The economic value of coral reefs under future climate scenarios for the Main Hawaiian Islands

AERE
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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)

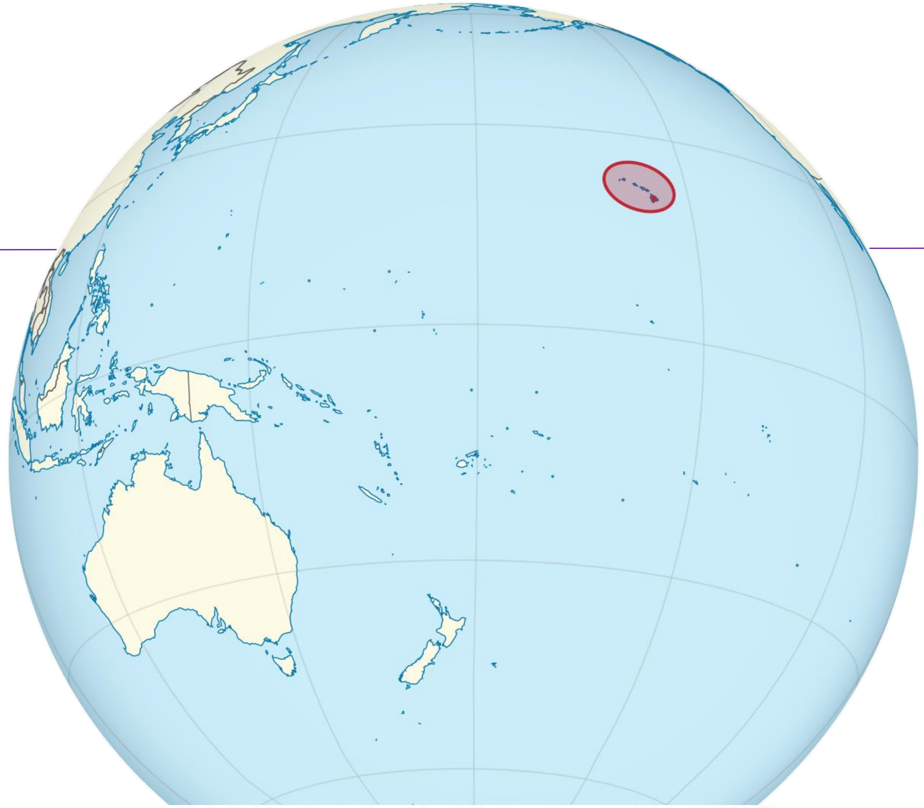
Recreation/Tourism

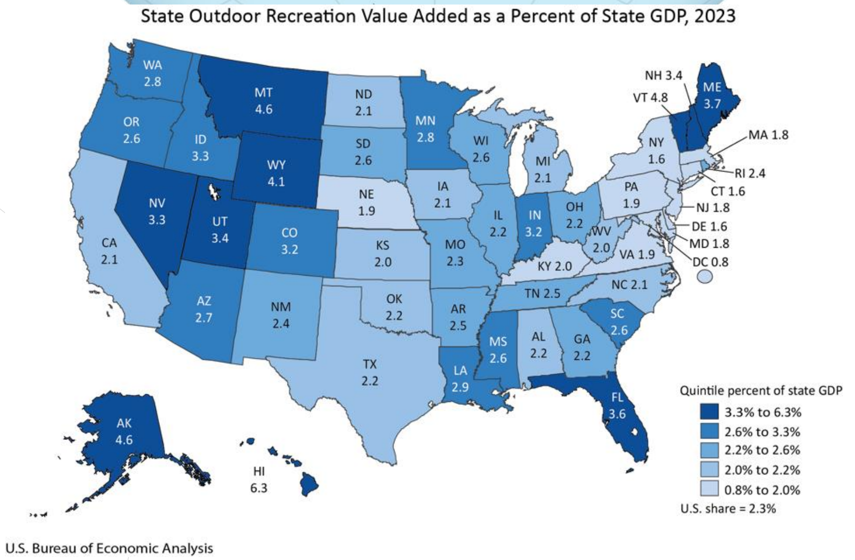
Snorkeling & Fishing

Value added Local Community business

HAWAII UNIQUE DEPENDENT ON EGS

- Isolation>imports >food security,
- Global Hotspot>Biodiversity
- EcoTourism
- Highest value-added to GDP BEA Outdoor recreation state





Local Management Needs

- Spatial heterogeneity (Beach have different features & amenities)
- Managers need the ability to prioritizes & target efforts for protection or restoration for communities.

Literature Review

- Cesar, H. S. J. et al (2004). Economic valuation of the coral reefs of Hawai’i. Pacific Science, 58(2), 231–242.
- Brander, L. M. et al(2012, 2013). Economic impact of ocean acidification on coral reefs. Climate Change Economics & NOAA report on Total Economic Value US Coral Reef….

Our Lab

- Peng, Marcus, et al. (2017) "Beach recreationalists' willingness to pay…." Ecological economics
- Fezzi, C., et al(2023). The economic value of coral reefs…Ecological Economics

Our Team

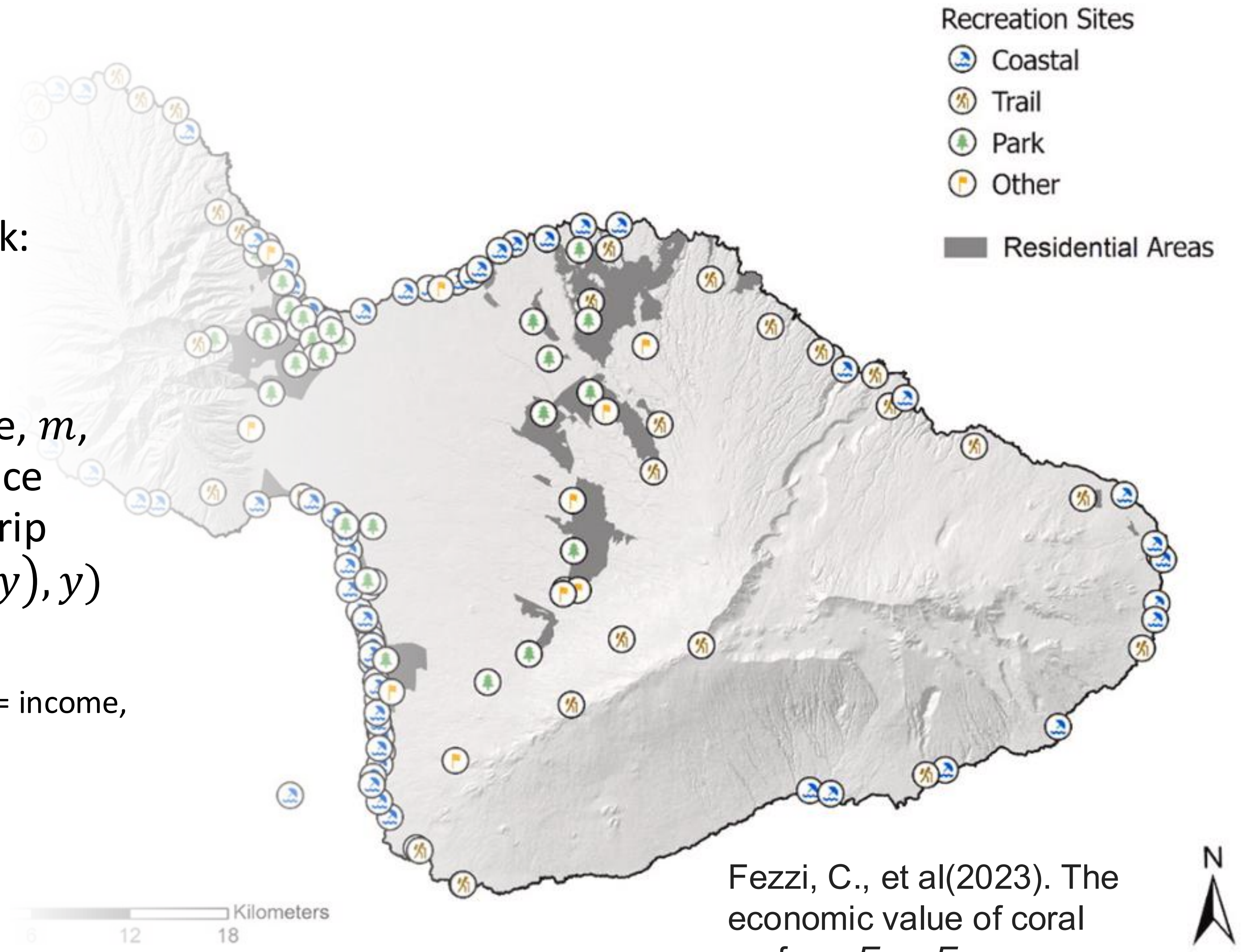
Random Utility Framework:

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

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

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

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



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

Benefit Transfer

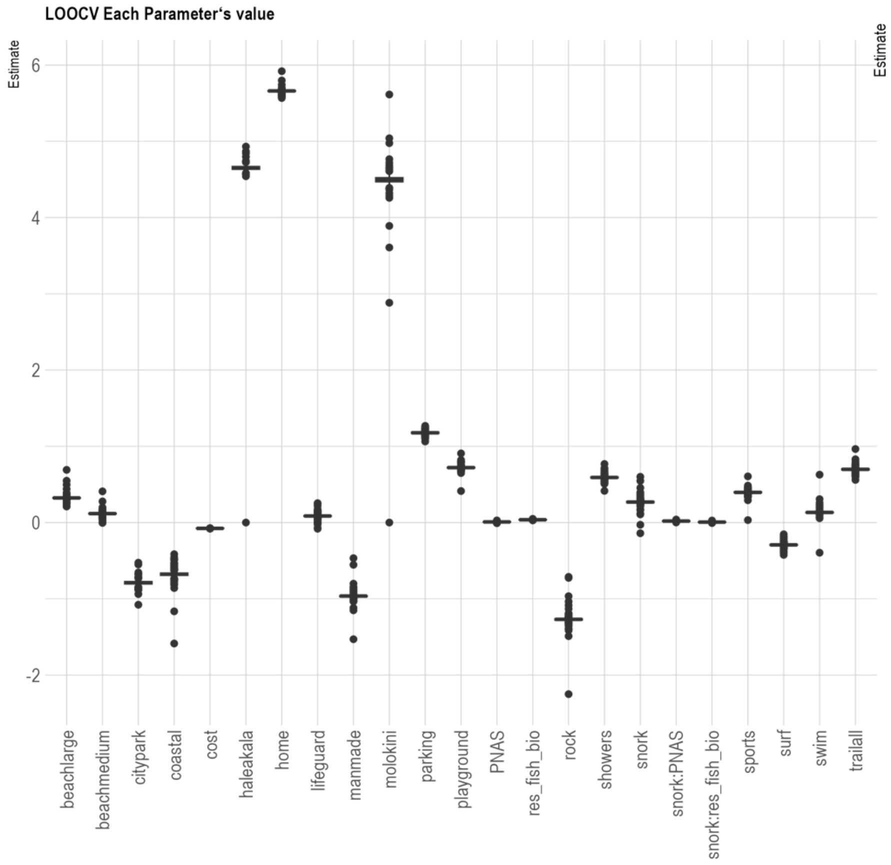
Value Transfer –

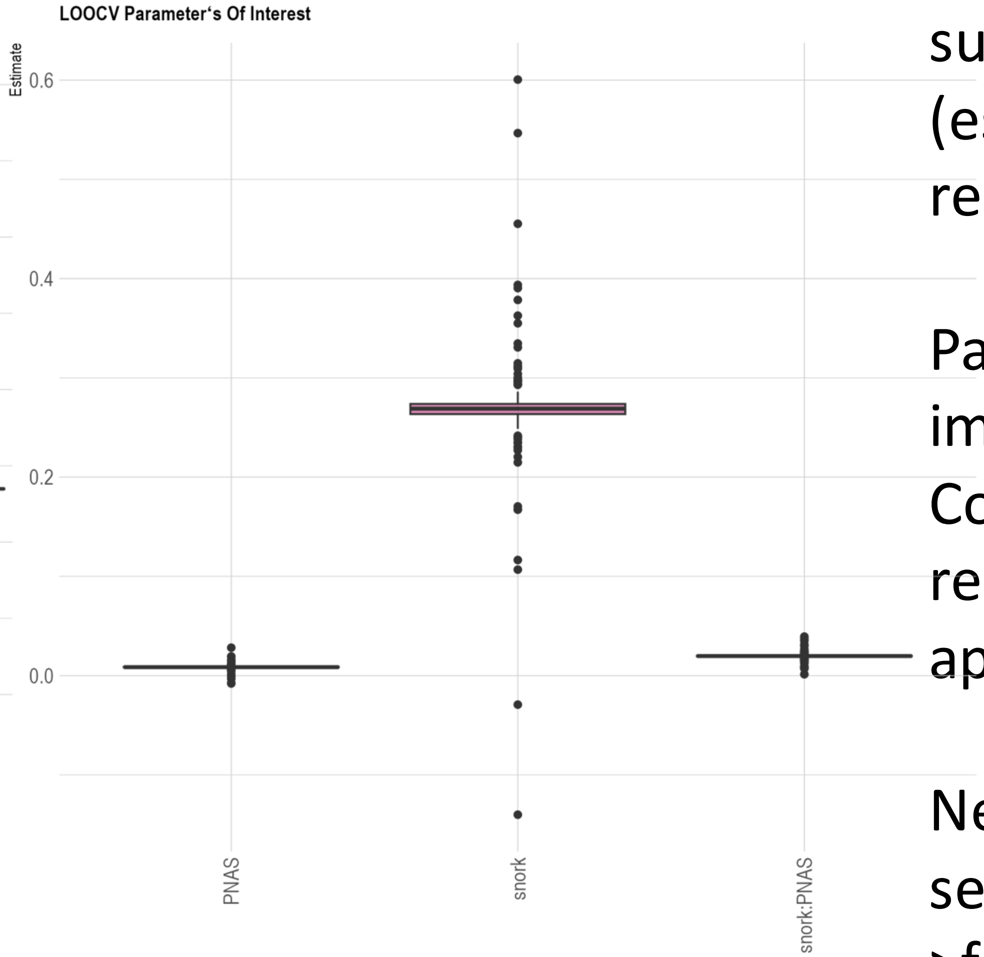
- *Direct values from one study to another location would come Done : (Lane et al 2015; Bander et al 2013)*

Function Transfer –

- *Parameterized functions form* Fezzi et al (2023) *study to another location by gathering all site and calculate the compensating variations.*

Leave One Out Cross Validation





RMSE produces .18 suggesting RUM (estimated on site shares) relatively low.

Parameter Value important for BFT using Coral Reef Condition relatively stable for our approach.

Need for consideration of seasonality of site. ->further research

Assumptions Resident Recreational Value

Original WTP for sites:

$$\widehat{WTP}_i = f(z_{ji}, \hat{\beta}_i)$$

Where $j = site$ & $i = population$

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

where s ≠ j & r ≠ i:

$$\widehat{WTP}_{sr}^{BT} = f([z_{sr}^1 z_{ji}^2], \hat{\beta}_i)$$

Annual Value :

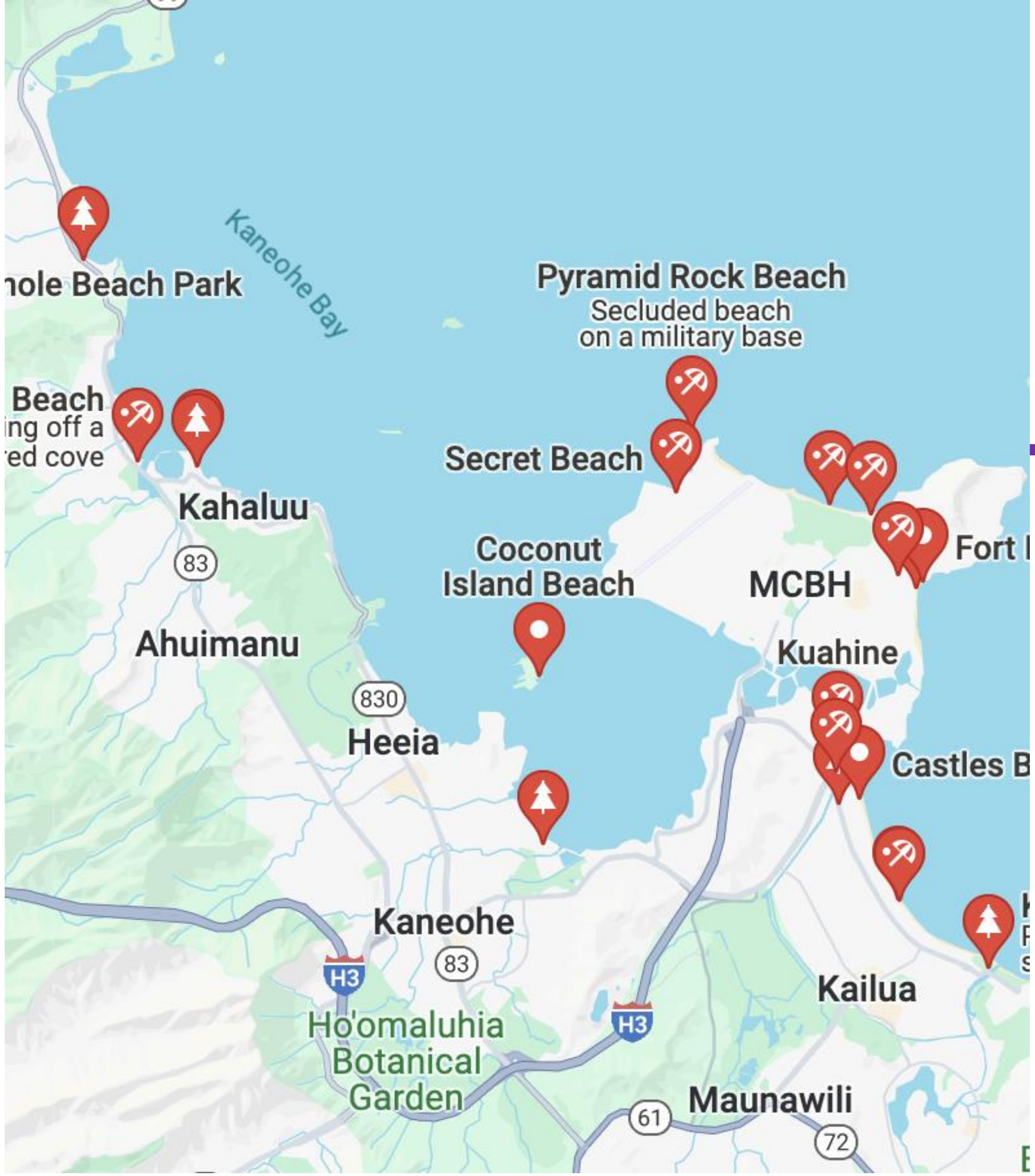
Where m *is income*

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

Benefit Function Transfer

Steps to define:

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

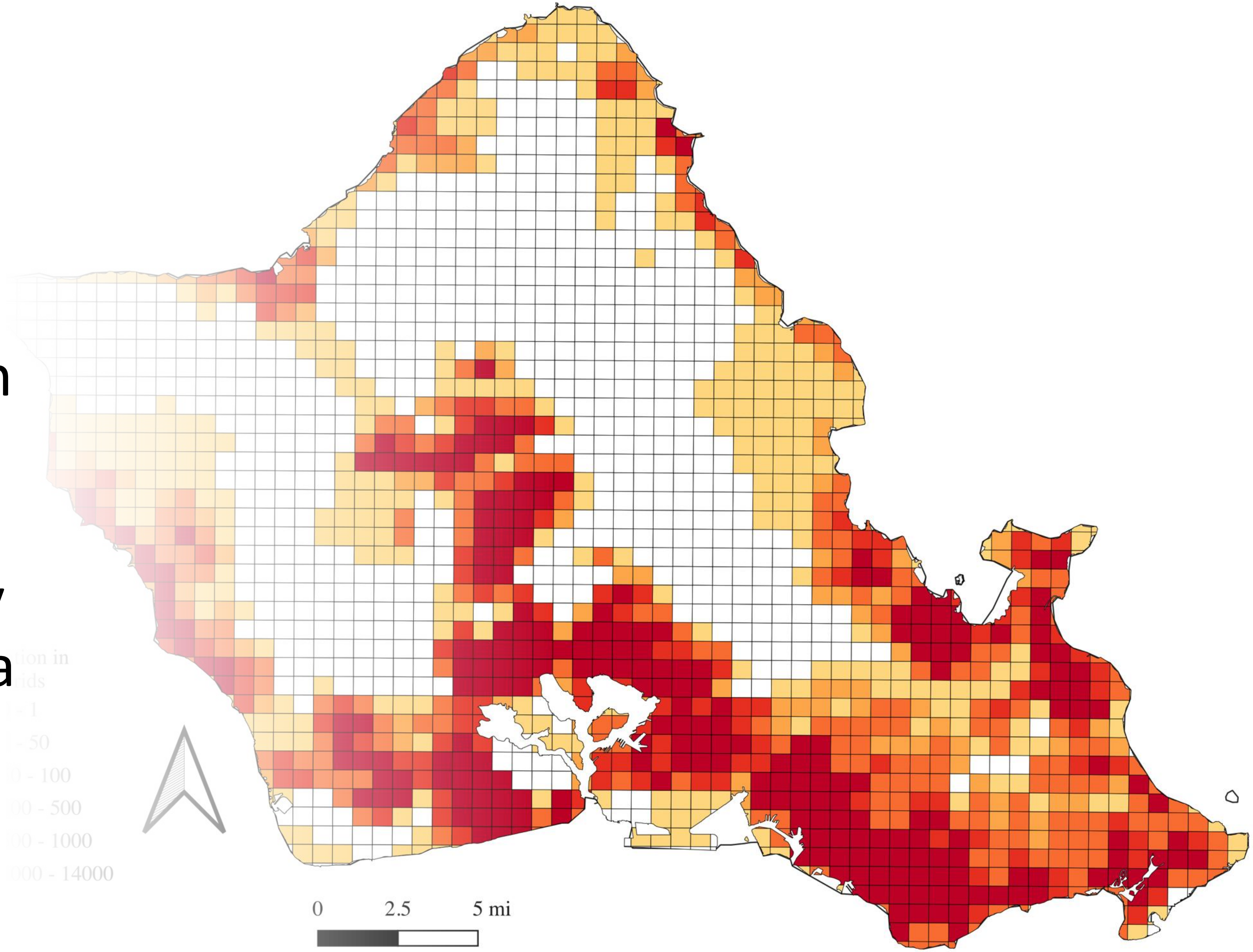


1. SITES & AMENITIES

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

Define Population & Income

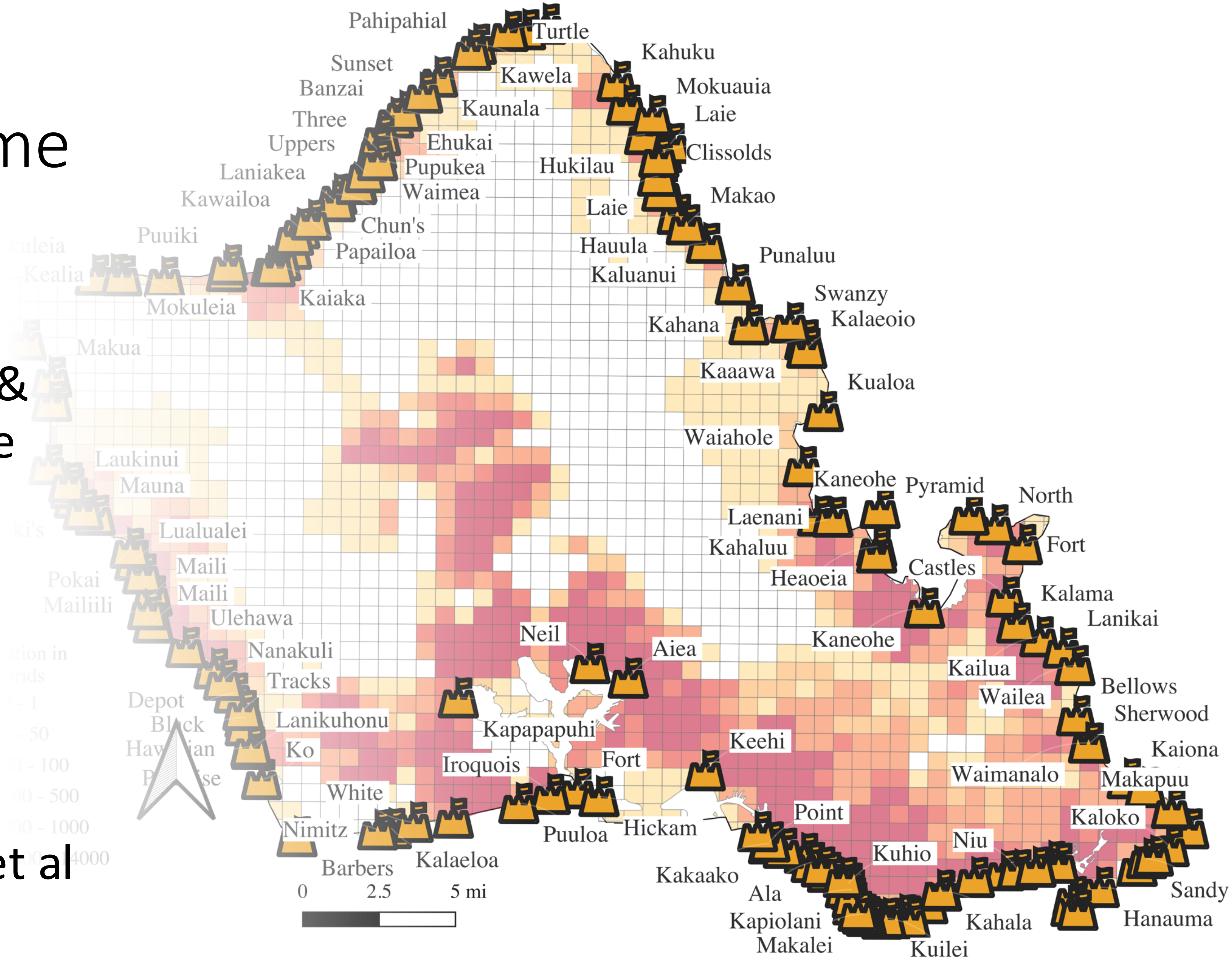
- 2020 Population across islands in Census Block
- Cal. Pop Density considering area within 1km Grid



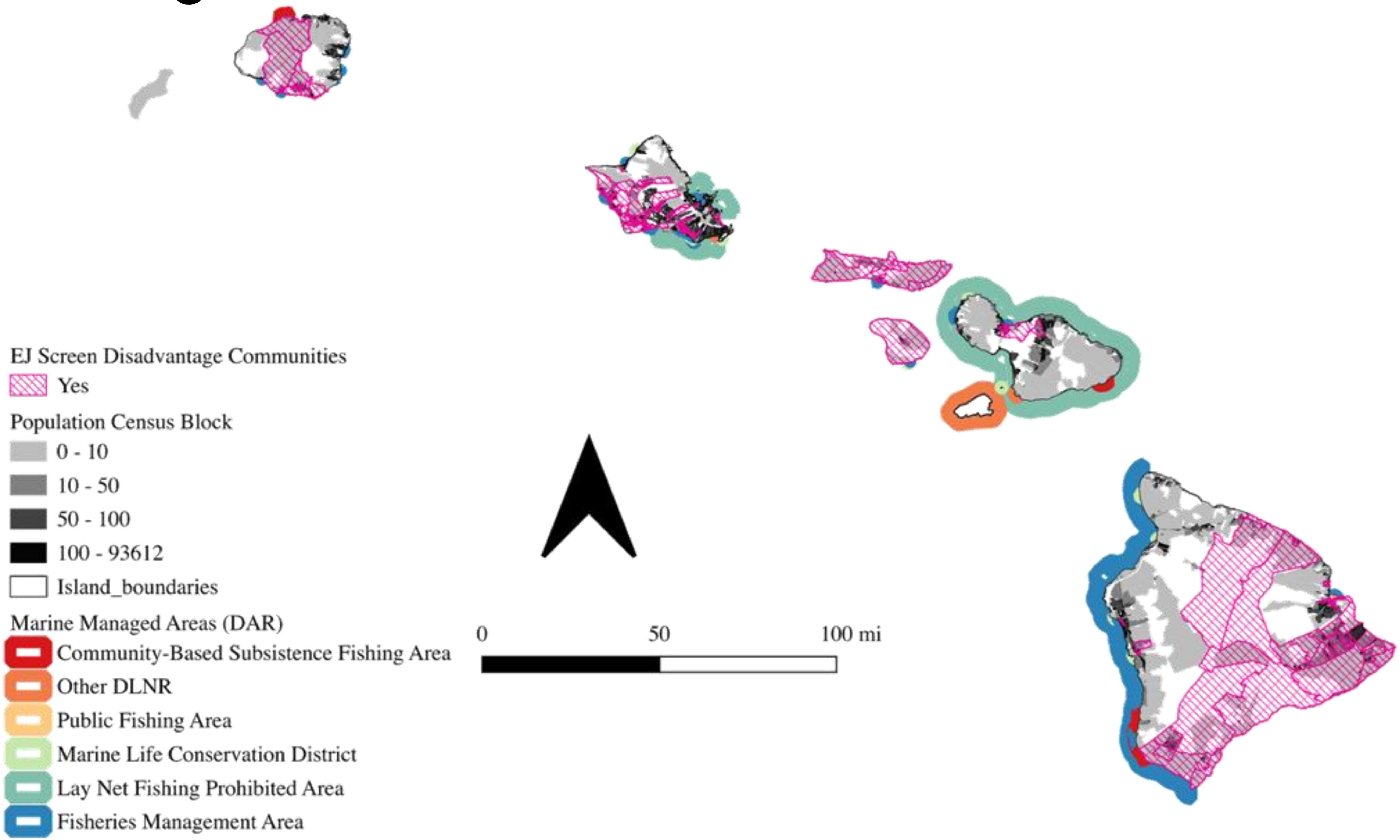
Distance & Time to each Site

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)



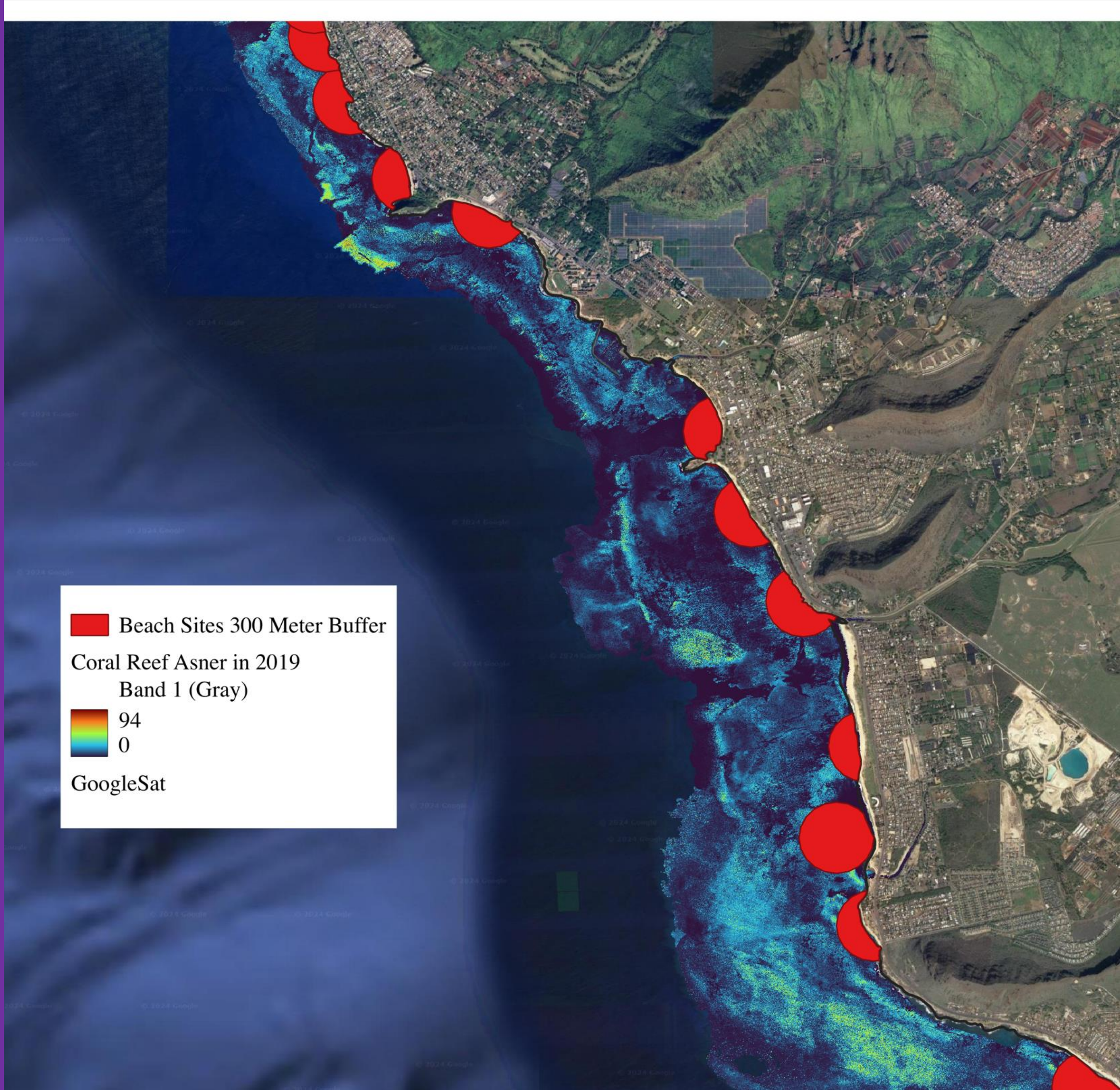
Define Population Resource & Environmental Concern
Marine Managed Areas



DEFINE ECOSYSTEM SERVICE

Recreation Site 300-meter buffer:

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

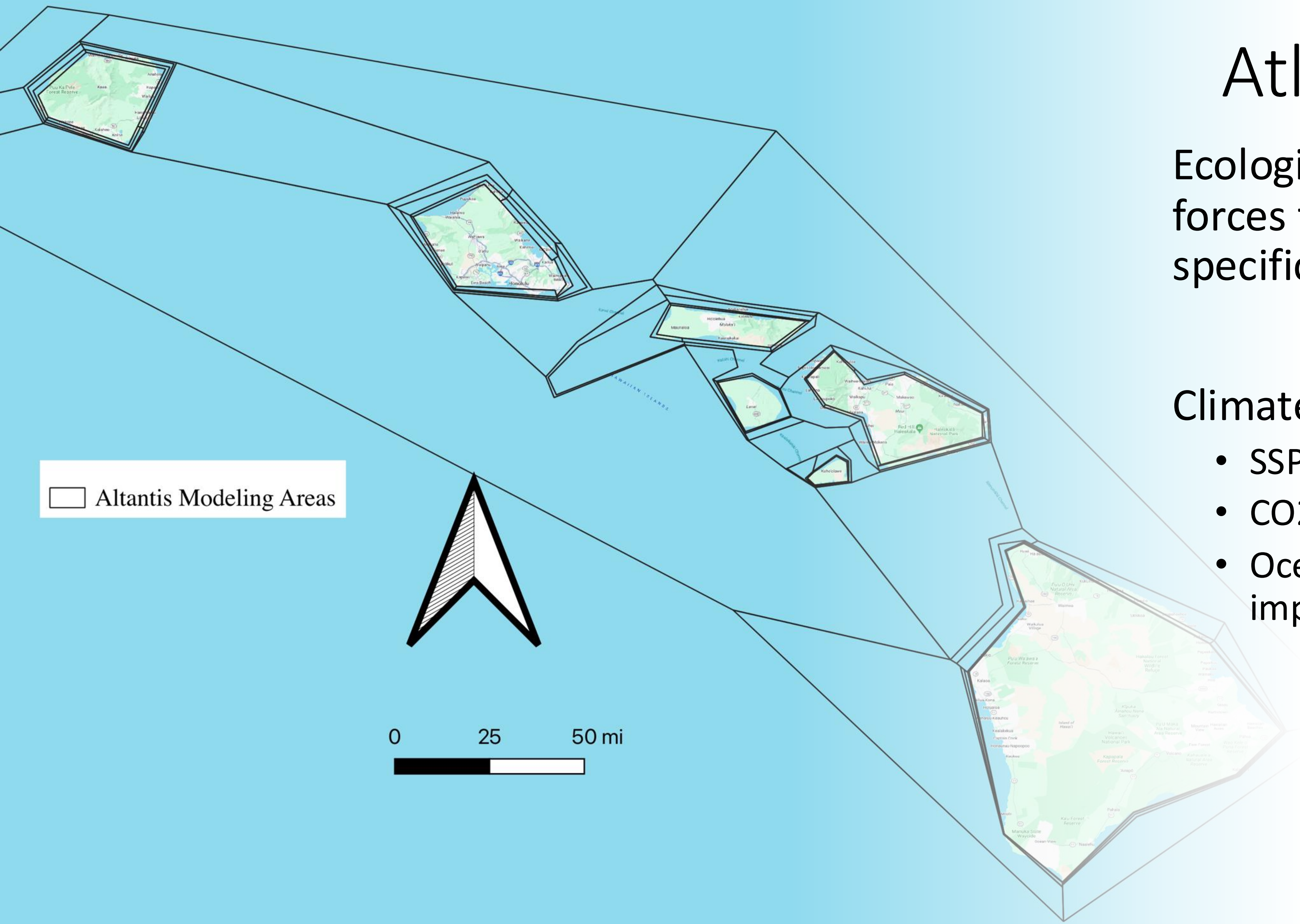


Atlantis Model

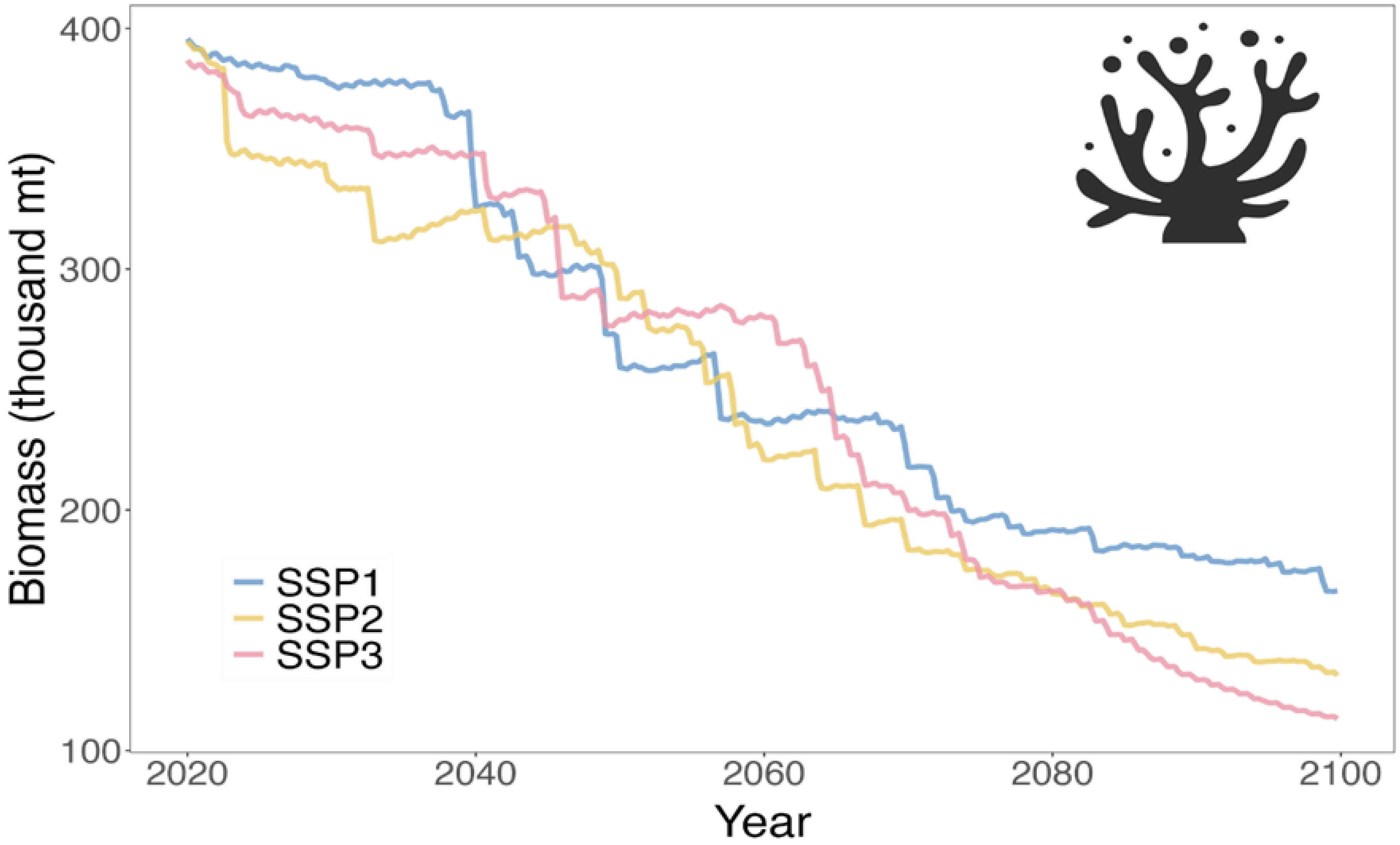
Ecological Model uses climate forces to model biomass of specific in Polygons.

Climate Scenarios

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

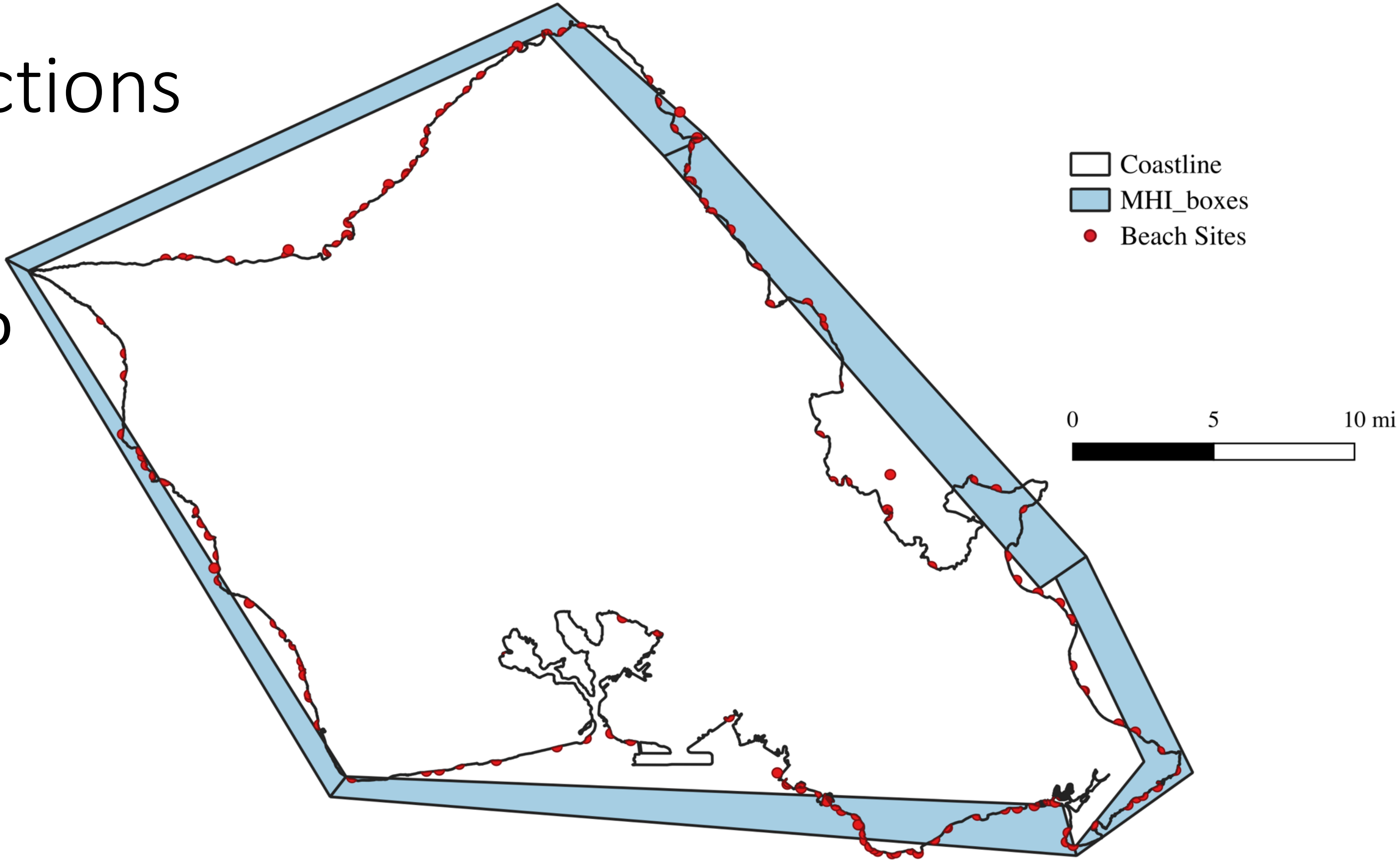


Overall Projections using Atlantis of Coral Cover Biomass



Nearshore Predictions

- Match rec site to nearest nearshore Atlantis site



Identify Genus within Atlantis

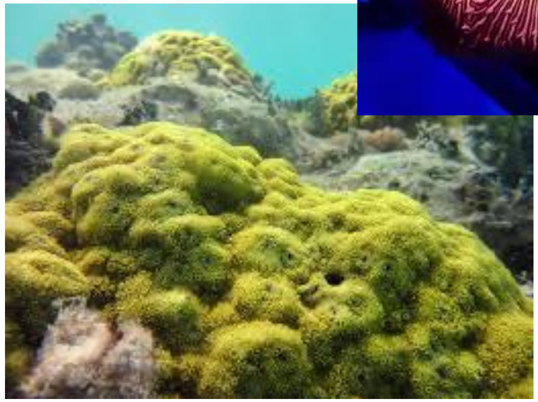
Coral Reef Types

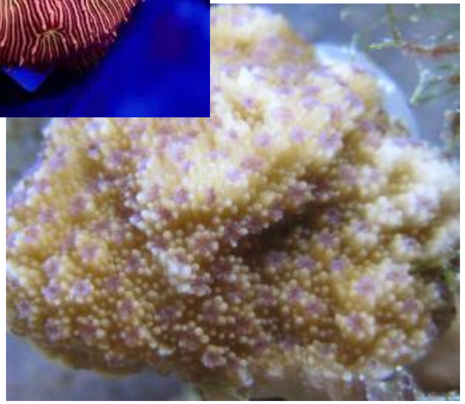
- Pocillopora, Porites branching, Porites massive, Montipora, Leptoseris

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

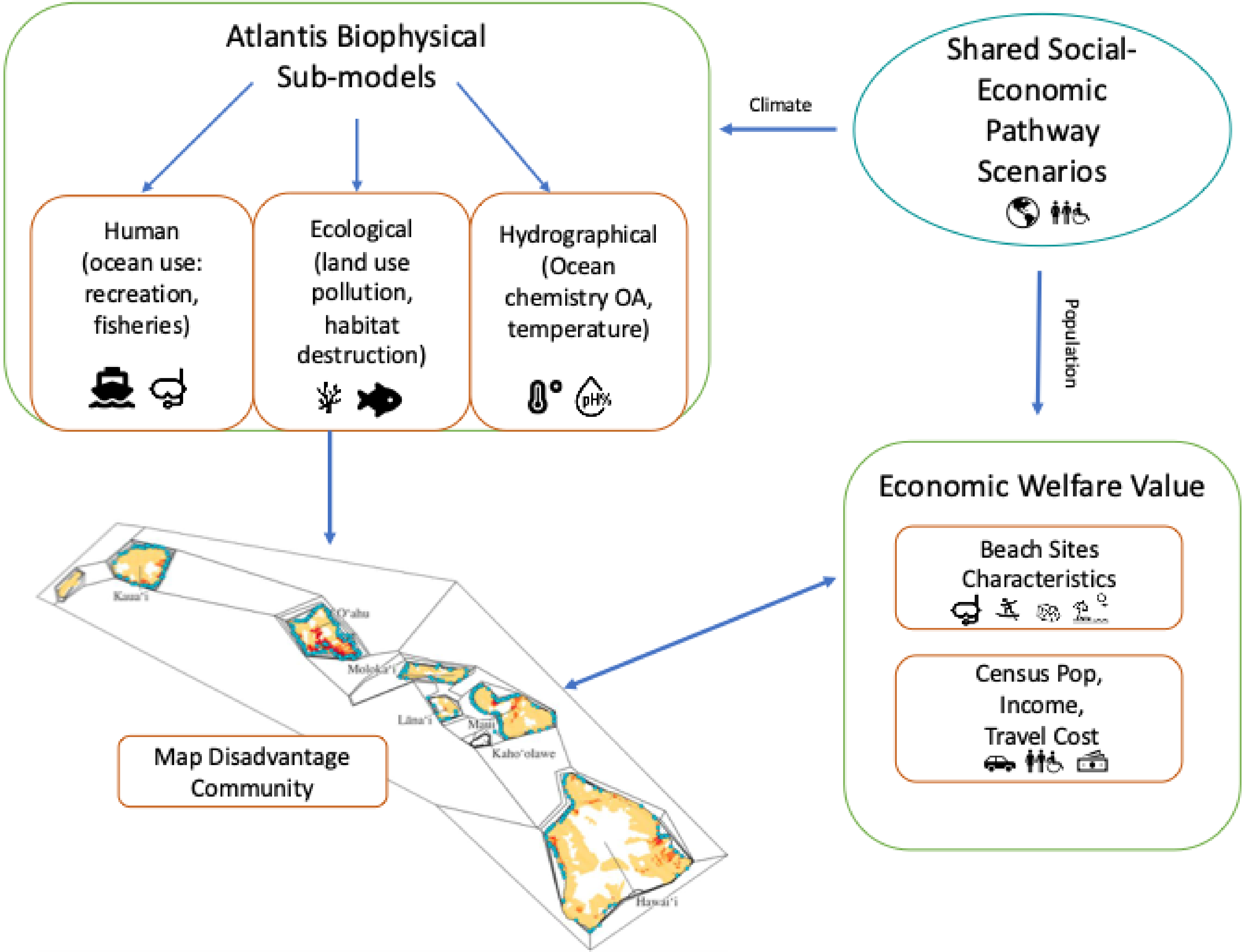
$$y_{bt} = \frac{\sum Vol_{bt}}{\sum Vol_{bt=0}}$$

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





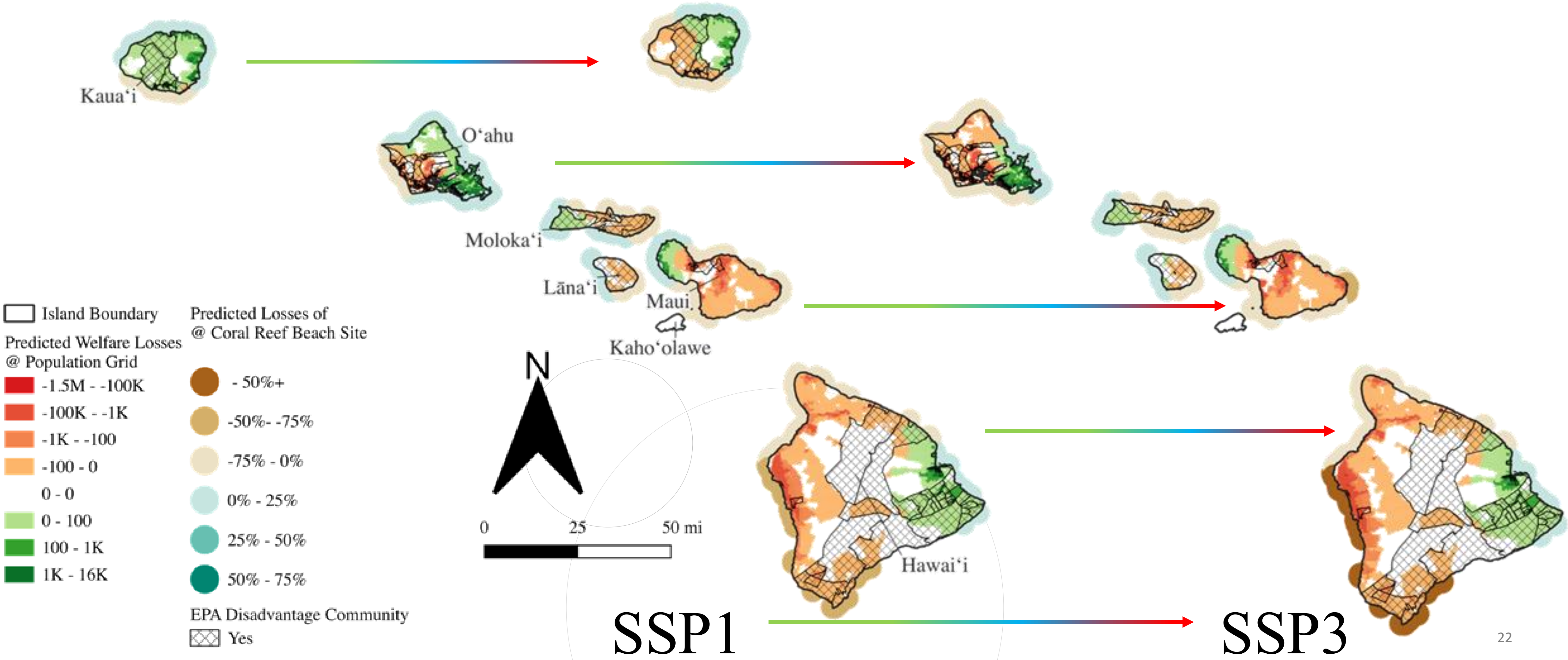
Framework to Integrating Assessment Model



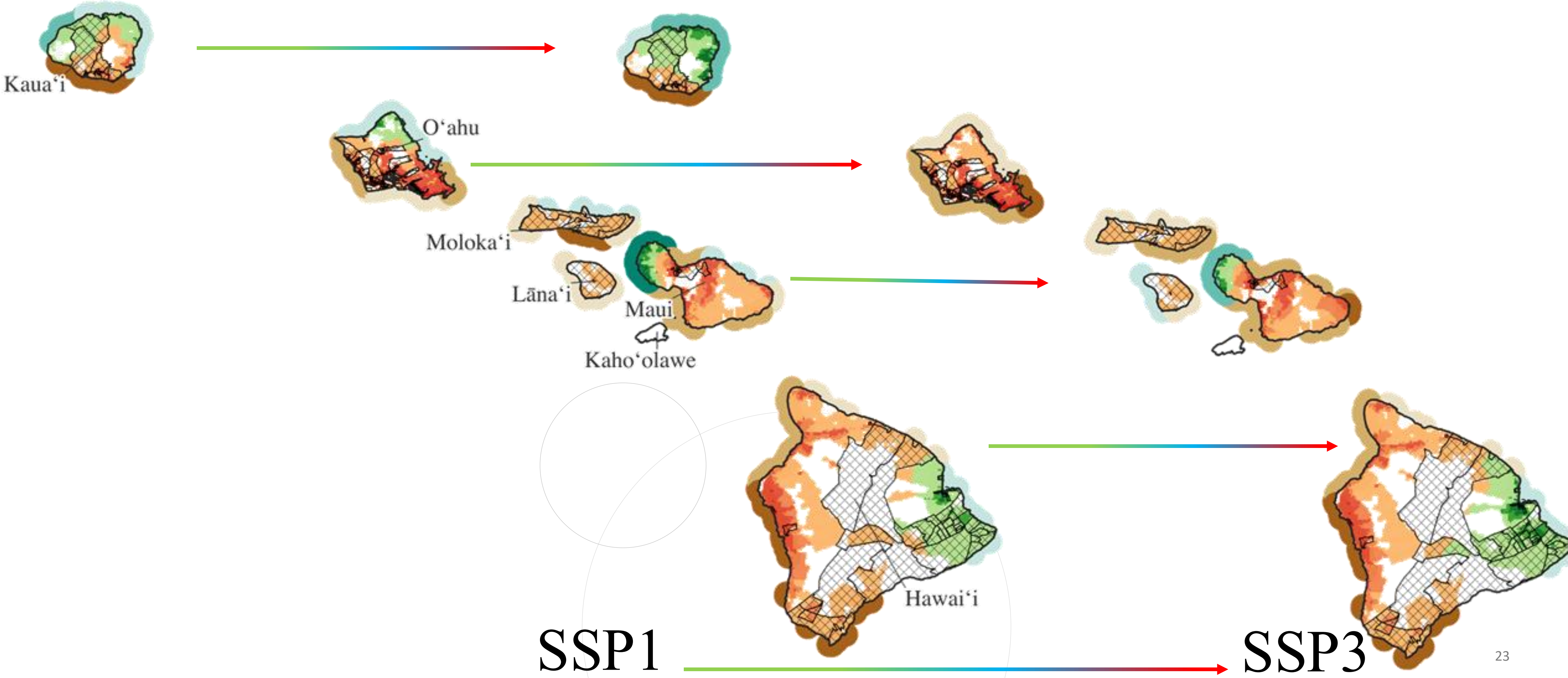
Spatially Simulated Scenarios for Hawaii's Nearshore Environment

Incorporating Ecological Modeling Under Climate Scenarios

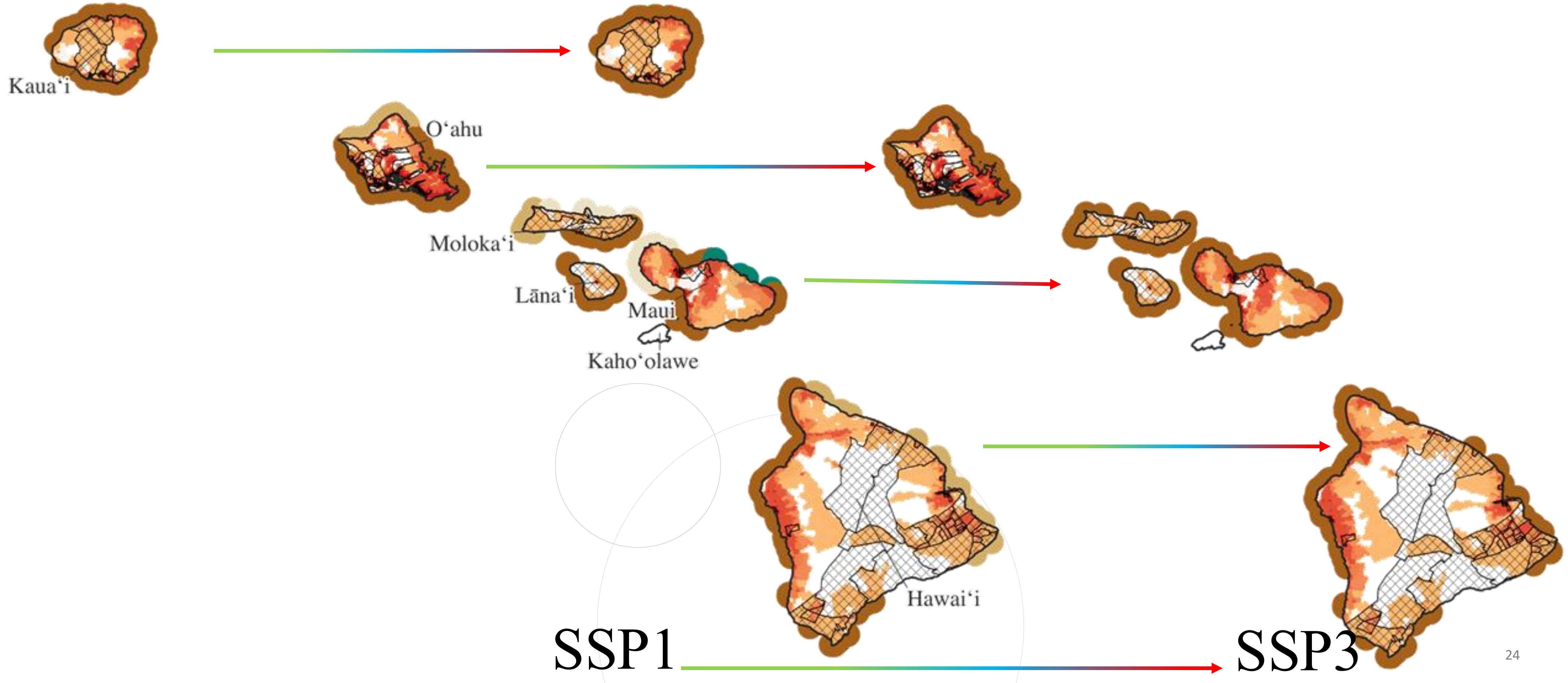
PROJECTED YEAR 2030 OR 30X30



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 $2017 Annual

	SSP1			SSP3		
Island	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**
Hawaiʻi	-0.76	-2.65	-3.94	-1.23	-1.54	-4.68
Kauaʻi	1.50	-3.76	-13.28	0.21	1.35	-15.86
Lānaʻi	-0.07	-0.53	-1.40	-0.01	-0.38	-1.68
Maui	-16.58	-62.80	-121.53	-28.10	-70.09	-161.83
Molokaʻi	-0.05	-0.48	-1.11	-0.15	-0.52	-1.99
Oʻahu	-1.49	-38.00	-65.25	-4.69	-35.78	-73.92
Average	**-2.91**	**-18.04**	**-34.42**	**-5.66**	**-17.82**	**-43.33**

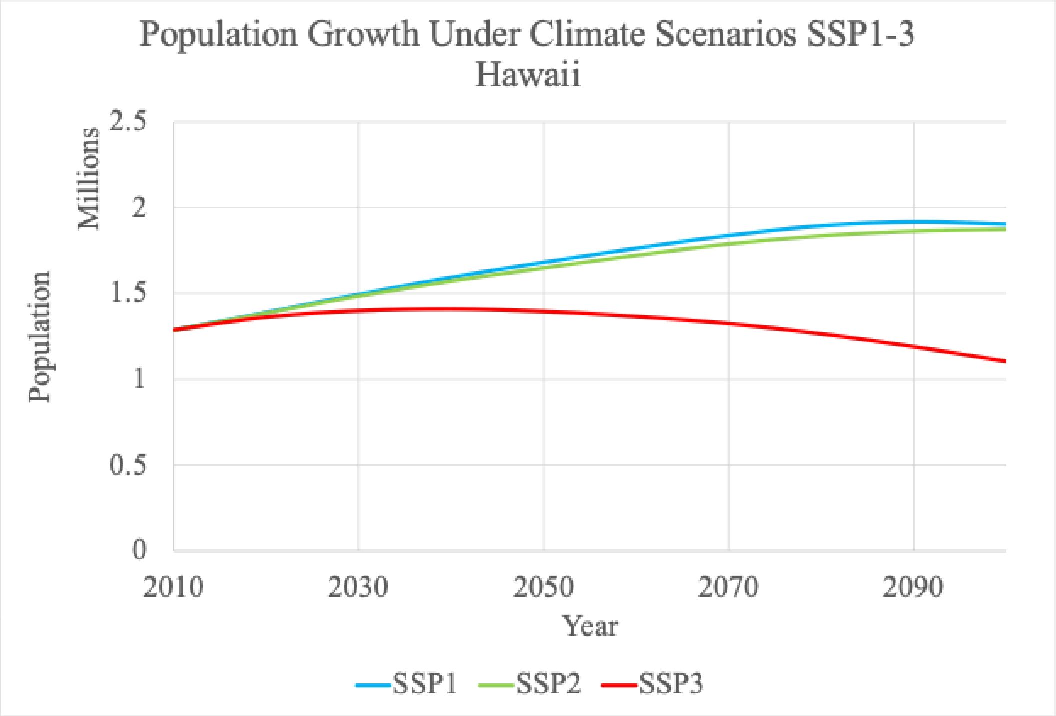
B. All Other Communities Average Predicted Welfare Loss Per Person

	SSP1			SSP3		
Island	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**
Hawaiʻi	-16.89	-42.09	-52.59	-24.24	-36.67	-53.53
Kauaʻi	3.43	-3.73	-20.95	1.40	7.18	-27.44
Lānaʻi						
Maui	-3.57	-31.25	-89.43	-15.86	-45.95	-132.95
Molokaʻi						
Oʻahu	4.18	-56.08	-90.19	1.07	-53.40	-109.85
Average	**-3.21**	**-33.29**	**-63.29**	**-9.41**	**-32.21**	**-80.94**

Population Growth Under Climate Scenarios Shared Socioeconomic Pathways 1-3 for Hawaii

- SSP1 & SSP2 driven by medium levels of fertility, mortality, and international migration in developed Nations

- SSP3 due to low fertility and international migration along with high mortality, and growth is high



Similar Results across work Jiang et al 2020;Hauer 2019;Zoraghein et al 2020

LONG TERM DISCOUNTING ON ECOSYSTEM FACING SCARCE FUTURE

Long-term Estimate of the Social Rate of Time Preference

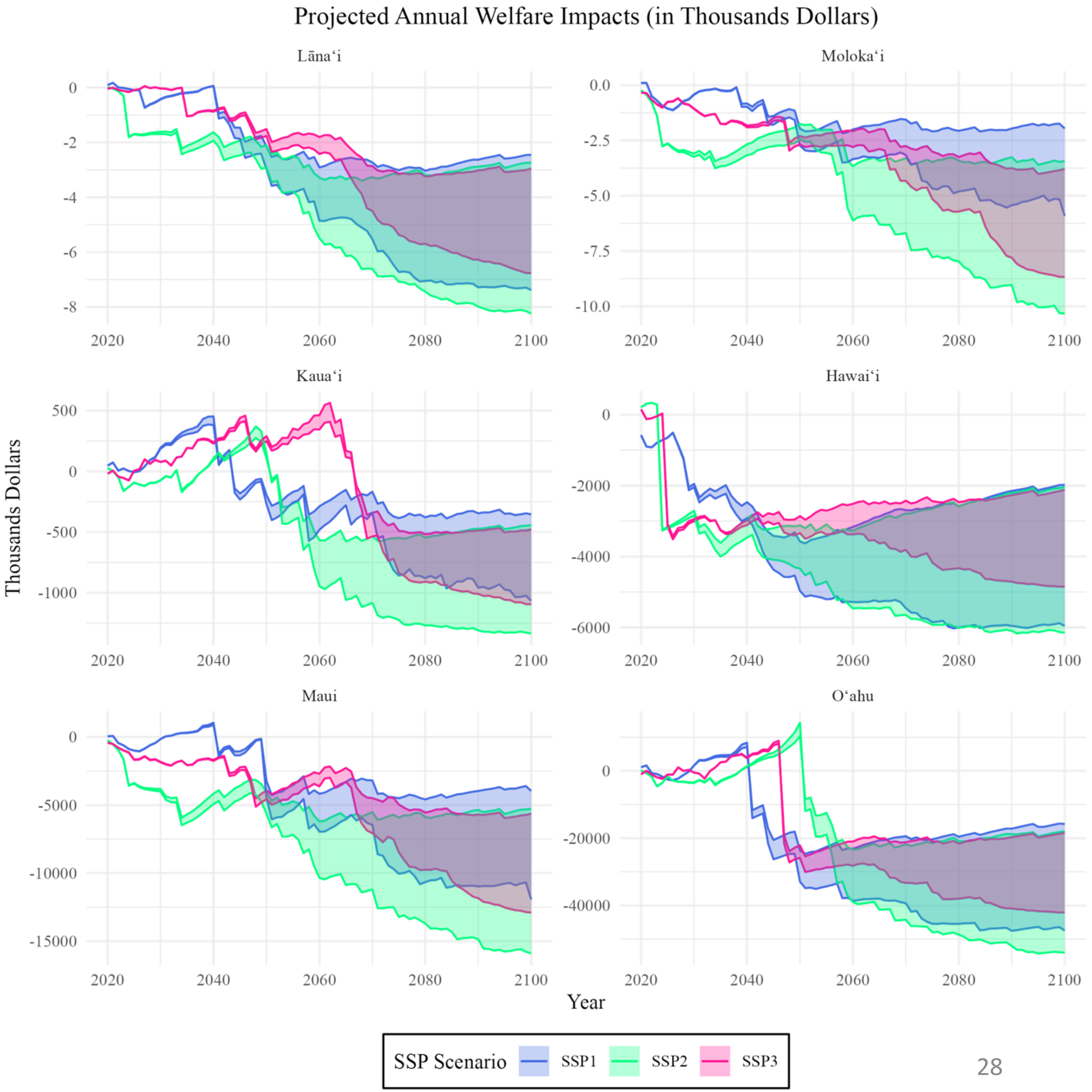
- OMB
- Ramsey model
- Declining
- Circular A-4

Pluralistic Discounting of Capital Assets (Costanza et al 2021)

- 40% Natural, 10% Social, 30% Human, 20% Built
- 0% Natural, 0% Social, 3% Human, 10% Built

Across Island Losses

- OMB lower bound & Pluralistic discounting - upper bound
- SSP1 & SSP2 higher due to more individuals to experience losses
- Island of Hawai‘i & O‘ahu sees large drops in abundance
- Slower declines Moloka‘i & Lān‘i
- $2.1 to 3.3 Billion (2024 dollars) by 2100



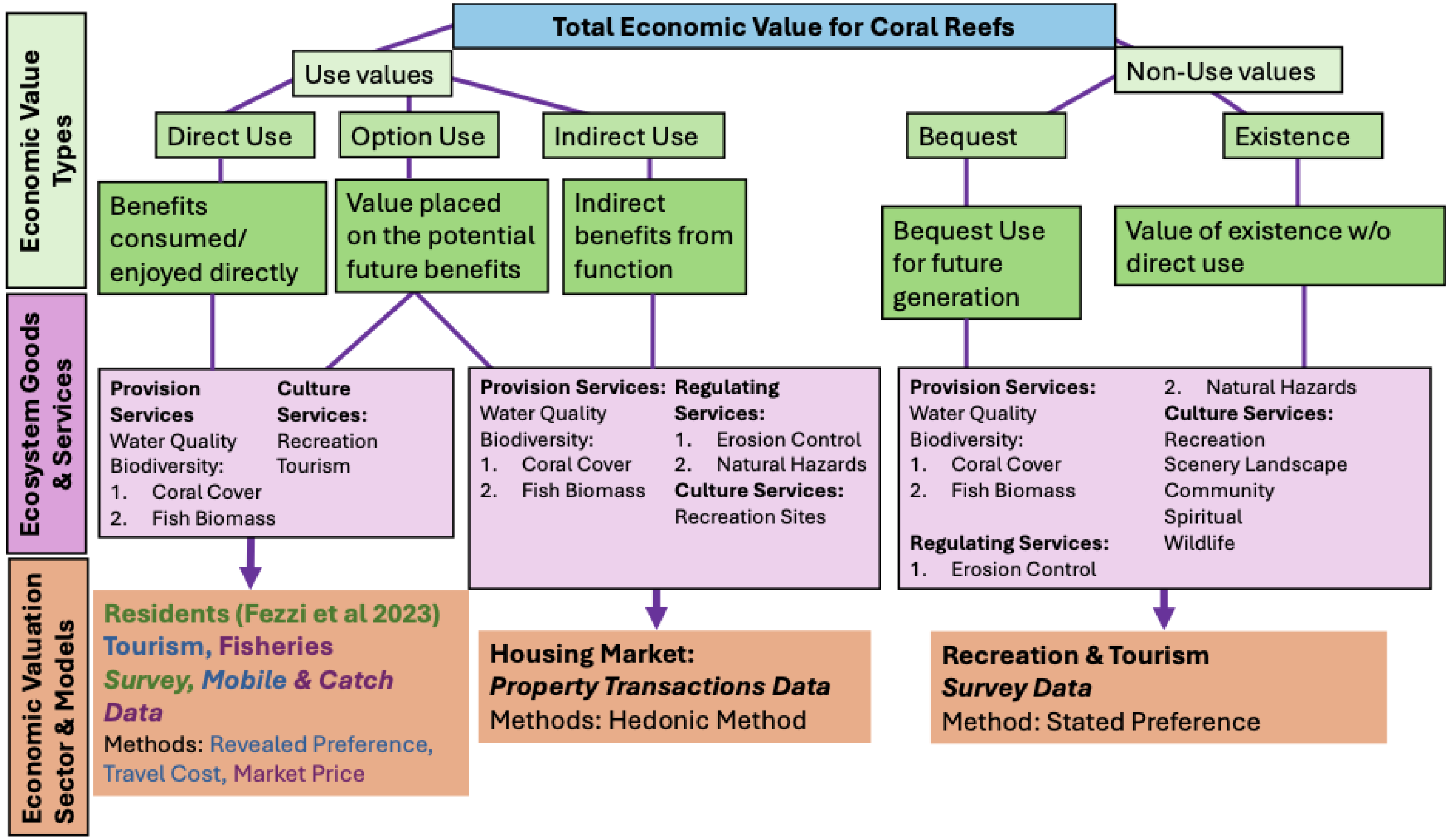
Shorting Comings

- As always – Lower bound estimate
- Only valuing ***Residents***
- Preferences remain constant through the timeframe, assume linear relationship overtime
  - Extreme high biodiversity loss/scarcity-- Drupp, M. Et al.(2024)

Next Steps

Expand to tourism sector values for spatially explicit reef-adjacent dependence.

Indirect values from housing market through erosion, flooding and recreation benefits



Thank You

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