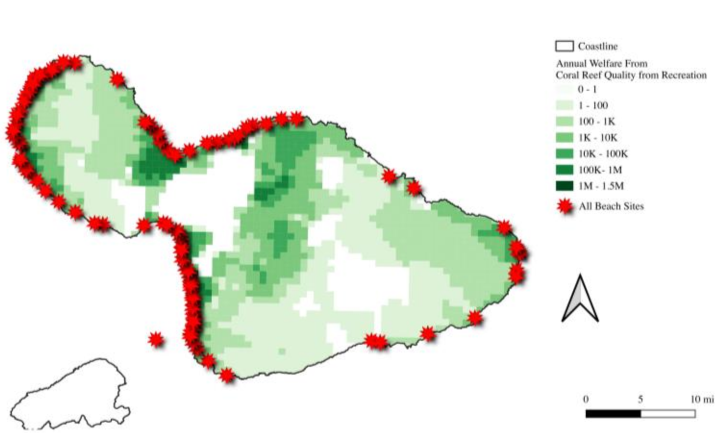
Resident Welfare Generated Annual

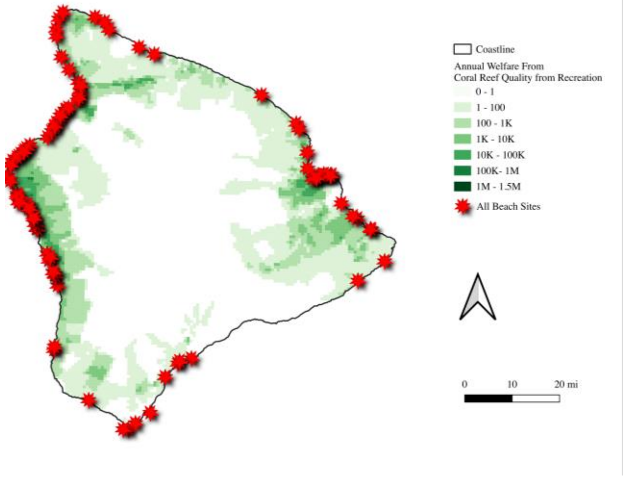
- $113 Million (2024 $$) which is .1% of Hawaii's Annual GDP

- Compared to Previous Study $23.78M (2024 $)







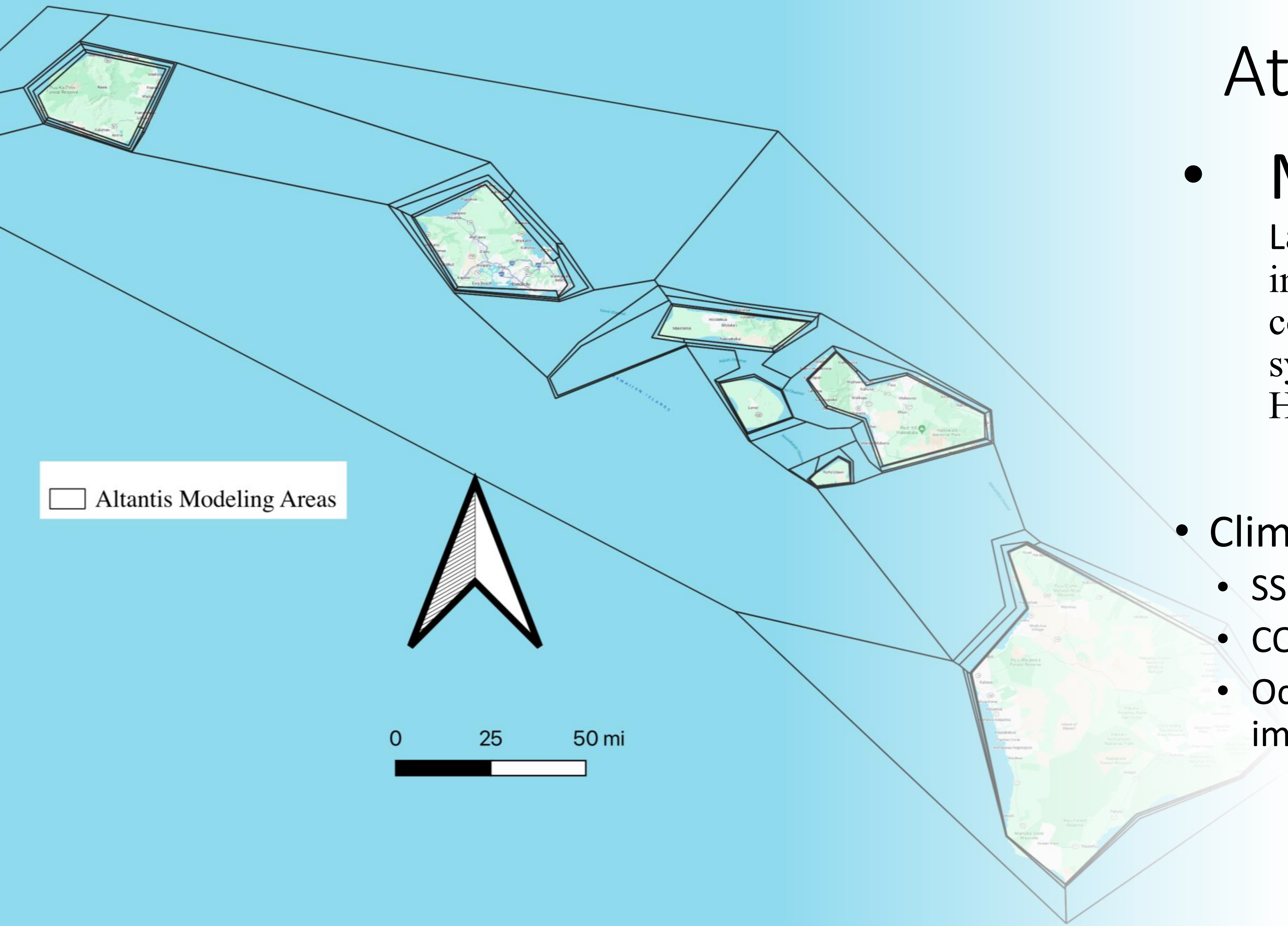


Spatially Simulated Scenarios for Hawaii's Nearshore Environment

Incorporating Ecological Modeling Under Climate Scenarios

Atlantis Model

- **MSEAS Season 10:**
  Lansing Perng: Modeling the impacts of climate change on coral reef social-ecological systems: Insights from the Main Hawaiian Islands



- Climate Scenarios
  - SSP1- SSP3
  - CO2 Emission pathways
  - Ocean Acidification & Warming impacts

Identify Genus within Atlantis

Coral Reef Types

- Pocillopora, Porites branching, Porites massive, Montipora

Time Steps to 2100 per box and calculate each time step:

$$y_{bt} = \frac{\sum Vol_{bt}}{\sum Vol_{bt=0}}$$

where vol is sum of volume coral reef in box, b, at time, t

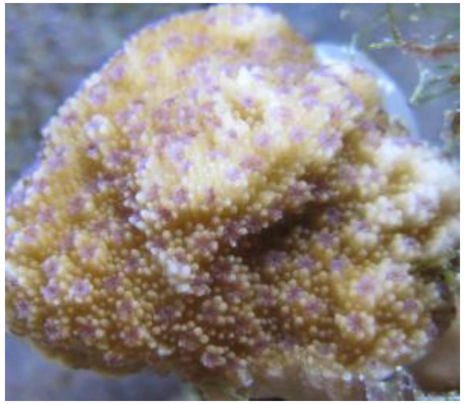
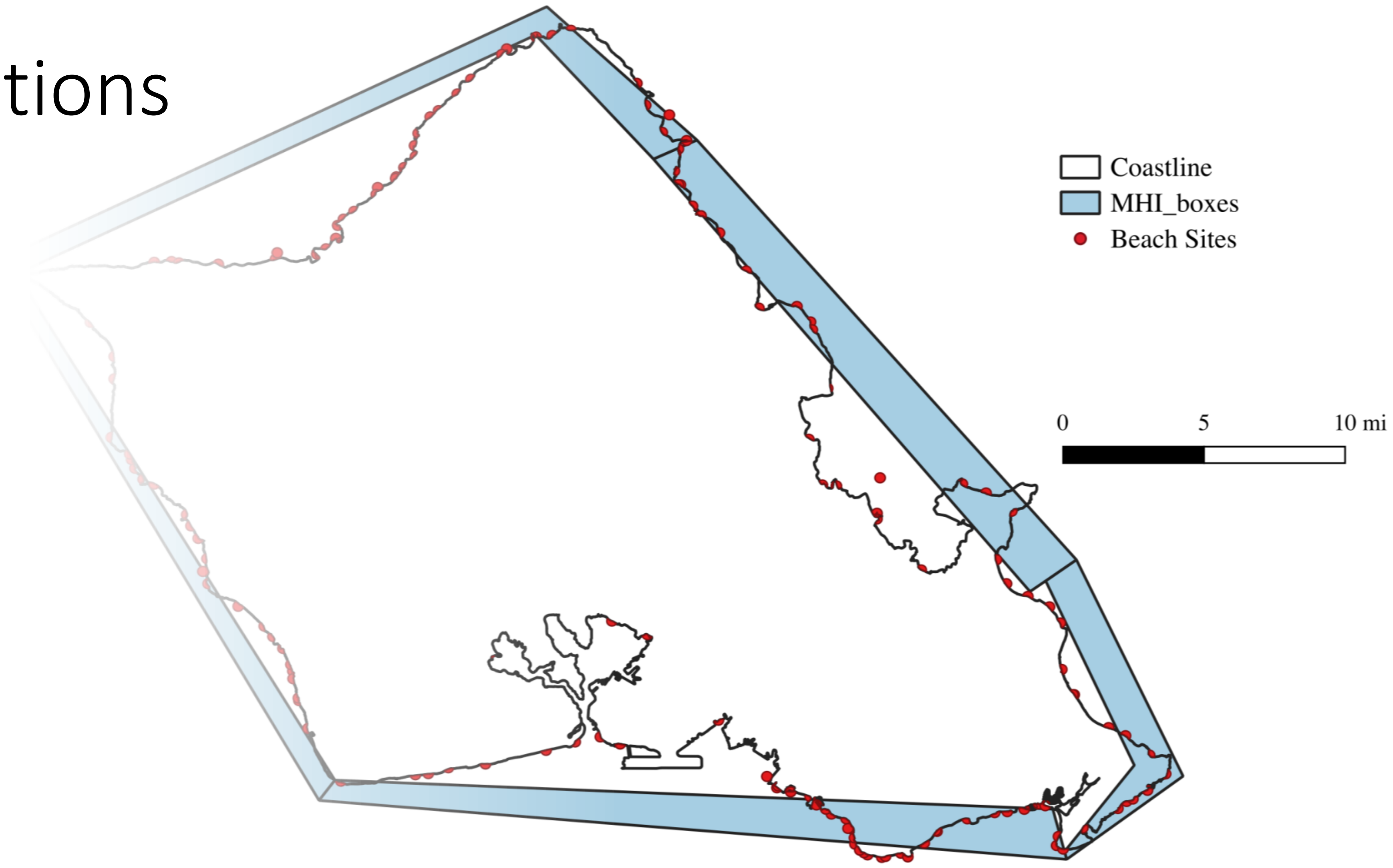


Photo: Zac Forsman

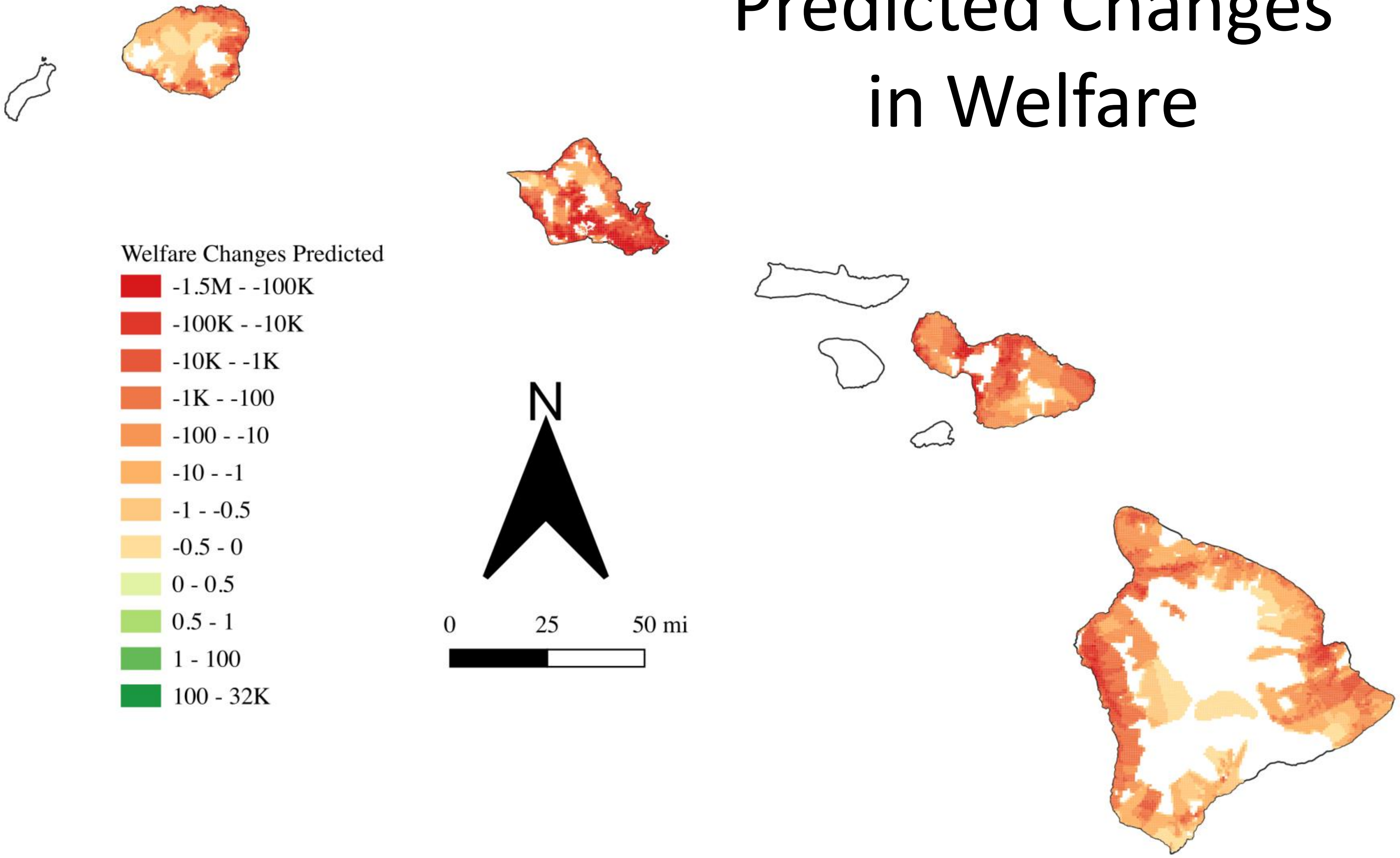
Nearshore Predictions

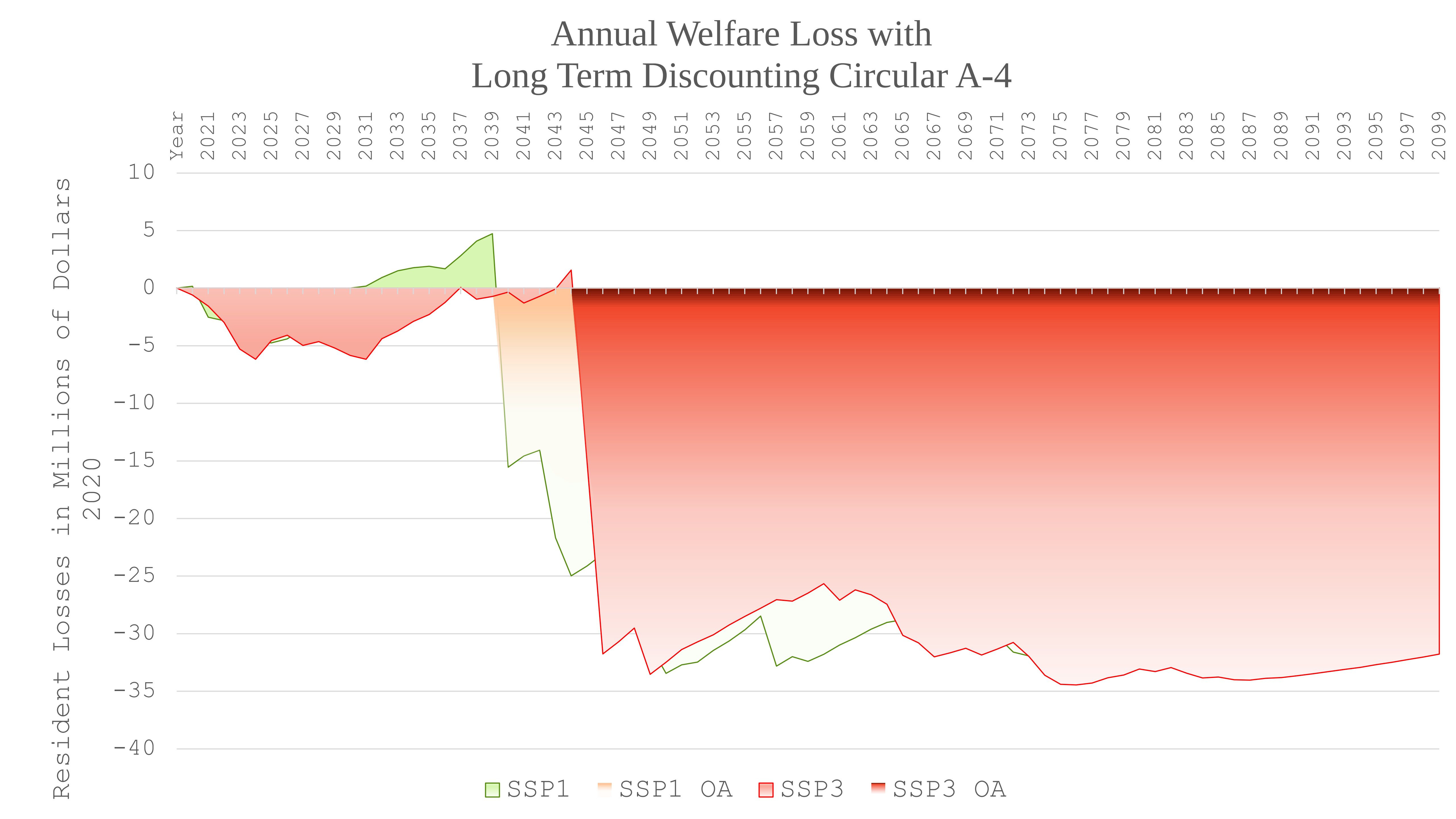
- ➢ Match rec site to nearest nearshore Atlantis site



SSP1 2100 Predicted Changes in Welfare

Using SSP1 Scenario and Spatially Predicted Outcomes from Atlantis Modeling




Annual Welfare Loss with
Long Term Discounting Circular A-4
Resident Losses in Millions of Dollars 2020
Year
2021
2023
2025
2027
2029
2031
2033
2035
2037
2039
2041
2043
2045
2047
2049
2051
2053
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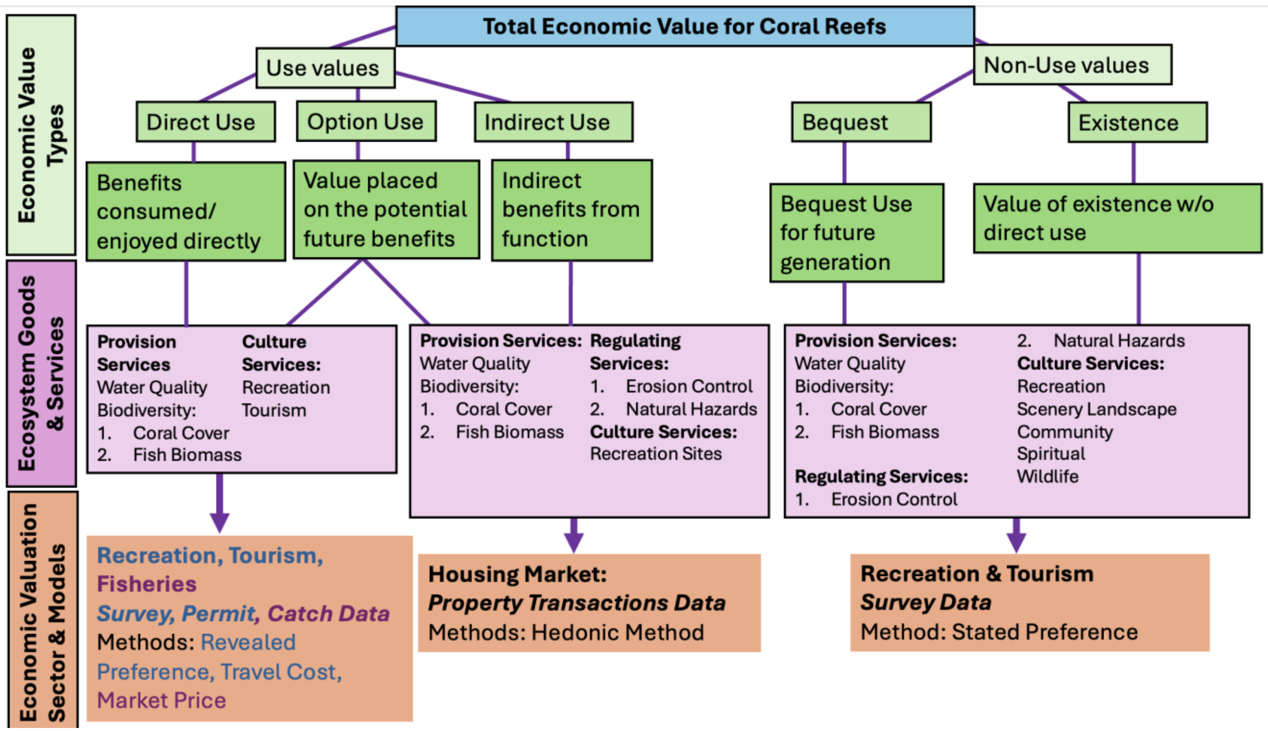
2081
2083
2085
2087
2089
2091
2093
2095
2097
2099
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
SSP1
SSP1 OA
SSP3
SSP3 OA

Shortcomings:

- Population Dynamics
- Explore Preference
- Marginal Benefit function

Expanding Sectors:

- Expand to tourism sector values reef-adjacent dependence.
- Indirect values from housing



Thank You

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