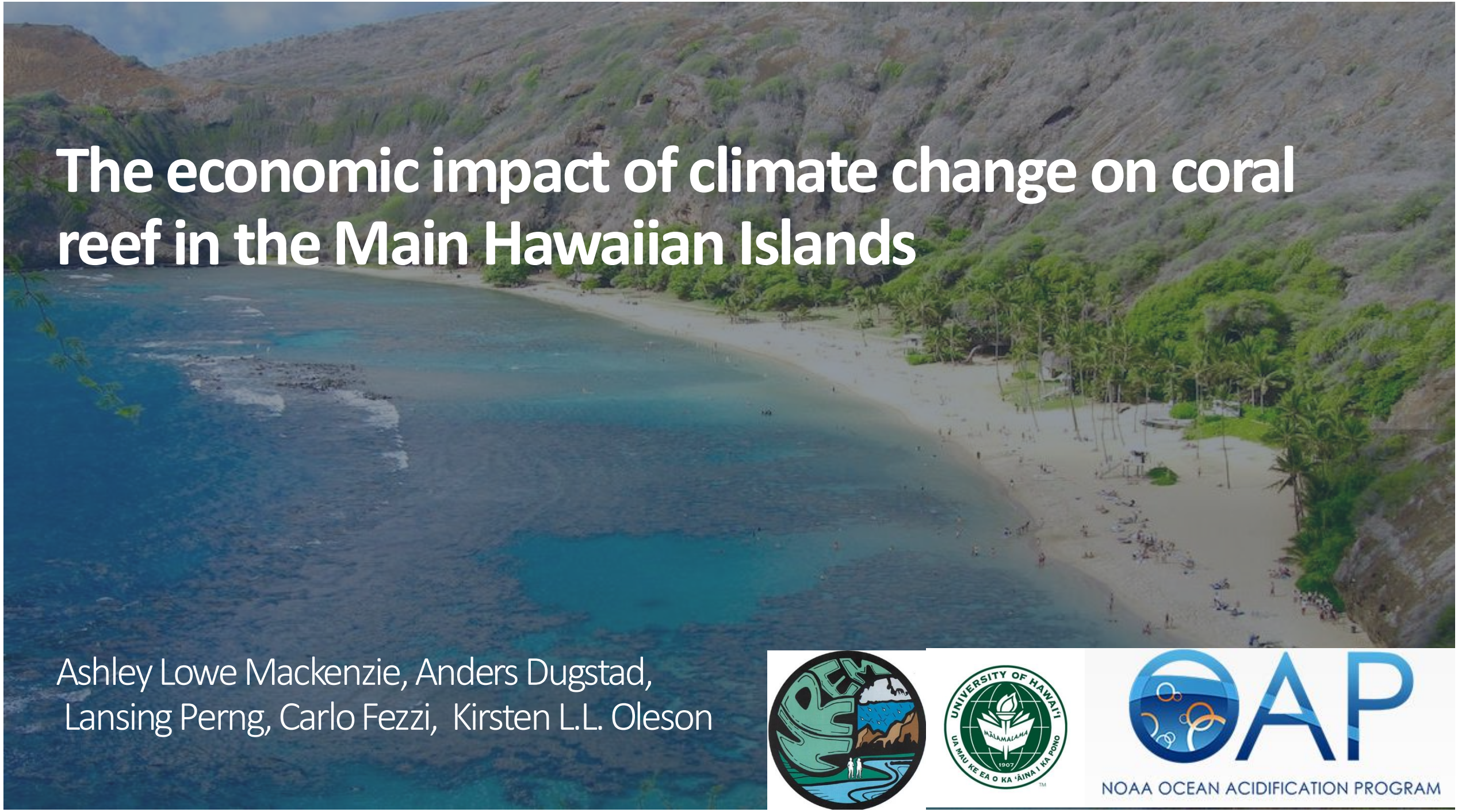
The economic impact of climate change on coral reef in the Main Hawaiian Islands



Ashley Lowe Mackenzie, Anders Dugstad,
Lansing Perng, Carlo Fezzi, Kirsten L.L. Oleson

NOAA OCEAN ACIDIFICATION PROGRAM

MOTIVATIONS

Coral reefs provide numerous ecosystem services, supporting life of more .5billion people (UN Envir. 2018)

Ecosystem Goods & Services (EGS):

Coastal Protection

Habitat (Fisheries- Food &Biodiversity hotspots)

Recreation/Tourism

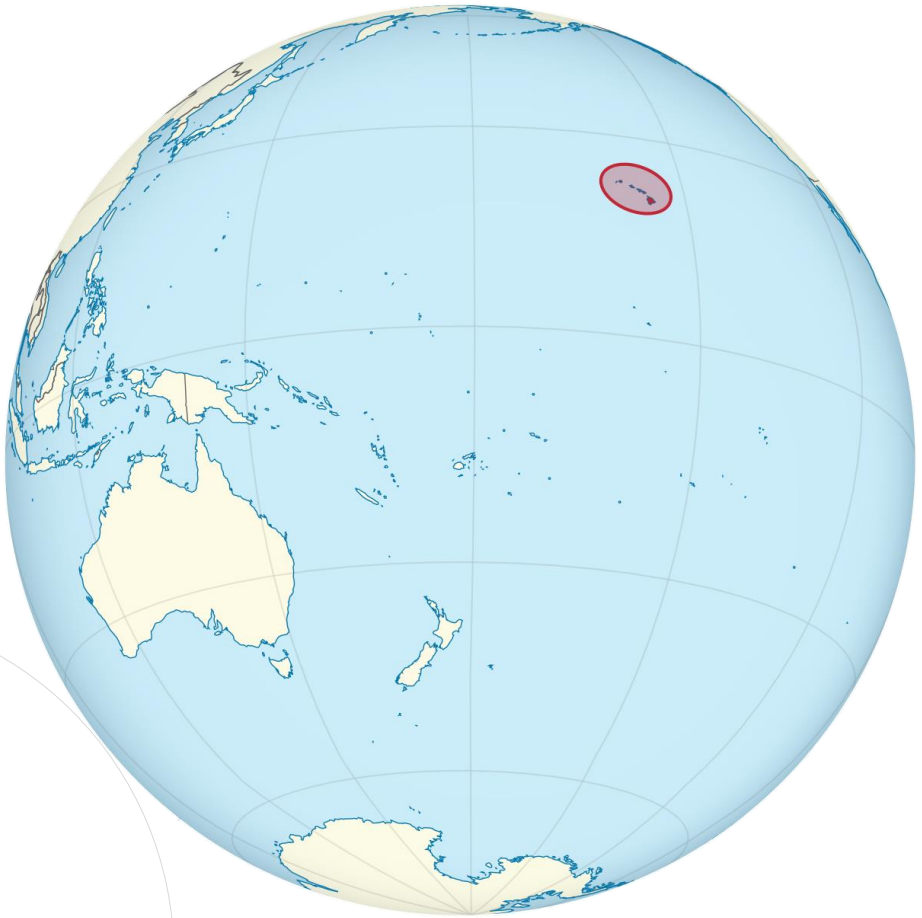
Snorkeling & Fishing

Value added Local Community business

HAWAIʻI UNIQUE DEPENDENT ON EGS

- Hawaiʻi is one of the most geographically isolated places on Earth, over 2,000 miles from nearest continent.

- Isolation increases reliance on local ecosystems for essential goods like fresh water, fisheries, and climate regulation.

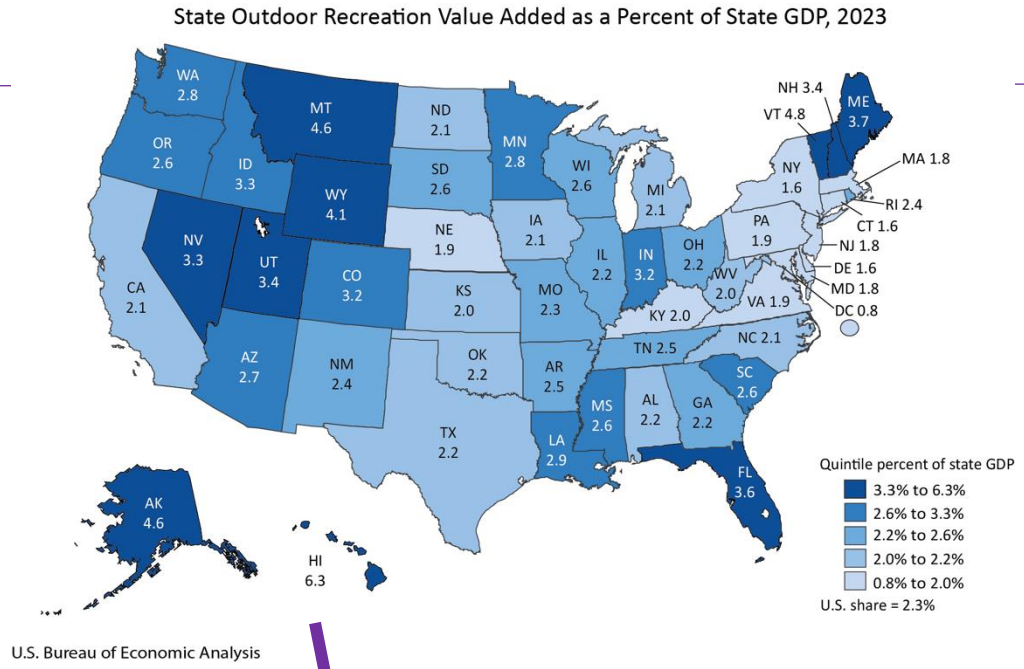


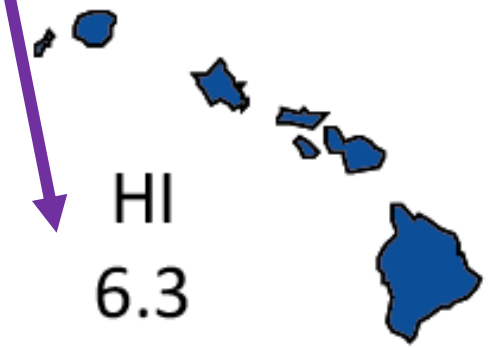
HAWAIʻI UNIQUE DEPENDENT ON EGS

- Native Hawaiian culture is deeply rooted in place-based resource management, (ridge-to-reef land divisions).

GDP – Share of Environmental Quality Reliant Industry:

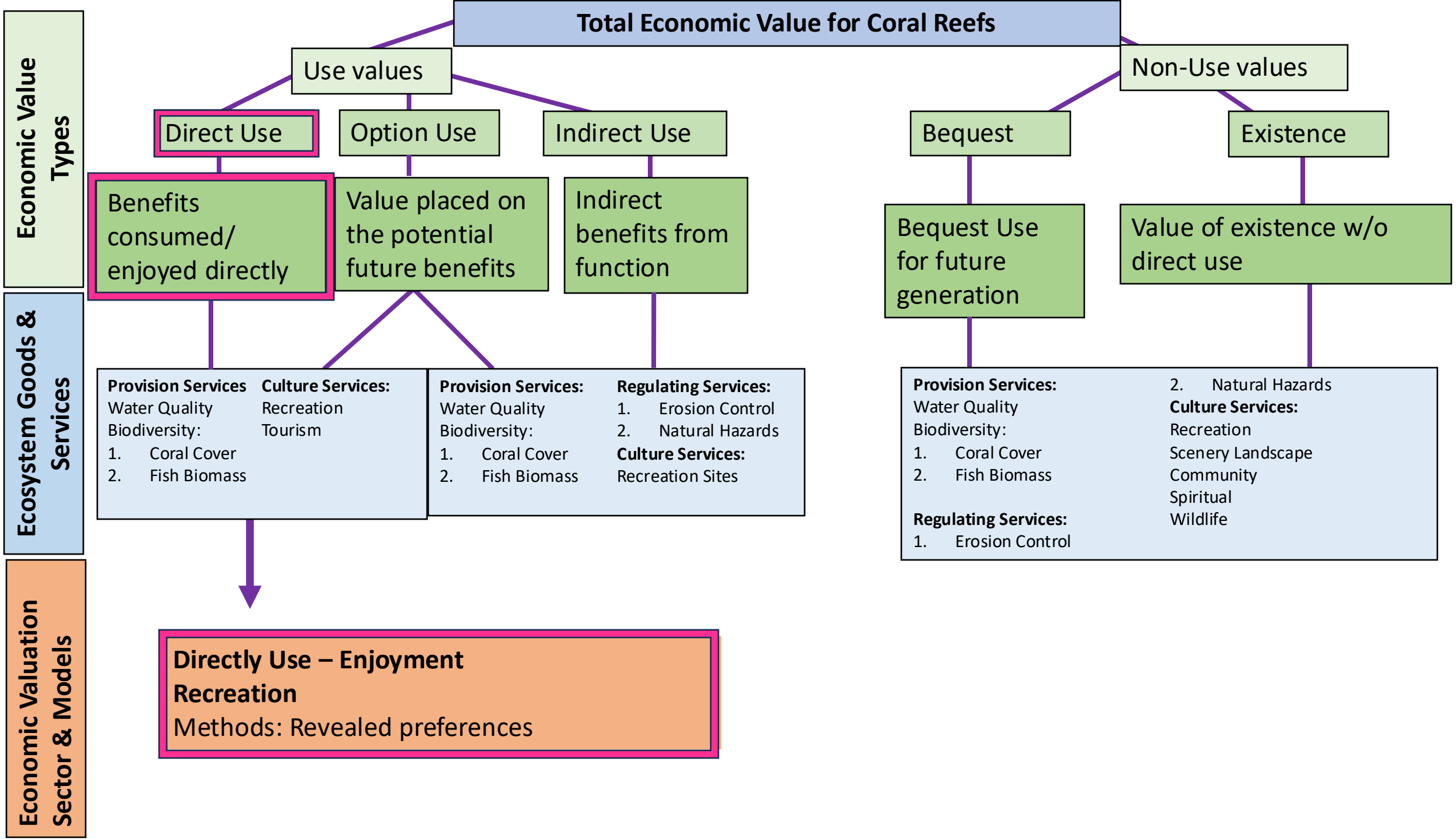
- Highest value-added to GDP from Outdoor Recreation in the nation





Local Management Needs

- Spatial Information
  - ➢ Preferences on beach features & amenities
- Managers need ability to prioritizes & target efforts for protection/restoration for communities.


Economic Value Types
Ecosystem Goods & Services
Economic Valuation Sector & Models
Total Economic Value for Coral Reefs
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
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
Directly Use – Enjoyment
Recreation
Methods: Revealed preferences

Travel Cost Captures Recreational Welfare

People spend *time & money* to recreate (ex. beach w/ coral reef & snorkeling)

Even if there's no admission fee:

- Spend money on gas
- Leisure/Work trade off

Cost act as **price** they're willing to pay to enjoy the site.

Demand to Welfare

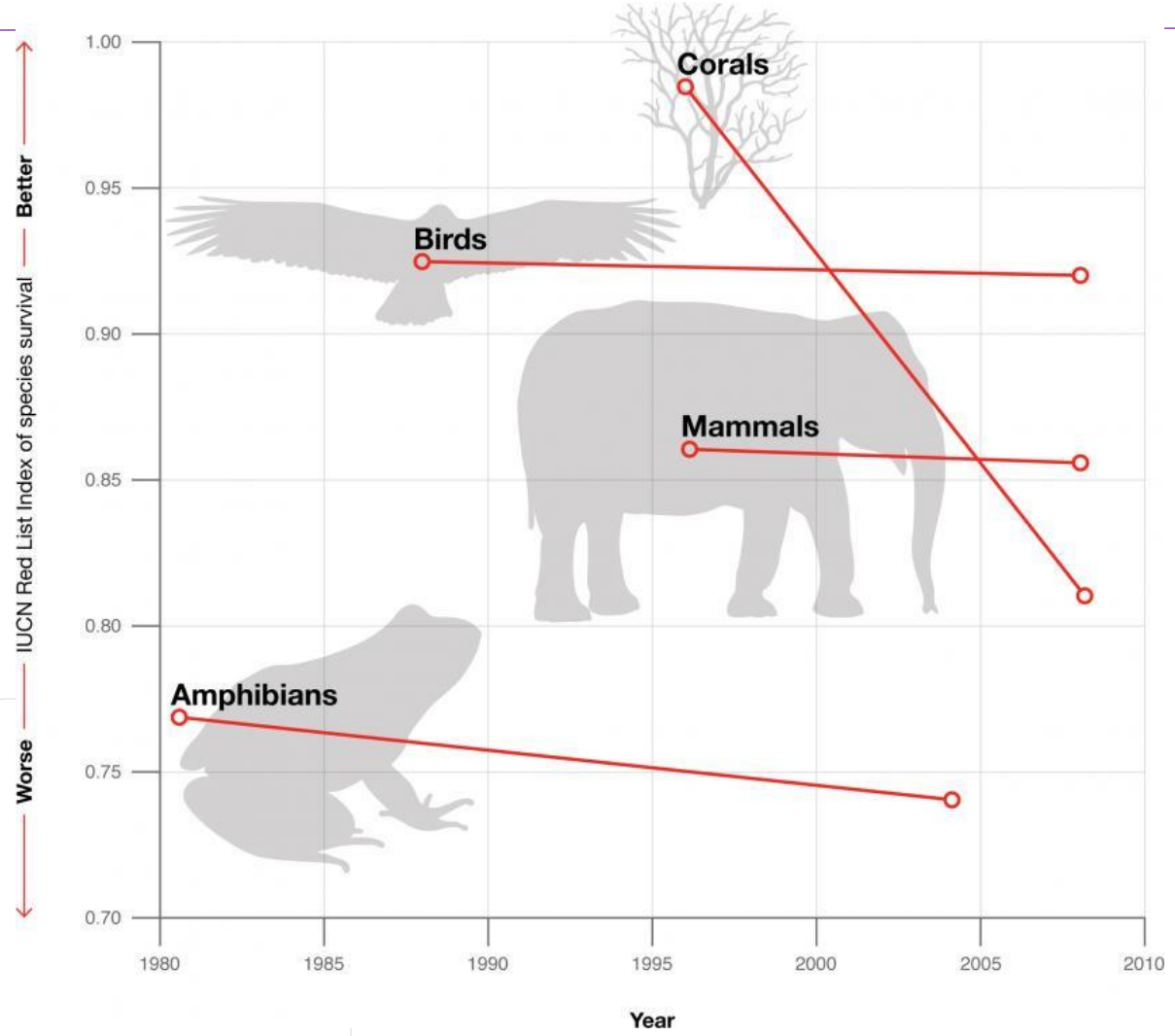
With information on trips people take at different cost economists can:

- Estimate Demand curve
- Calculate the consumer surplus

Surplus is a direct measure of **welfare** (**benefit)** someone gets from visiting the site.

Preview Results

- Annual Welfare loss of $2 to $170 by per person (resident) by 2100
- Disadvantaged communities particularly vulnerable
- Coupled with project pop. growth suggest $1.2 to 2.8 billion loss by 2100 in residential recreation alone
- However, scarcity & WTP these likely lower bounds

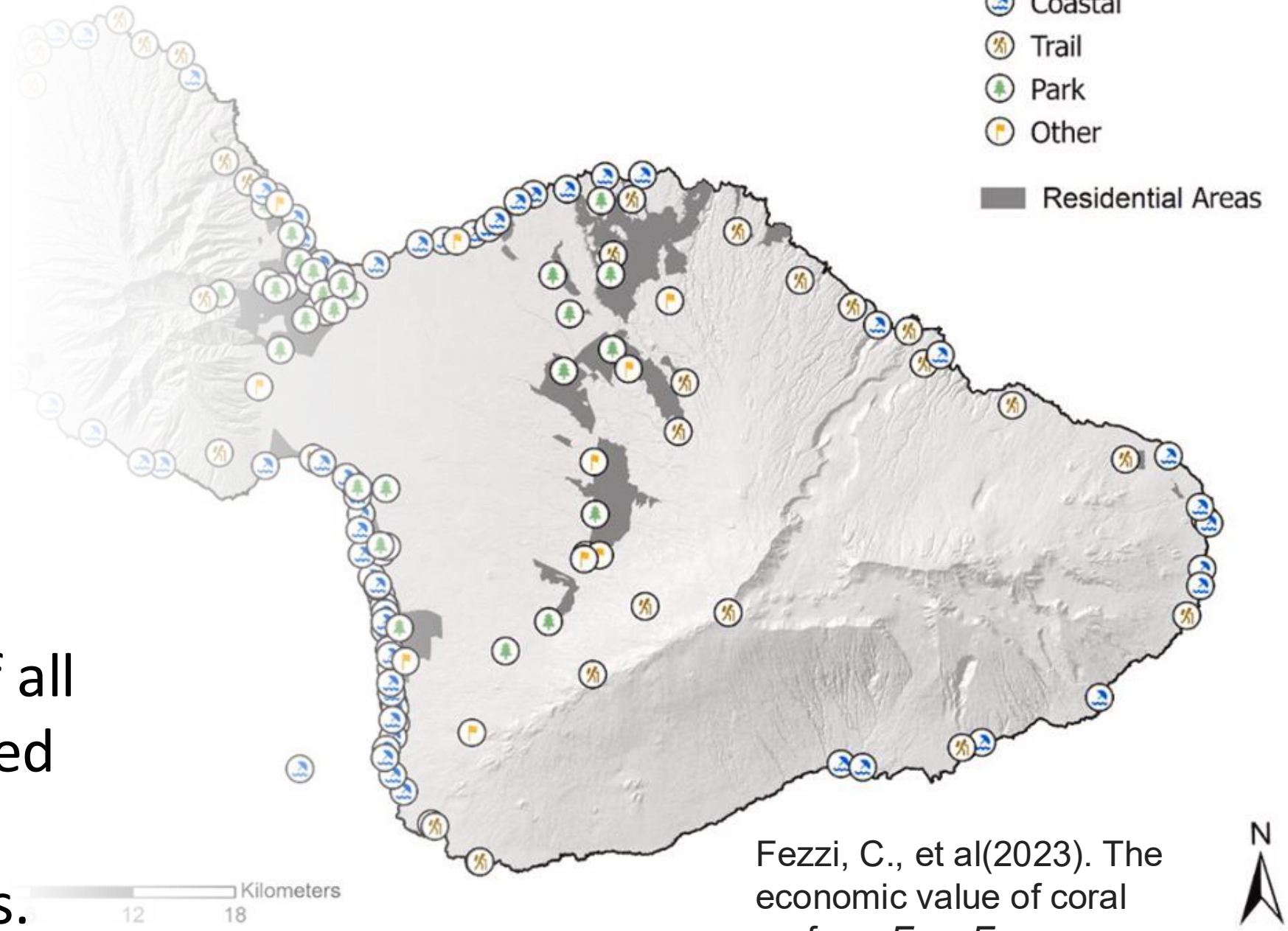


IUCN 2021

Our Team

Developed a Model Based on Resident (place-based information)

Making trade-offs of all recreation sites, based on amenities and ecological conditions.



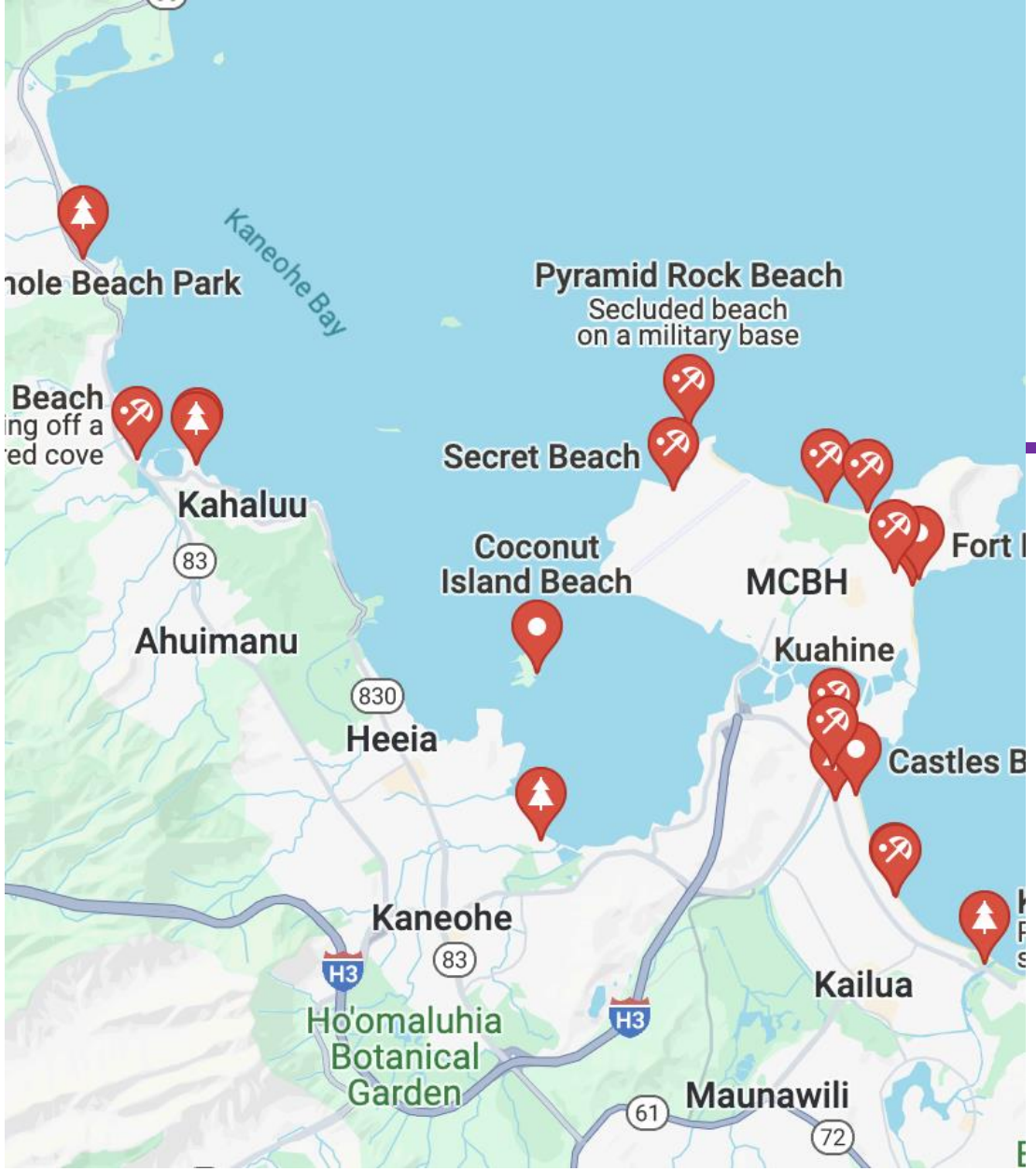
Fezzi, C., et al(2023). The economic value of coral reefs…. *Eco. Econ.*

Benefit Function Transfer

To use our model, we need to follow Fezzi et al. (2023) to match following information:

Steps to define:

1. Sites & Amenities
2. Population & Income
3. Changes in Ecosystem Service

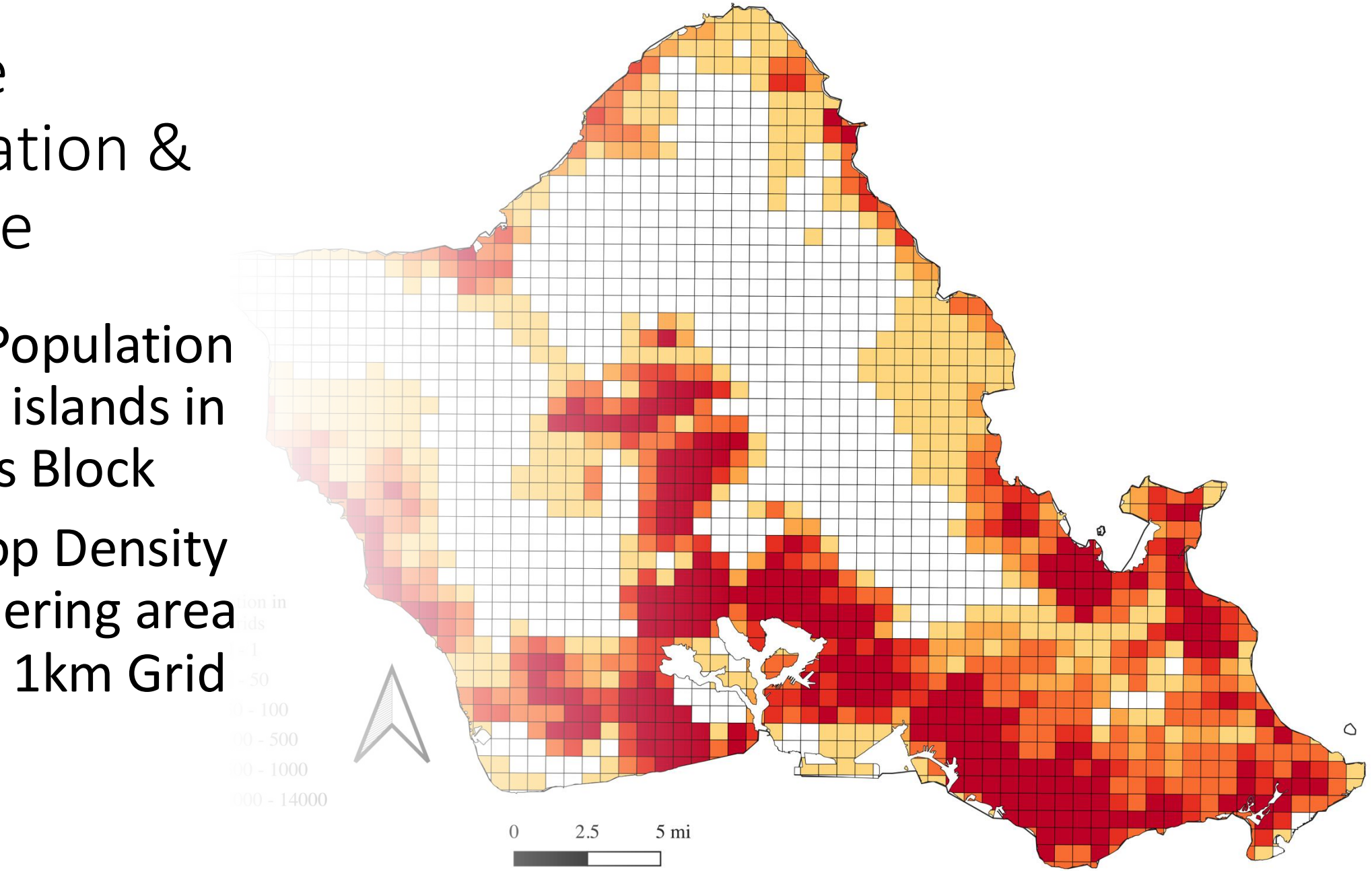


1. SITES & AMENITIES

- State Coastal Sites
- Merge w/ Google Places
- Manual incorporation
  - Identify amenities (restrooms, parking, shower, swimming, snorkeling, surfing)

Define Population & Income

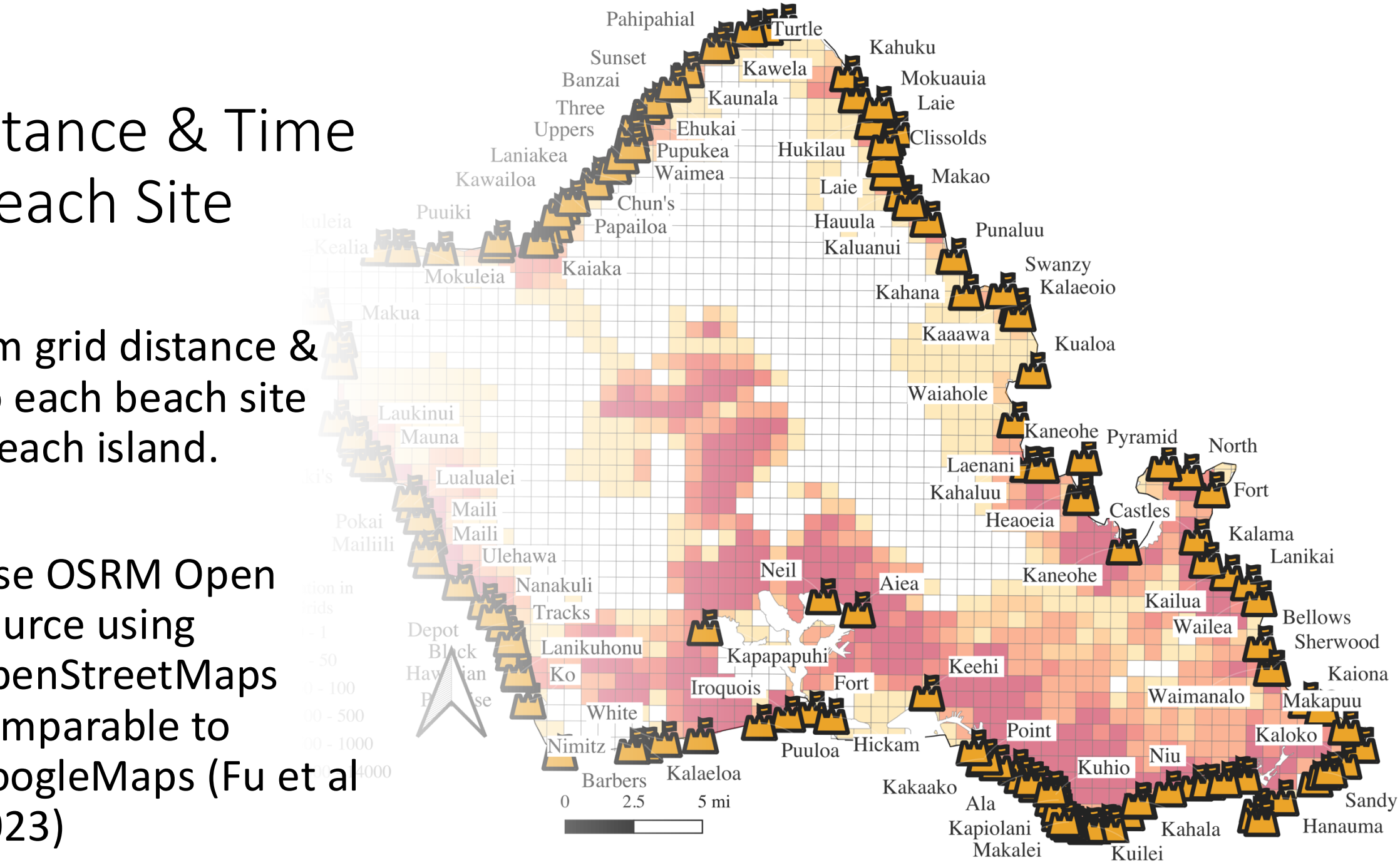
- 2020 Population across islands in Census Block
- Cal. Pop Density considering area within 1km Grid



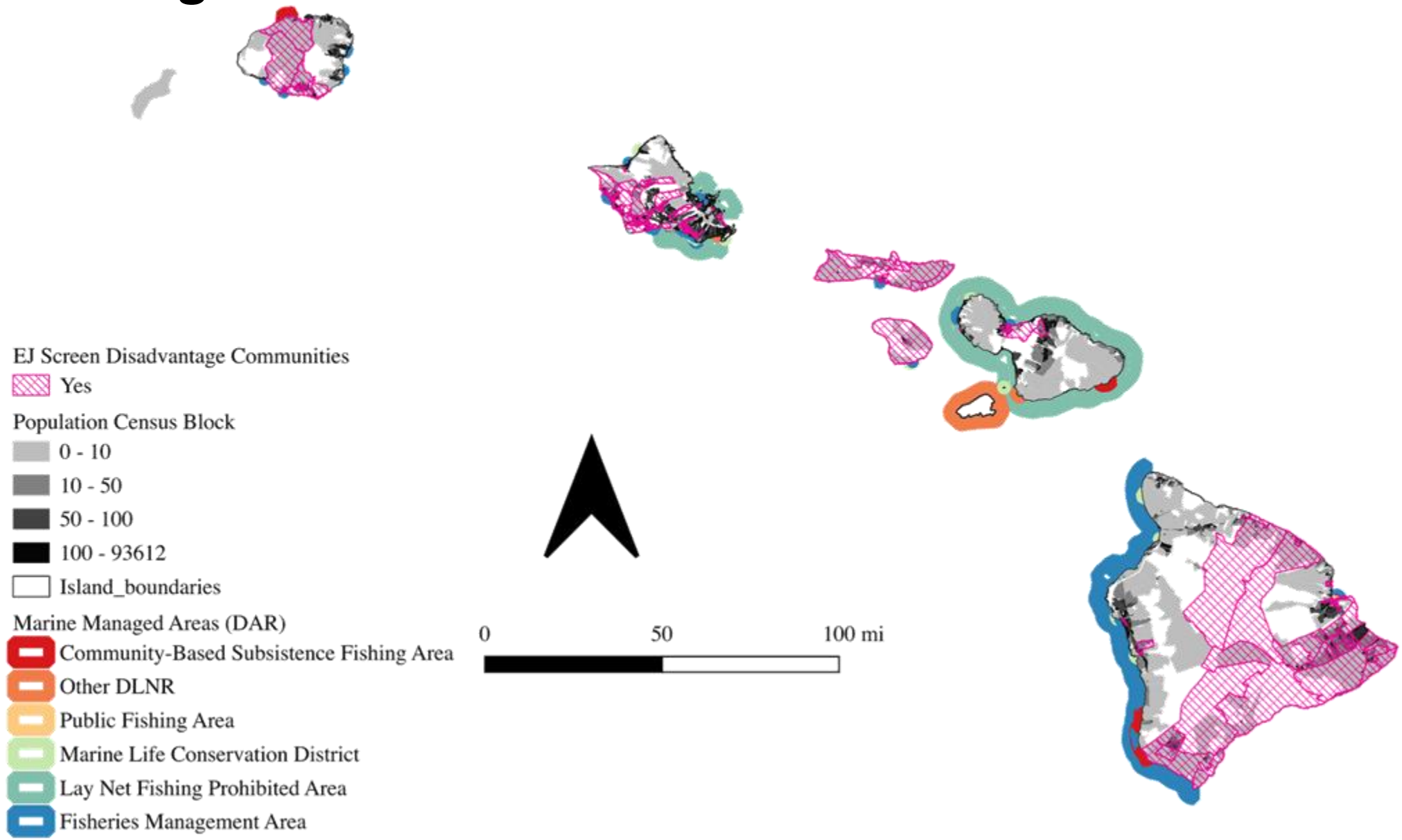
Distance & Time to each Site

Each km grid distance & time to each beach site across each island.

- Use OSRM Open Source using OpenStreetMaps comparable to GoogleMaps (Fu et al 2023)



Define Population Resource & Environmental Concern
Marine Managed Areas

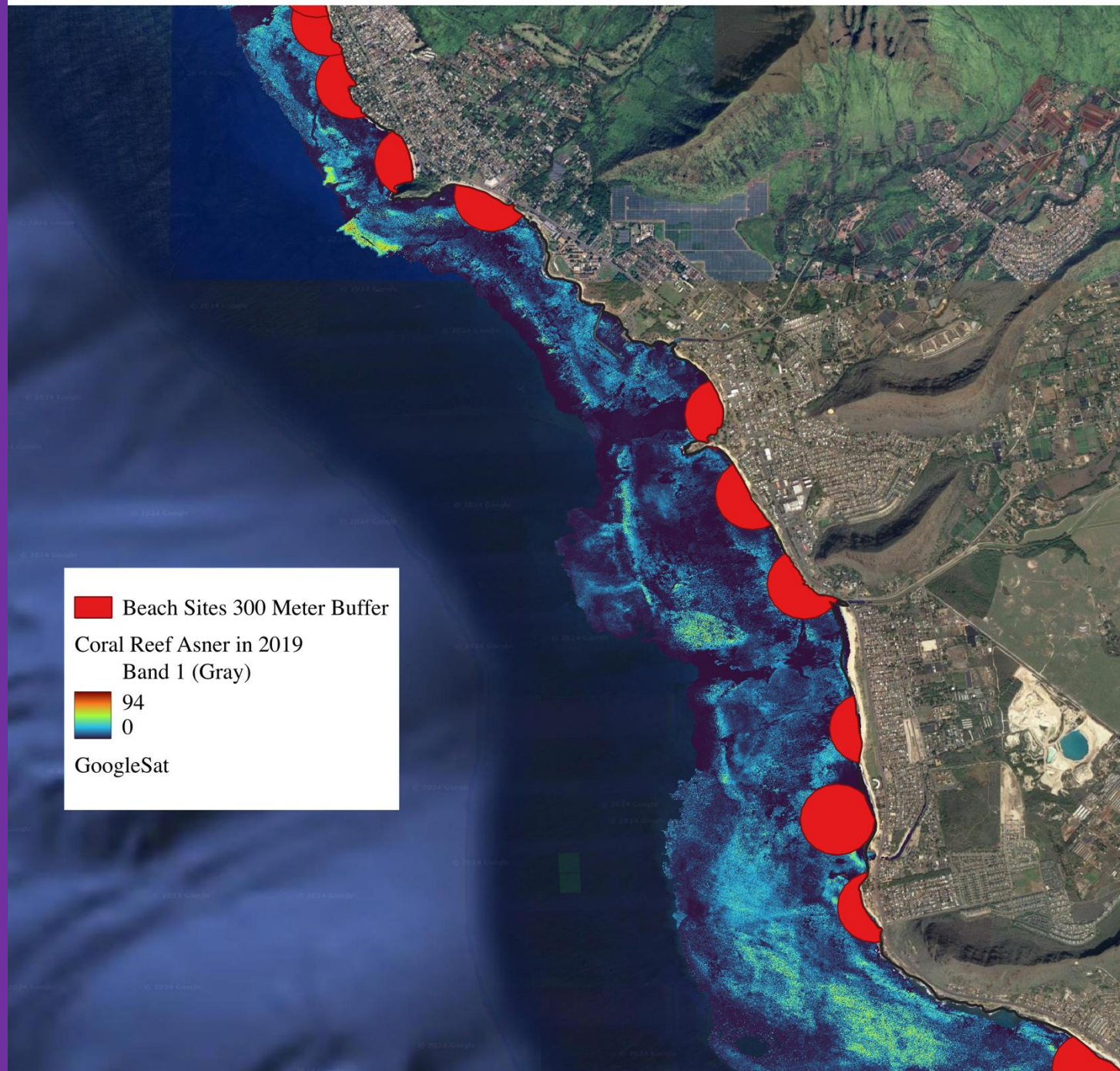


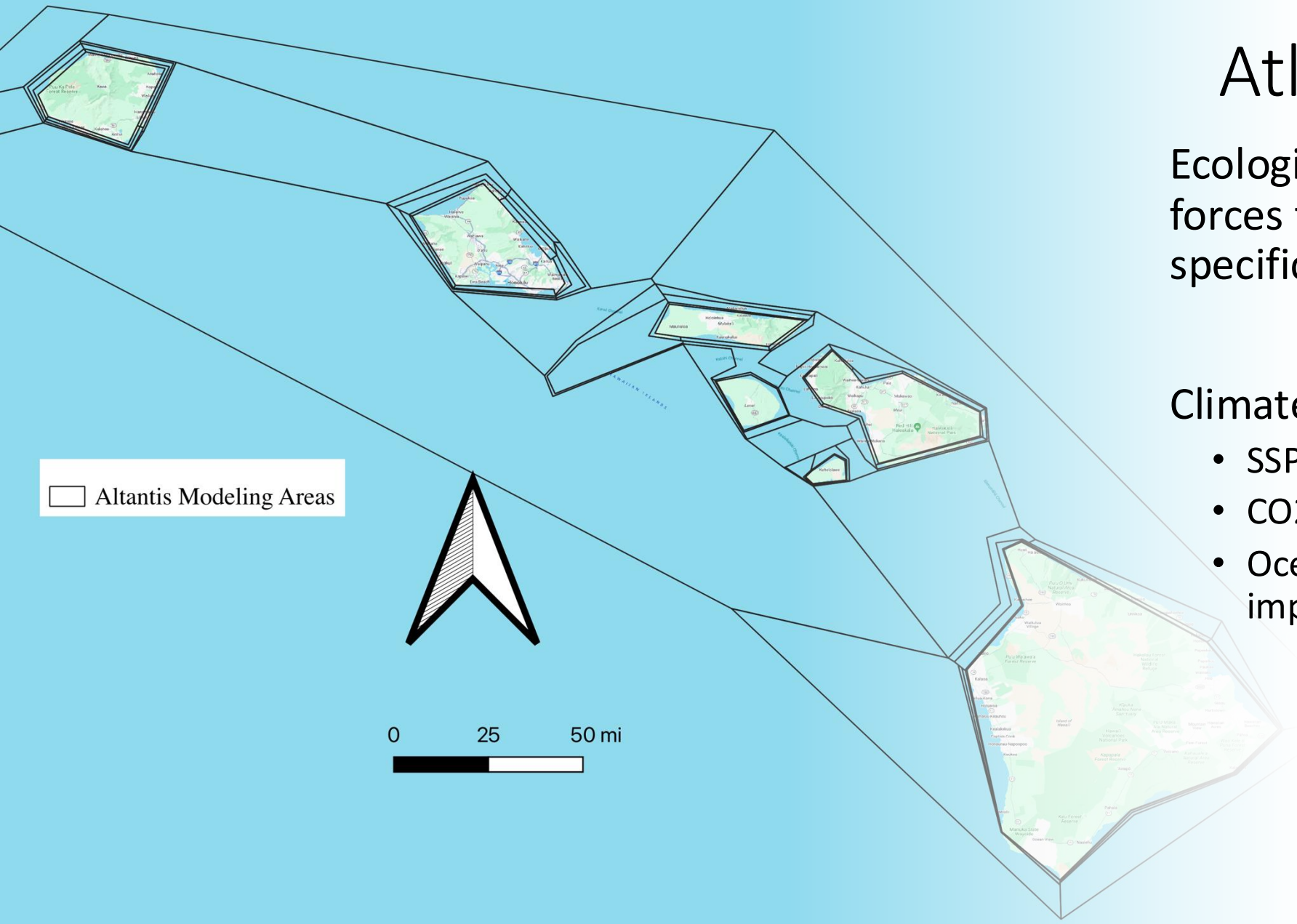
DEFINE ECOSYSTEM SERVICE

Recreation Site 300-meter buffer.

Calculate from Raster:

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





Atlantis Model

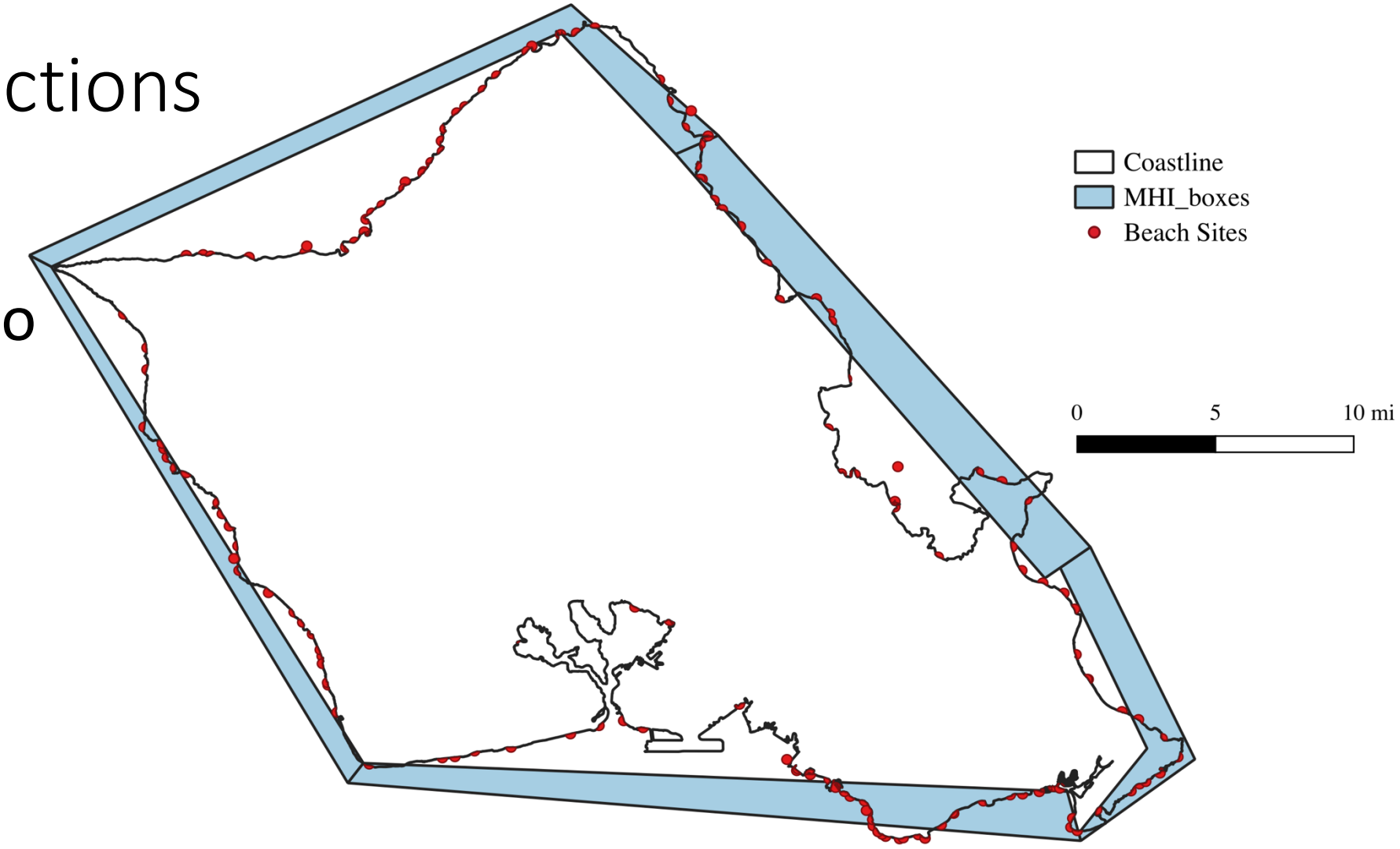
Ecological Model uses climate forces to model biomass of specific in Polygons.

Climate Scenarios

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

Nearshore Predictions

- Match rec site to nearest nearshore Atlantis site



Identify Genus within Atlantis

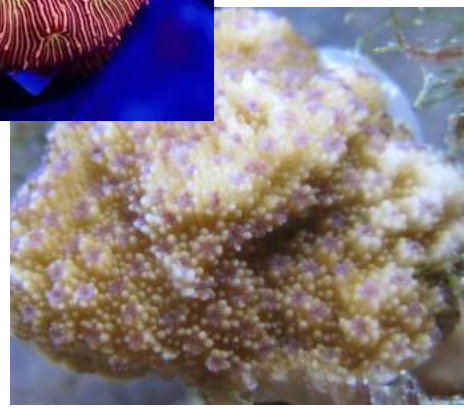
Coral Reef Types

- Pocillopora, Porites branching, Porites massive, Montipora, Leptoseris

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



Framework to Integrating Assessment Model

Atlantis Biophysical Sub-models

Human (ocean use: recreation, fisheries)

Ecological (land use pollution, habitat destruction)

Hydrographical (Ocean chemistry OA, temperature)

Climate

Shared Social-Economic Pathway Scenarios

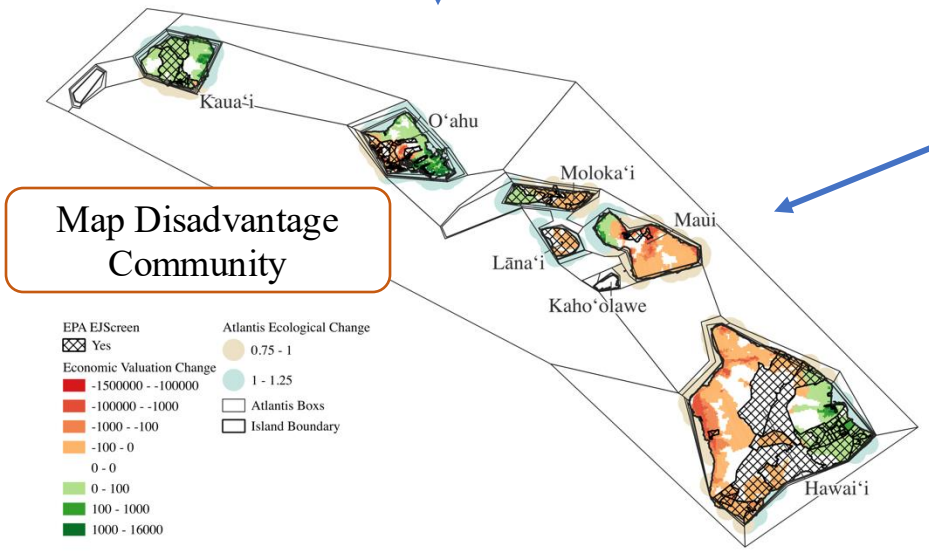
Population

Economic Welfare Value

Beach Sites Characteristics

Census Pop, Income, Travel Cost

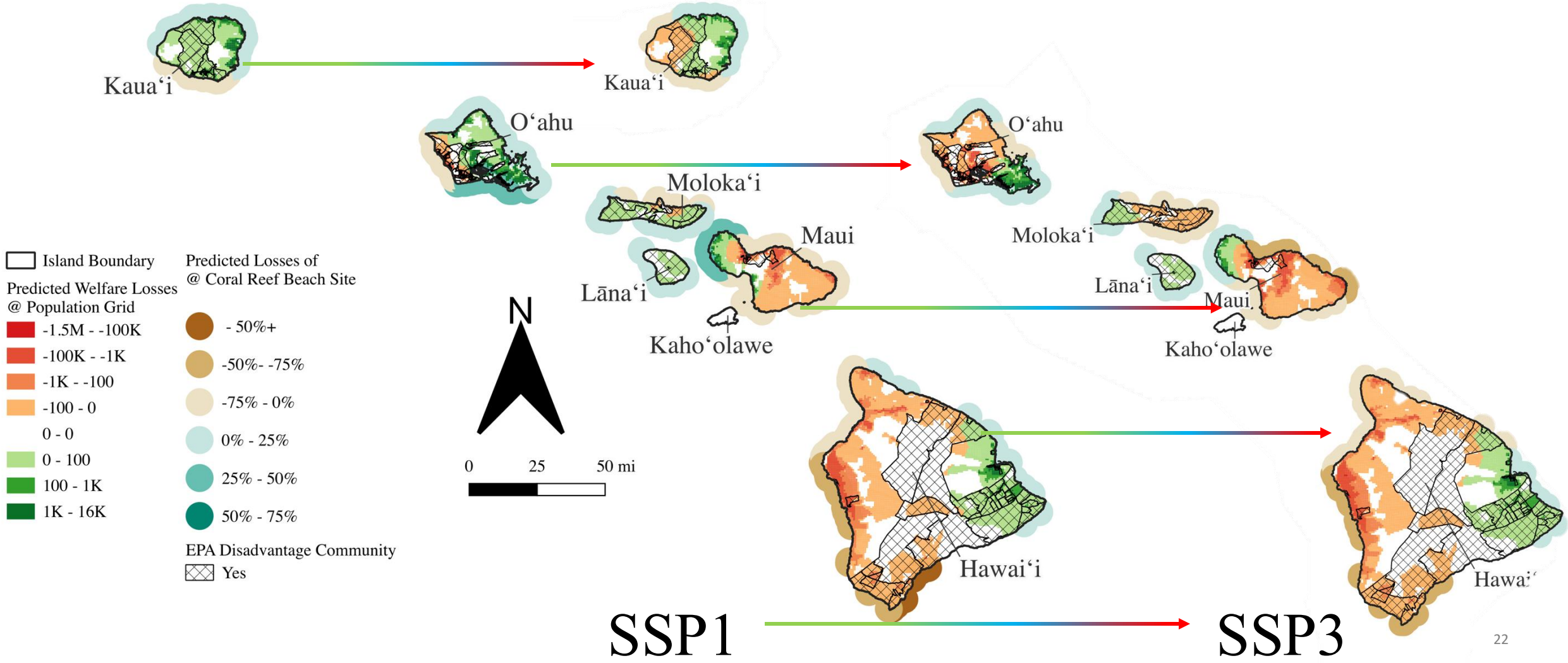
Map Disadvantage Community



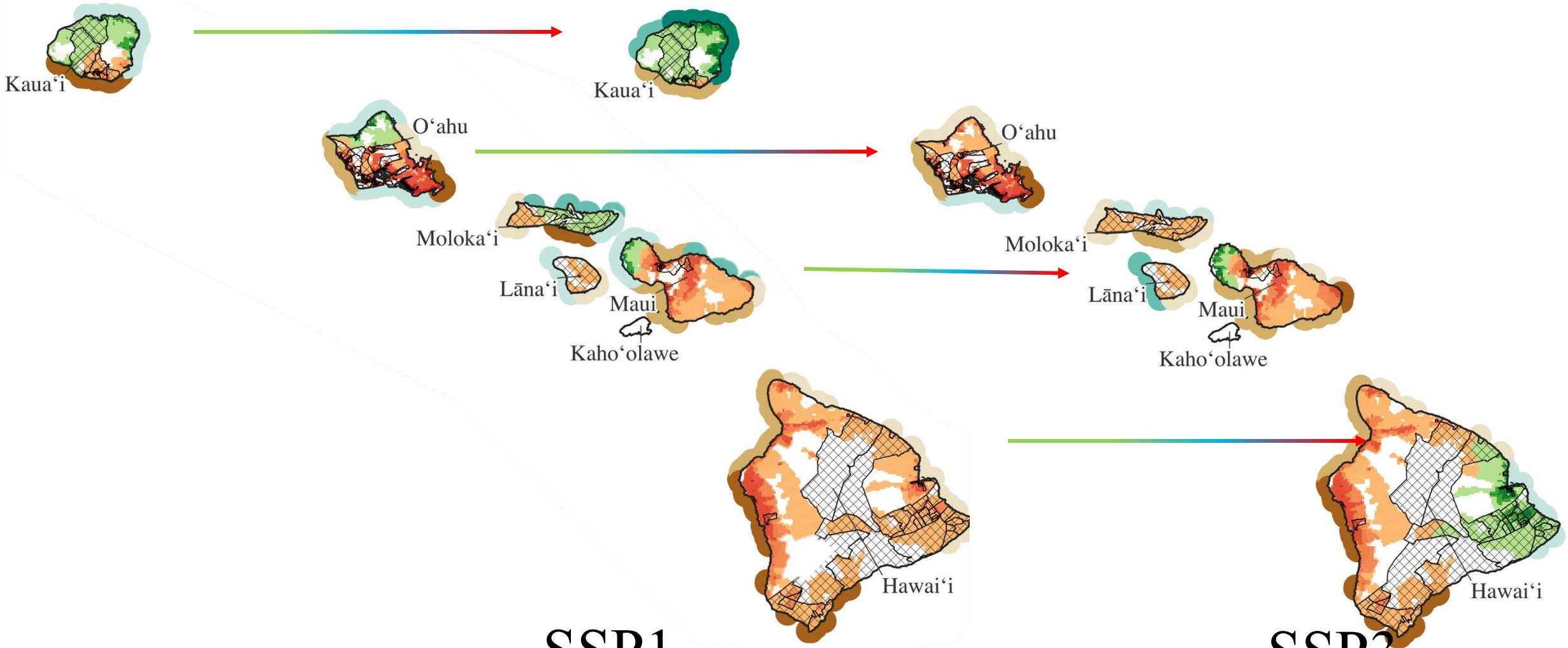
Spatially Simulated Scenarios for Hawaii's Nearshore Environment

Incorporating Ecological Modeling Under Climate Scenarios

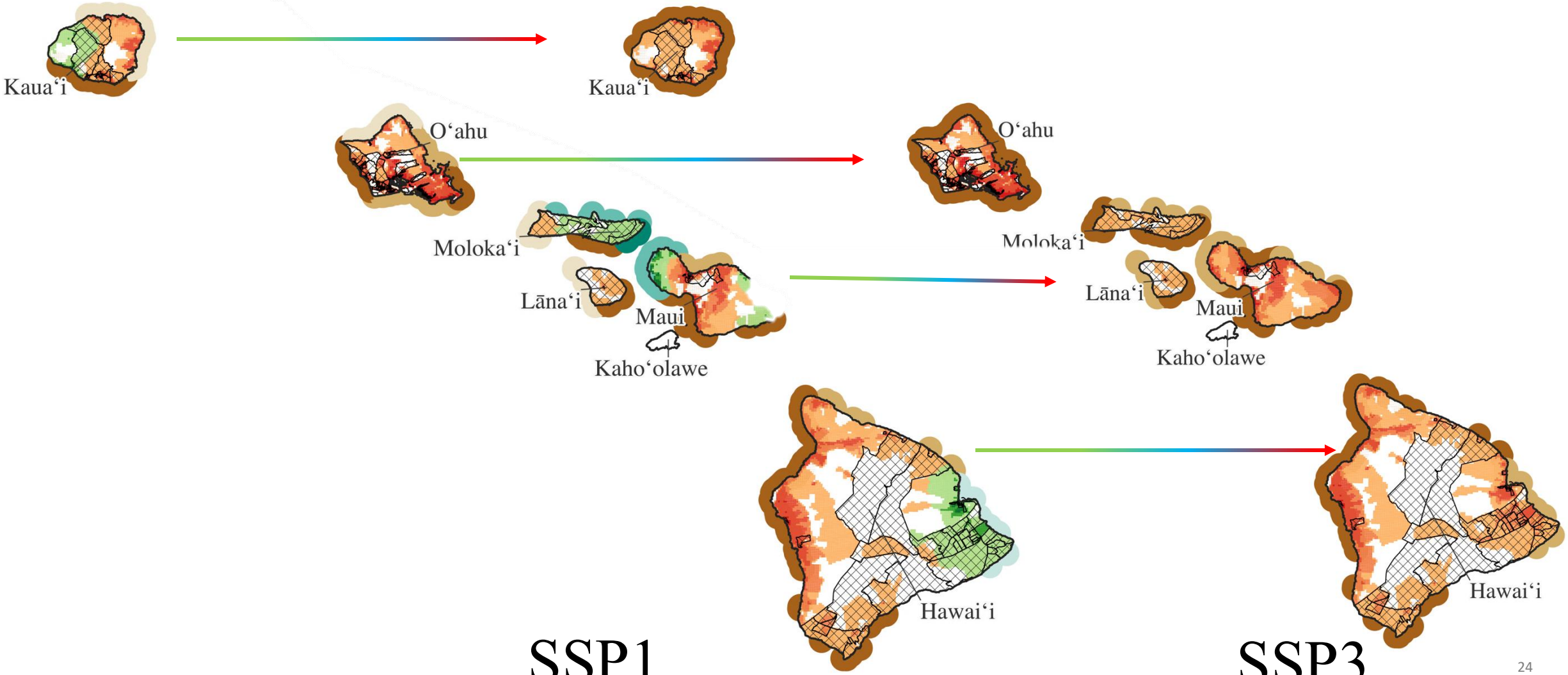
PROJECTED YEAR 2030 OR 30X30



PROJECTED YEAR 2050



PROJECTED YEAR 2100



Impacts are Heterogenous across communities within island & across

Table 2.A Disadvantaged Communities Average Welfare Loss Per Person in 2024$ Annual

	SSP1			SSP3		
Island	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**
Hawai'i	-0.97	-3.39	-5.04	-1.57	-1.97	-5.99
Kaua'i	1.92	-4.81	-17.00	0.21	1.73	-20.30
Lāna'i	-0.09	-0.68	-1.79	-0.01	-0.49	-2.15
Maui	-21.22	-80.38	-155.56	-28.10	-89.72	-207.14
Moloka'i	-0.06	-0.61	-1.42	-0.15	-0.67	-2.55
O'ahu	-1.91	-48.64	-83.52	-4.69	-45.80	-94.62
Average	**-3.72**	**-23.09**	**-44.06**	**-5.72**	**-22.82**	**-55.46**

B. All Other Communities Average Predicted Welfare Loss Per Person

	SSP1			SSP3		
Island	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**
Hawai'i	-16.89	-42.09	-52.59	-24.24	-46.94	-68.52
Kaua'i	3.43	-3.73	-20.95	1.40	9.19	-35.12
Lāna'i						
Maui	-3.57	-31.25	-89.43	-15.86	-58.82	-170.18
Moloka'i						
O'ahu	4.18	-56.08	-90.19	1.07	-68.35	-140.61
Average	**-5.68**	**-33.29**	**-63.29**	**-9.41**	**-41.23**	**-103.61**

Long Term Welfare given Scarce Resource

- Economists estimate **value of future benefits** from coral reefs (recreation), they use a tool called **discounting**.
  - People tend to like benefits now rather than later.
- Coral reefs expected to become **much scarcer** over time

➢ **Future benefits they provide could actually become more valuable.**

Ecosystem Facing Scarce future

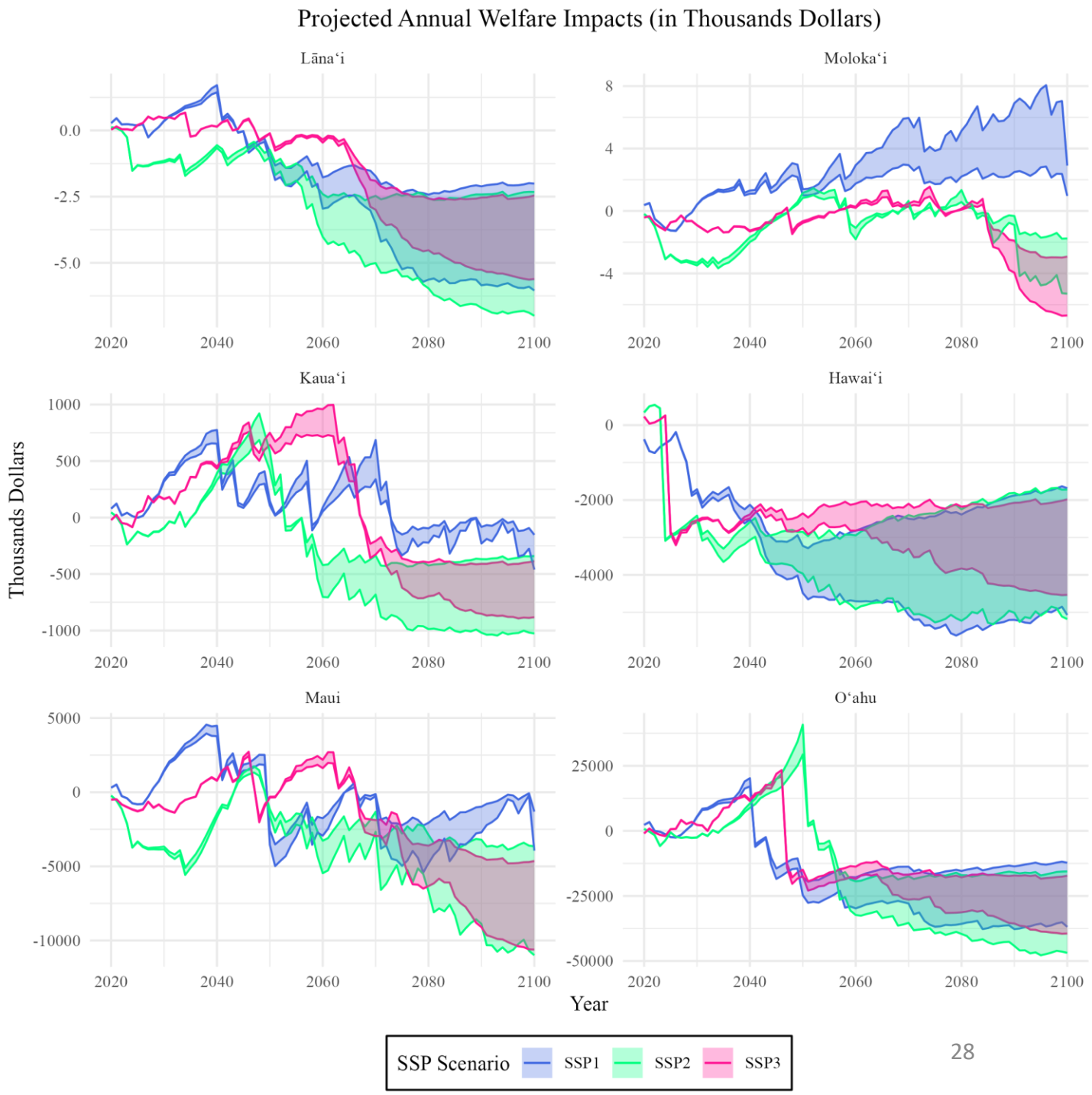
High discount rate downplay value of protecting ecosystems in long run

We use <u>Low Discount Rate</u>:

- OMB - Ramsey (declining) : 2%-1.8% (Circular A-4 2023)
- Pluralistic based on the capital assets of coral reef : 40% Natural, 10% Social, 30% Human, 20% Built. **(Costanza et al 2021)**

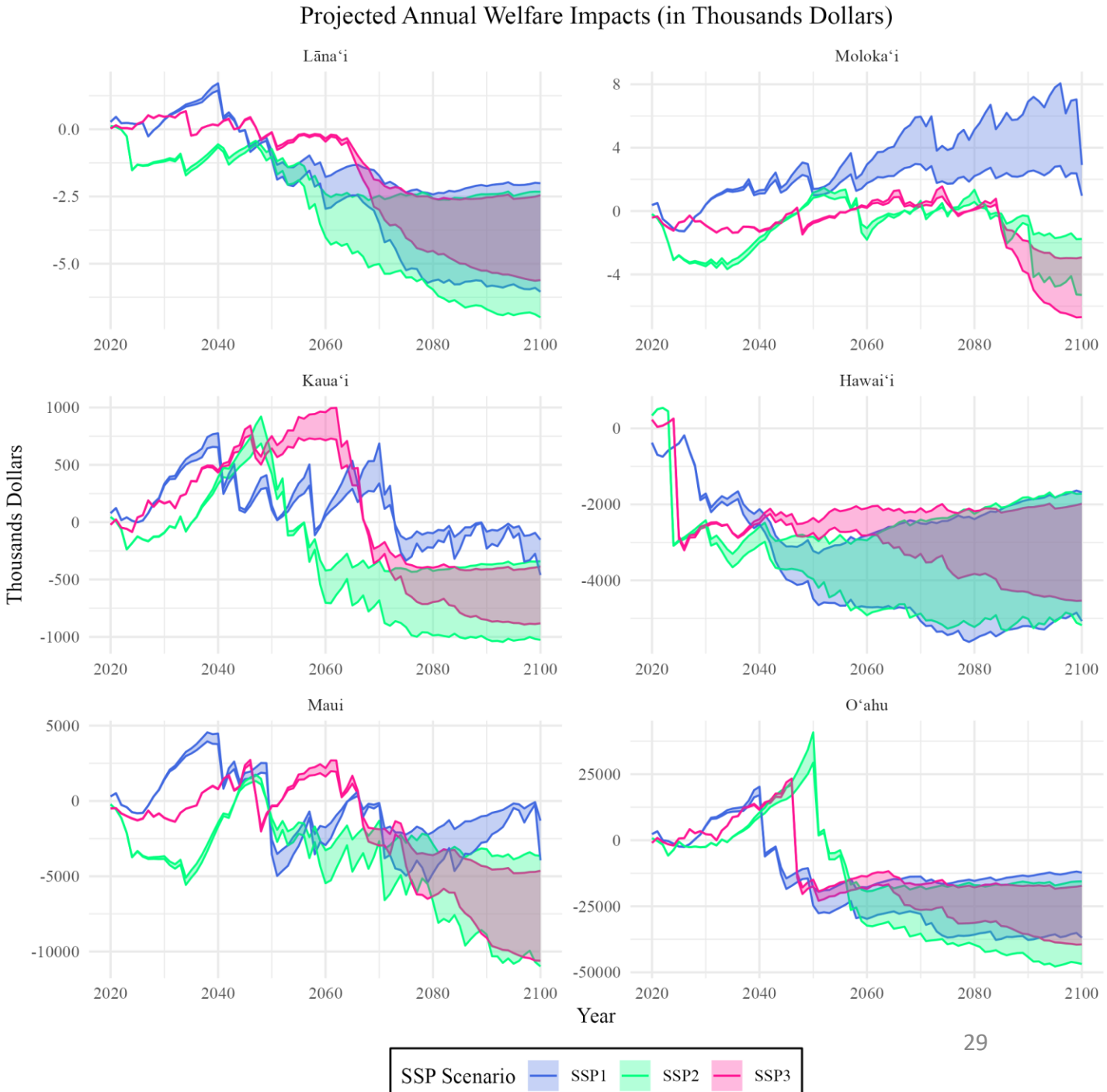
Across Island Losses

- OMB lower bound & Pluralistic discounting - upper bound
- SSP1 & SSP2 higher due to more individuals to experience losses



Across Island Losses

- Island of Hawai‘i & O‘ahu sees large welfare impacts
- Slower Lān‘i & Maui
- $1.2 to 2.8 Billion (2024 dollars) by 2100



Shorting Comings

- Only valuing *<u>Residents</u>*
- Preferences remain constant through the timeframe, assume linear relationship overtime
  - Extreme high biodiversity loss/scarcity-- Drupp, M. Et al.(2024)

BRIEF EXPLORATION OF TOURISM VALUES

Tourist less familiar with place-based information

Tricker to tie directly to Quality measurement

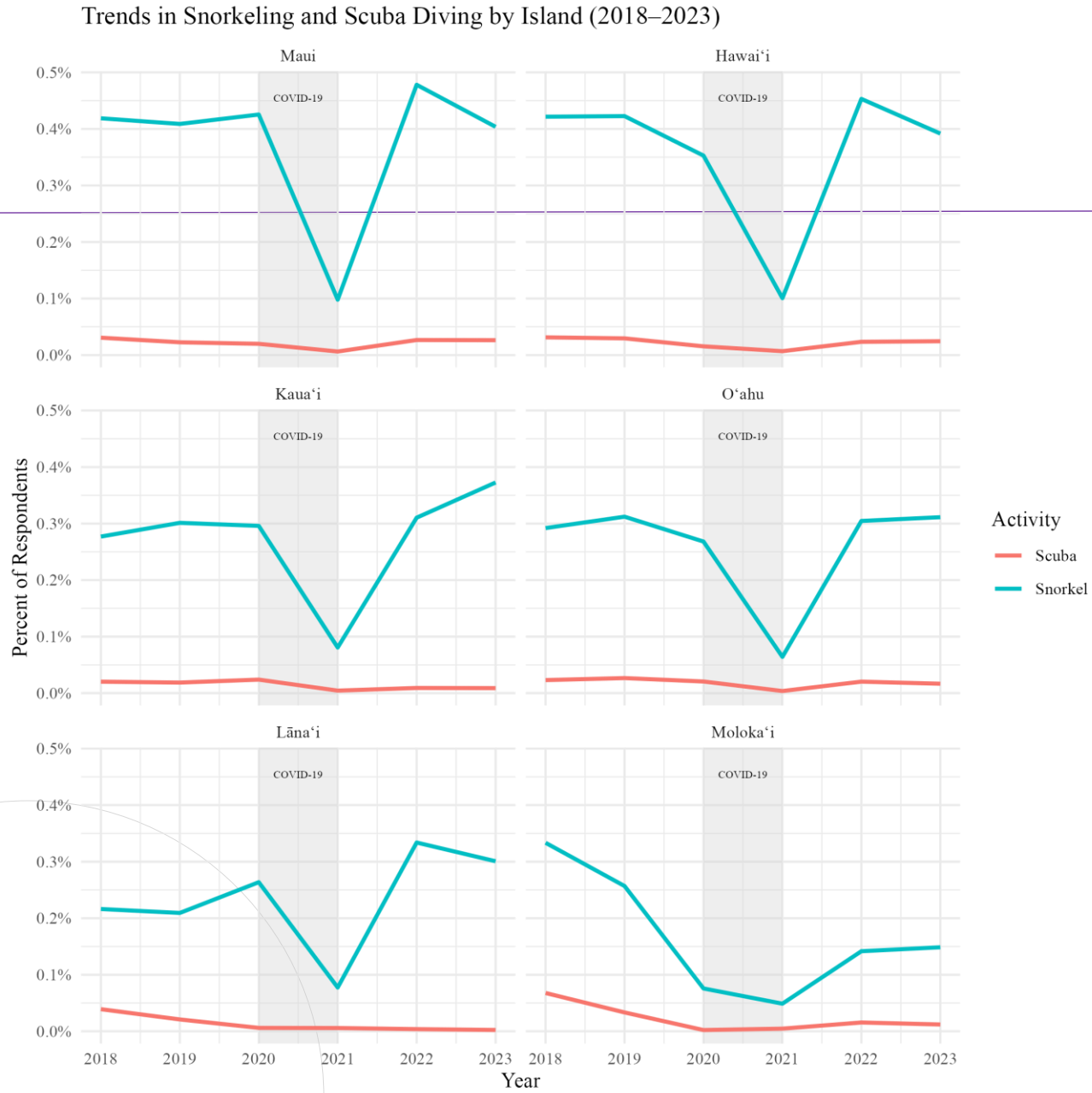
ISSUES APPLYING SAME METHOD

1. Tourists Often Choose the Entire Trip, Not Individual Sites
2. Site Substitution Is Harder to Observe
3. Ecological Awareness May Be Low
4. Single or Few Trips = Limited Behavioral Variation
5. Confounding With Vacation Budgets

TOURIST RESPONSE BY ISLAND

- Highest participation of tourist participating in Snorkeling is on the Hawai'i and Maui
- Much higher than literature relying value % (Spalding et al 2017; Cesar et al 2004)

Island	Snorkel	Scuba
Hawai'i & Maui	40-42%	2.5%
O'ahu & Kaua'i	29-31%	1.6-2.1%
Lāna'i & Moloka'i	19-26%	1.4-2.6%



Yearly Survey Hawaii Tourism Satisfaction Survey 2018-2023

CALCULATING EXPENDITURES

- HTA Survey to weight market share responses and actual arrivals # to each market.
- Assume 1 trip snorkeling per arrival w/recreational spending by market share
- ~ GDP added by Islands.
- More work needed.

VALUE ADDED FROM SNORKEL/SCUBA MILLIONS

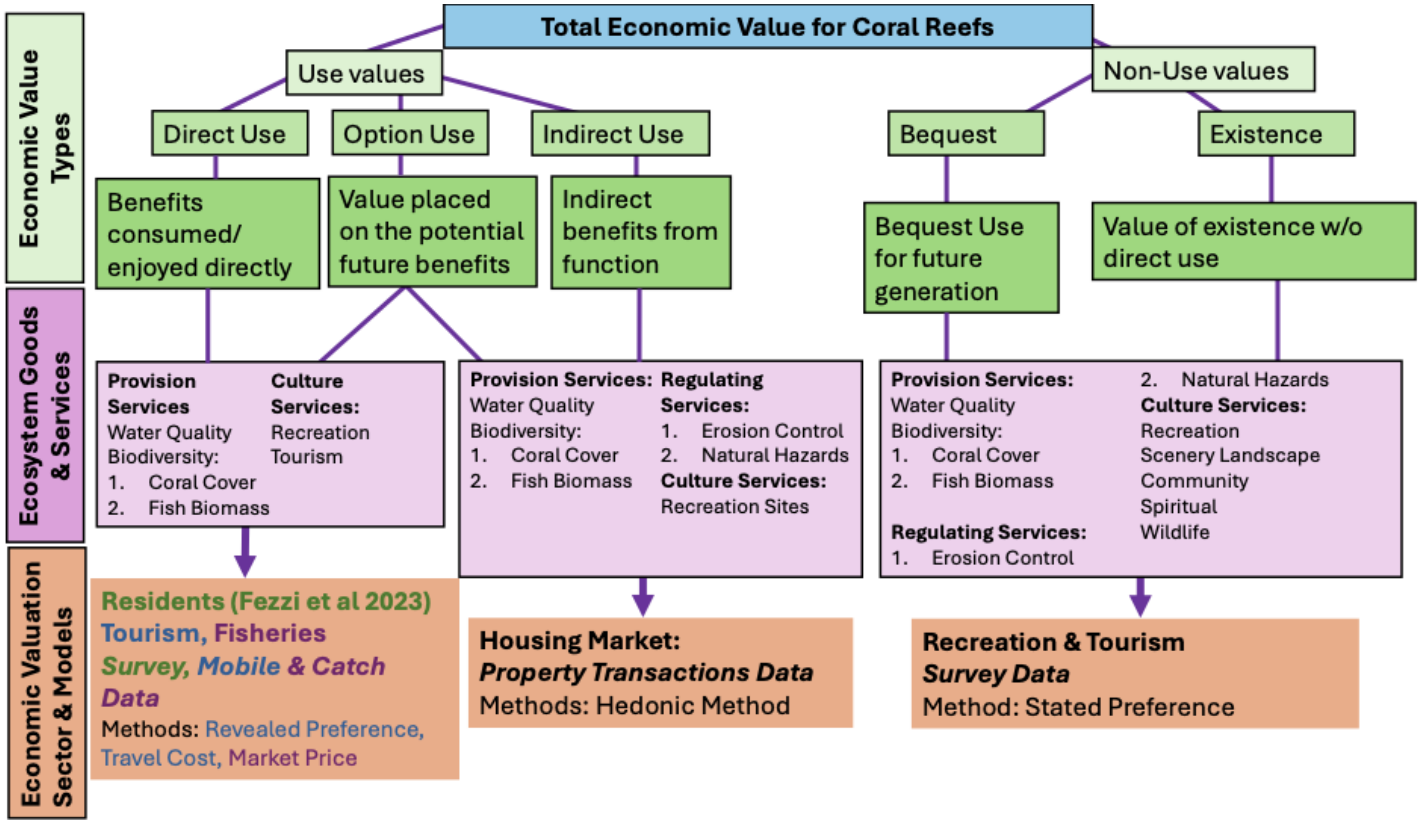
Island	2018	2019	2020	2021	2022	2023
Hawai‘i	5.48	5.60	1.65	5.86	8.06	6.83
Kaua‘i	3.63	3.74	0.97	3.21	5.42	4.75
Lāna‘i	0.19	0.21	0.06	0.18	0.19	0.13
Maui	10.28	10.83	1.83	11.03	11.35	9.69
Moloka‘i	0.11	0.11	0.02	0.06	0.07	0.06
O‘ahu	10.59	11.38	2.79	12.51	13.73	13.90
Grand Total	**30.28**	**31.86**	**7.32**	**32.85**	**38.83**	**35.36**

Findings and Next Step

Large loses & spatial difference based on preferences for residents.

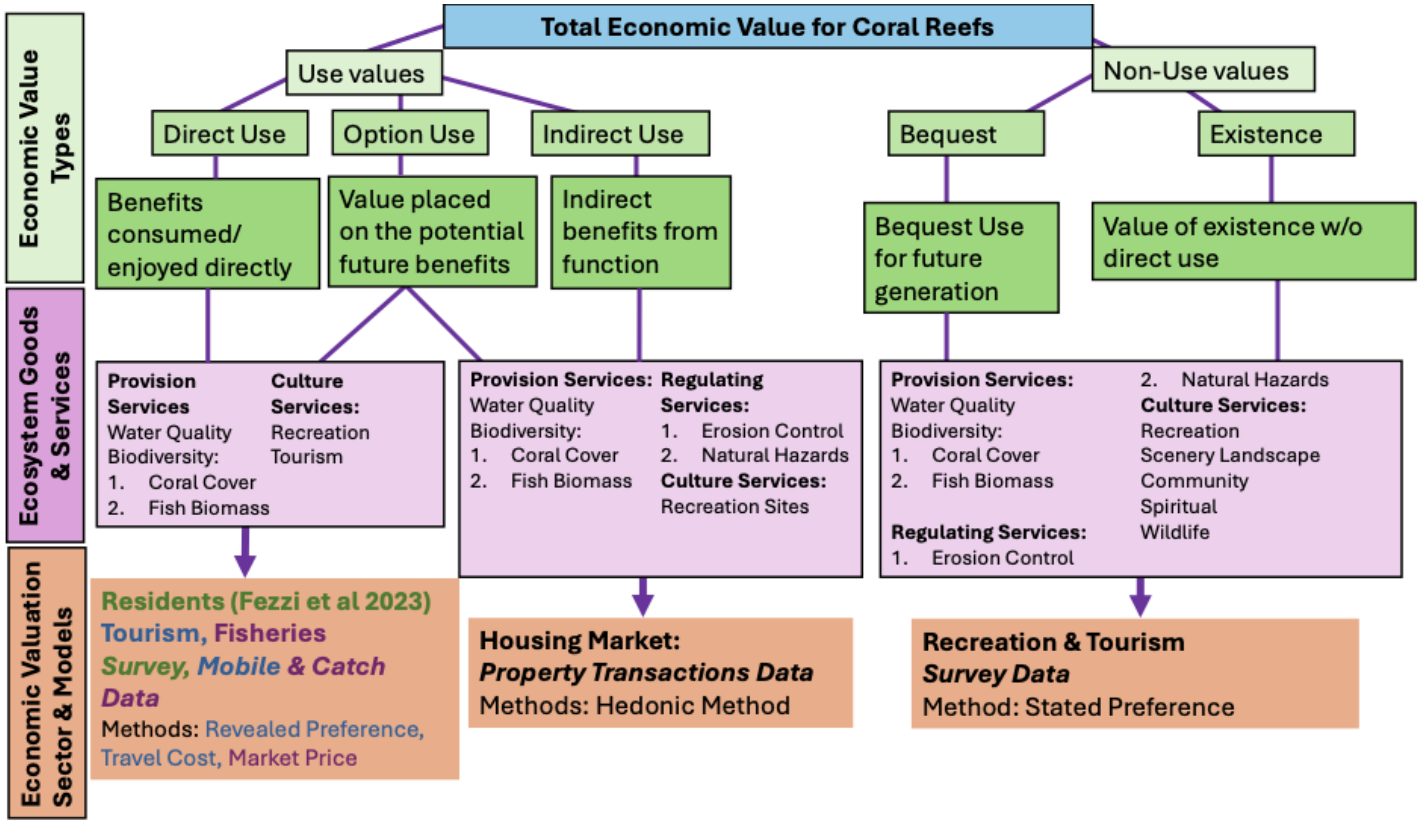
Valuing Future Matters

High value added and island diverse across tourist markets.



Findings and Next Step

- More defined Sites of tourist use.
- Expand indirect values in housing through Hedonic Frameworks
- Non-market values



Thank You

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