Use of Eco-epidemiology to Assess the Potential Risks of UV Filters to Corals

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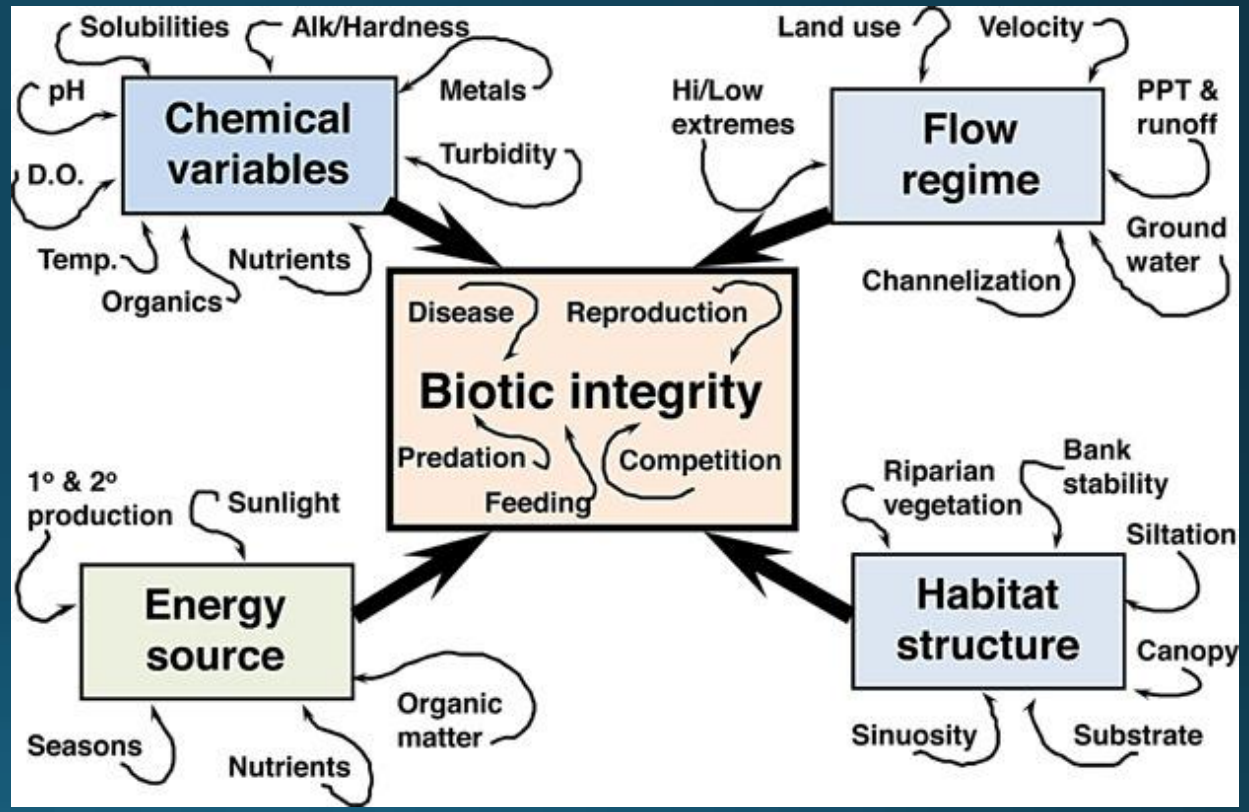
16 September 2021

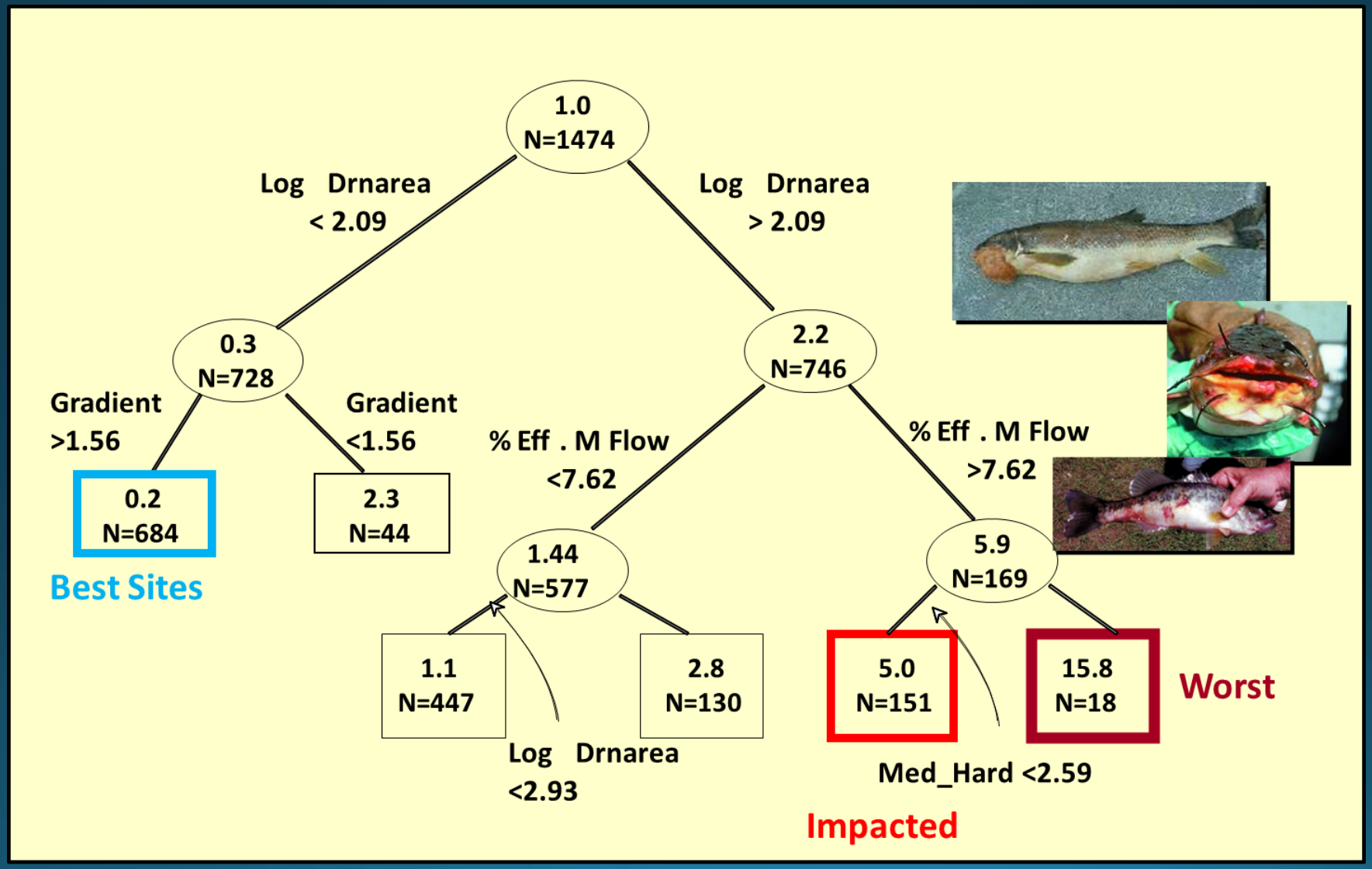
Eco-epidemiology

- Retrospective method that relies on high quality biological monitoring data[1]
- Holistic risk assessment approach that integrates physical and chemical factors that can affect the ecological status of a water body

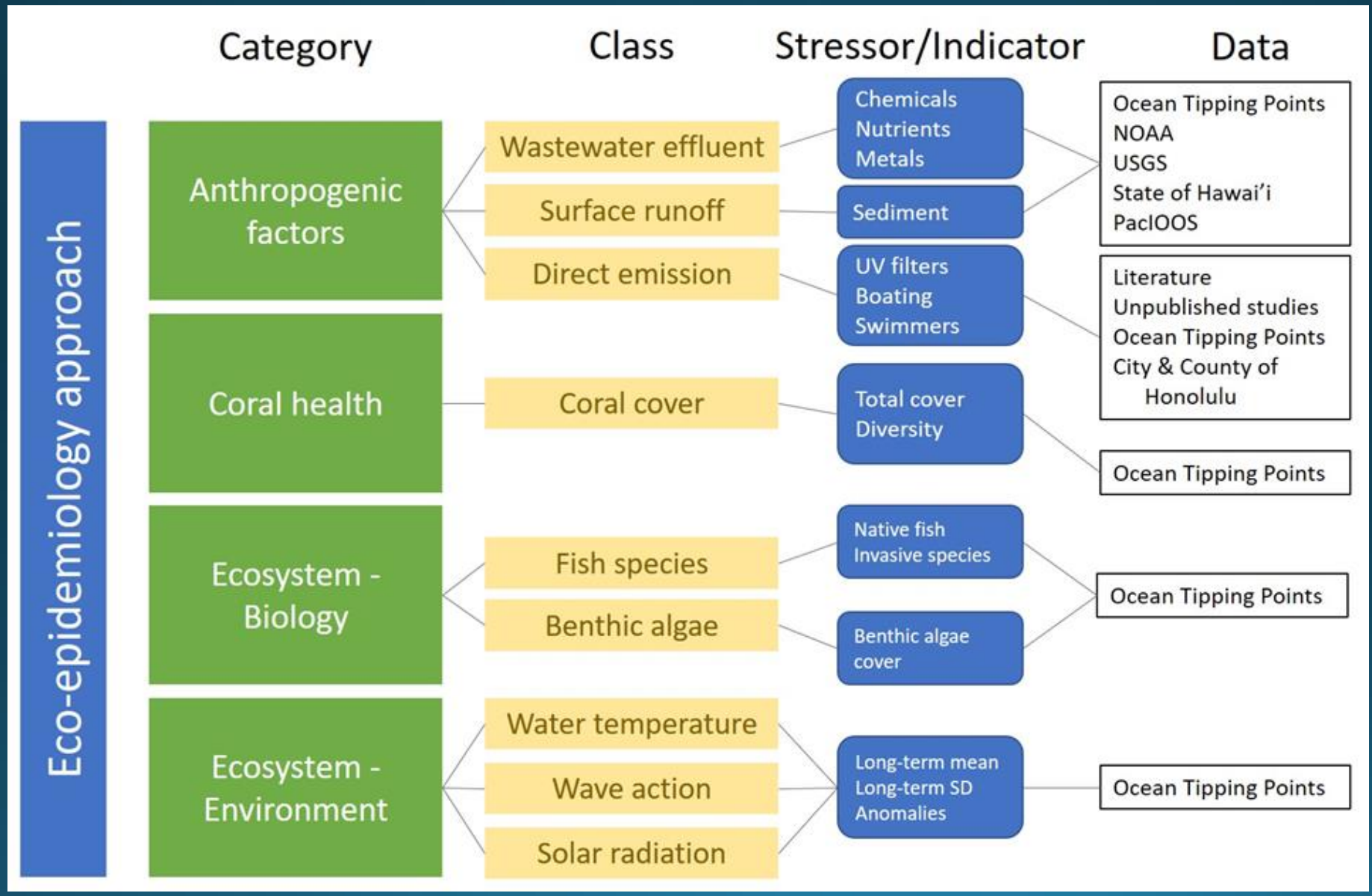


[1]Dyer S. 2015. Environmental Toxicology and Chemistry 34: 1206-1208. DOI: https://doi.org/10.1002/etc.2982

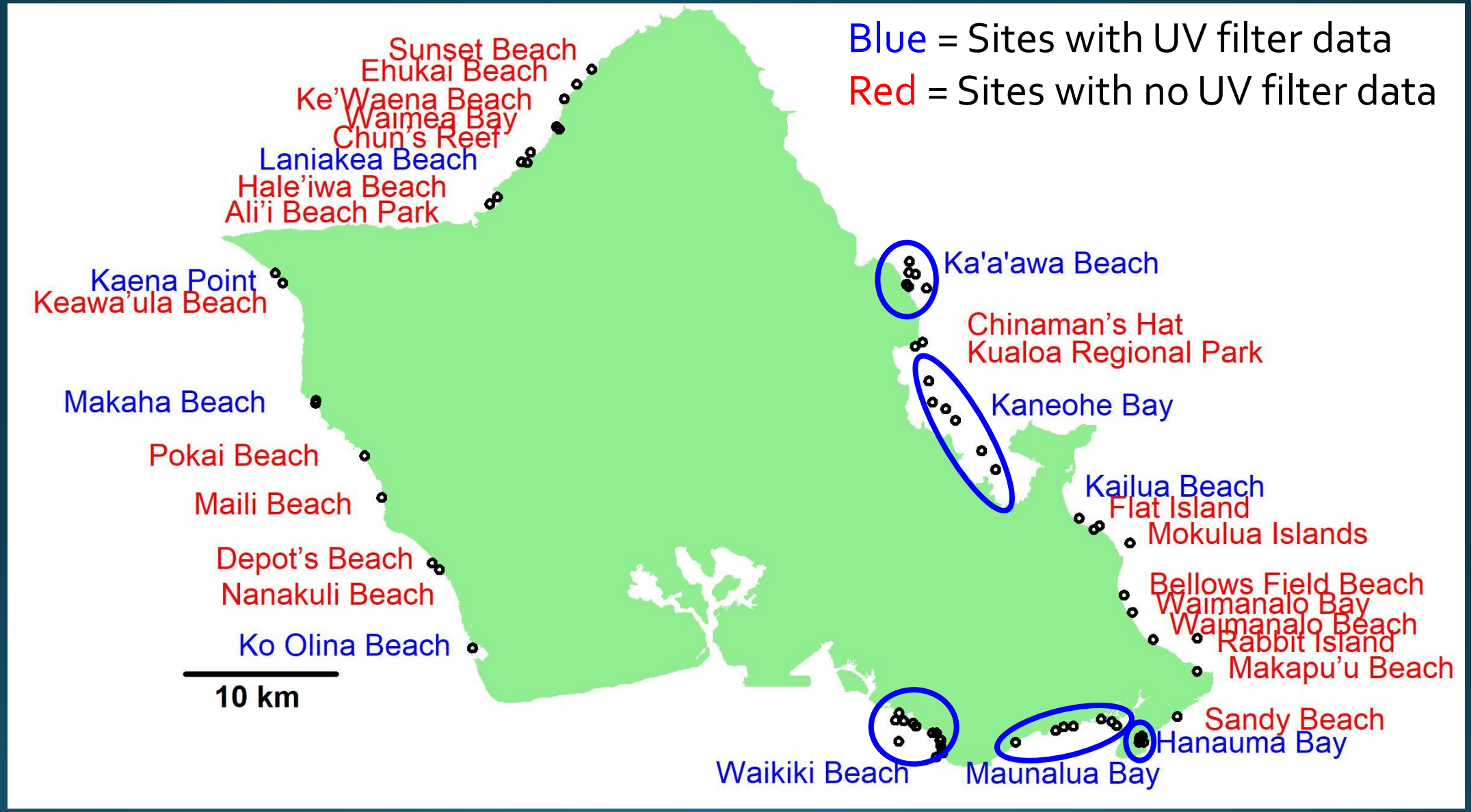
Example: Percent of Fish with Deformities, Fin Erosions, Lesions & Tumors (DELTs) in Ohio streams



Nested hierarchy of potential influences

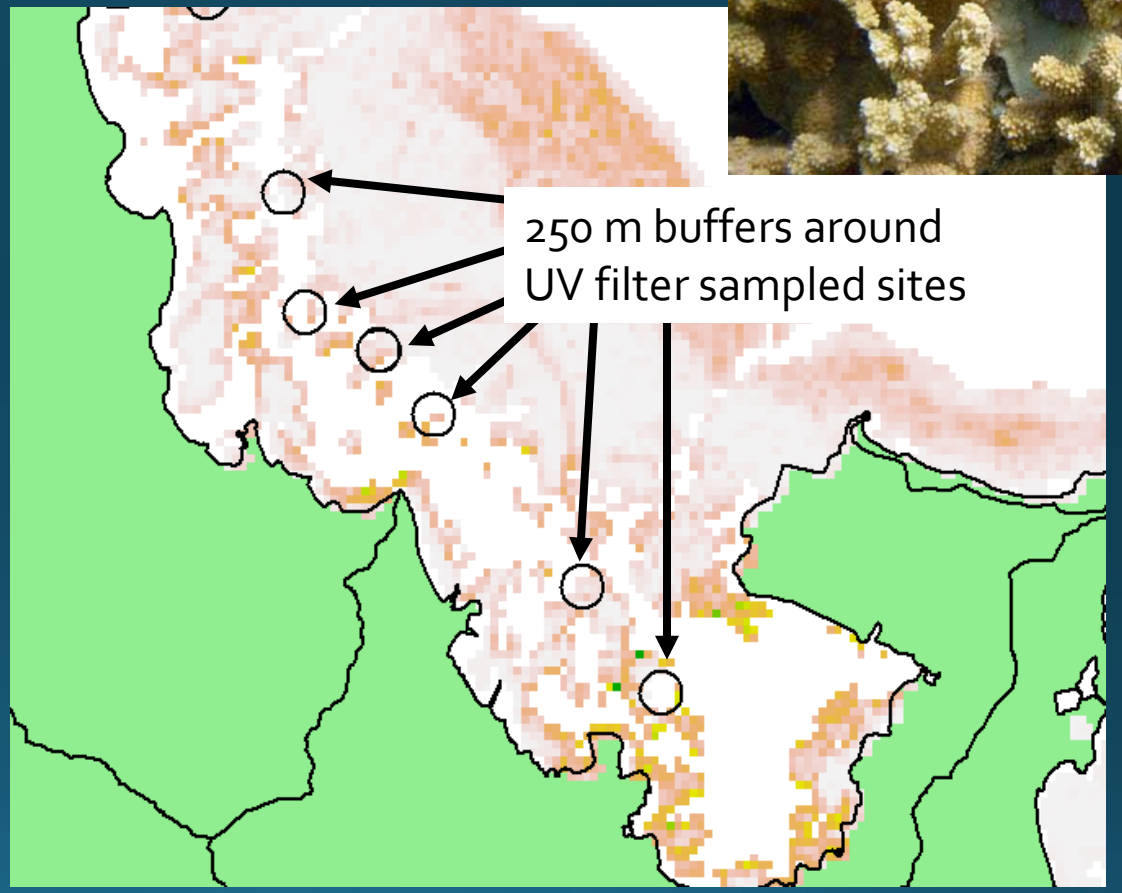


Sites


Blue = Sites with UV filter data
Red = Sites with no UV filter data
Sunset Beach
Ehukai Beach
Ke'Waena Beach
Waimea Bay
Chun's Reef
Laniakea Beach
Hale'iwa Beach
Ali'i Beach Park
Kaena Point
Keawa'ula Beach
Makaha Beach
Pokai Beach
Maili Beach
Depot's Beach
Nanakuli Beach
Ko Olina Beach
10 km
Ka'a'awa Beach
Chinaman's Hat
Kualoa Regional Park
Kaneohe Bay
Kailua Beach
Flat Island
Mokulua Islands
Bellows Field Beach
Waimanalo Bay
Waimanalo Beach
Rabbit Island
Makapu'u Beach
Sandy Beach
Hanauma Bay
Waikiki Beach
Maunalua Bay

Coral data: PacIOOS

- Model-estimated coral cover by 6 species[3] at 50 m raster resolution:
  - Rice coral (*Montipora capitata)*
  - Blue rice coral (*M. flabellata*)
  - Sandpaper rice coral (*M. patula*)
  - Cauliflower coral (*Pocillopora meandrina*)
  - Finger coral (*Porites compressa*)
  - Lobe coral (*Porites lobata*)
- Estimates based on >4000 observations per species for Main Hawaiian Islands
- Principal components analysis (PCA) to synthesize information about multiple species



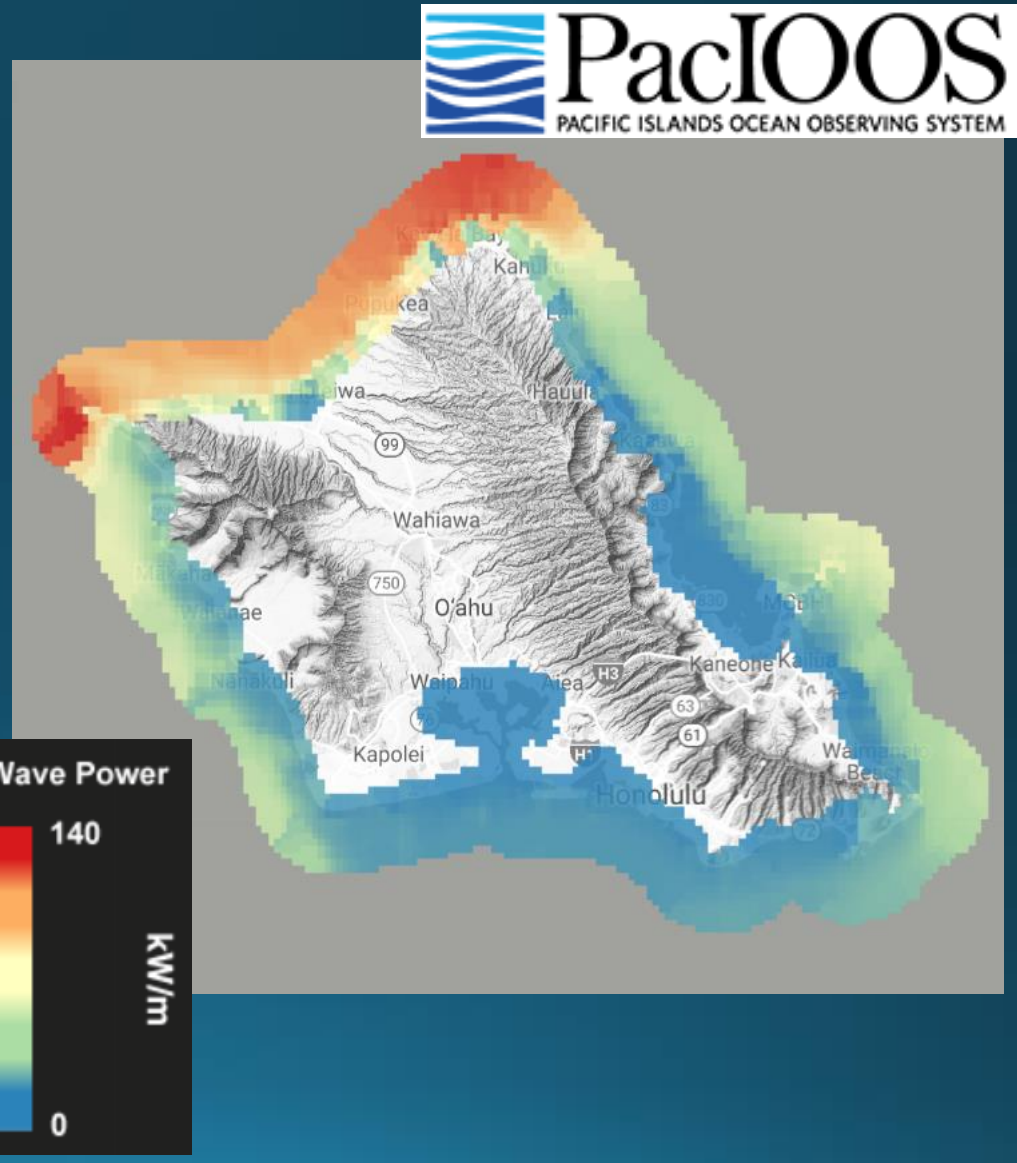
Rice coral (*Montipora capitata*) cover (%) in Kaneohe Bay

[3] Franklin EC, et al. 2013. Marine Ecology Progress Series 481: 121-132

Coral photo: S. Godwin, National Park Service

Methods: Marine environmental data

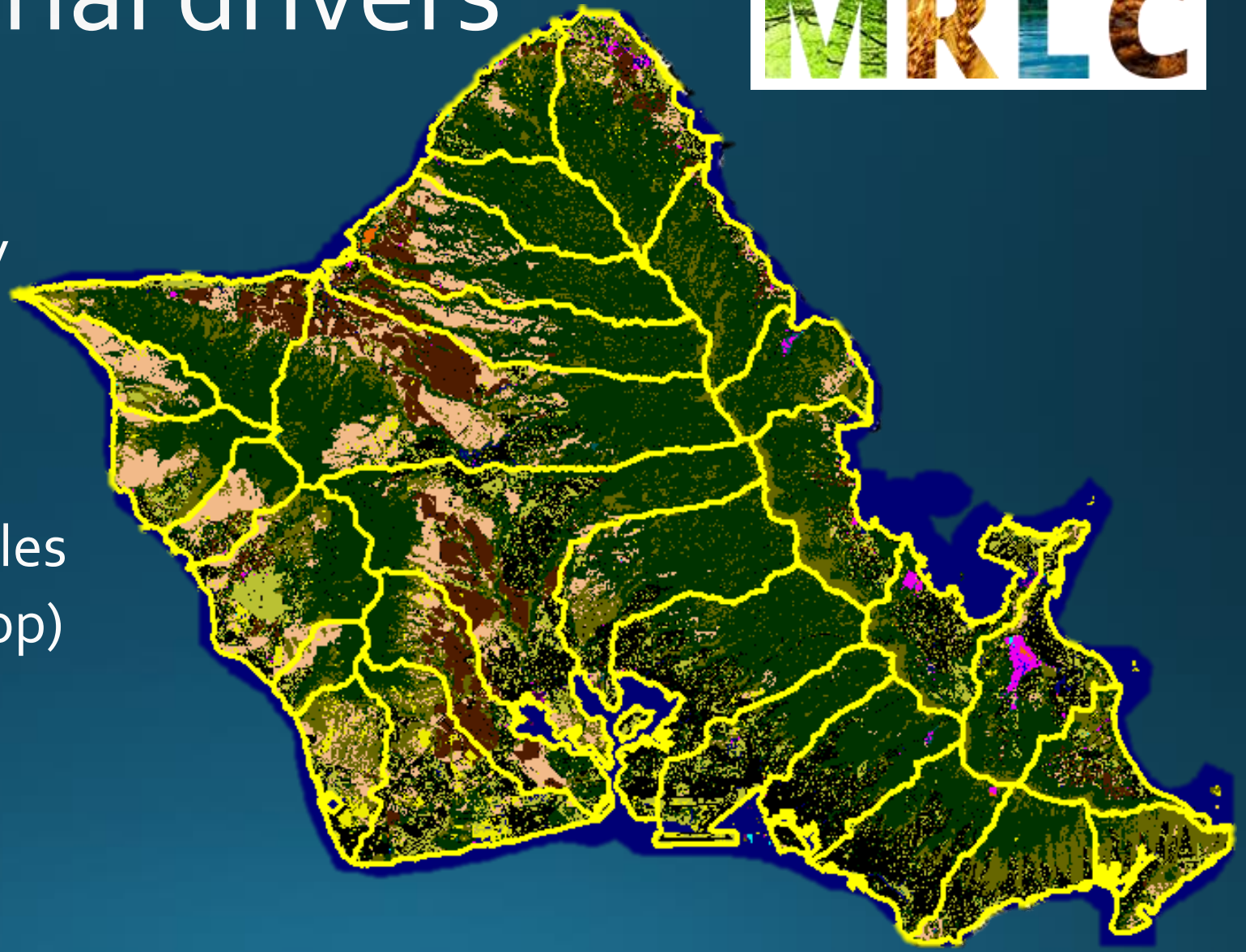
- Estimates of potential drivers of coral reef status[3] based on data covering ≈2000-2013
- Data obtained:
  - Sea surface temperature (°C)
  - Wave power (kW/m)
  - Fisheries catch (ton/ha/yr)
  - Sewage effluent (N, P, total) (g/km²/d) or (gal/km²/d)
  - Sediment export (ton/yr)



[3] Franklin EC, et al. 2013. Marine Ecology Progress Series 481: 121-132

Methods: Terrestrial drivers

- Potential terrestrial drivers related to off-shore sites by nearest USGS HUC12 watershed:
  - Land cover (MRLC); PCA to synthesize numerous variables
  - Population density (WorldPop)
  - Onsite sewage disposal systems (State of Hawai'i)
  - Impervious surface (NLCD)
  - Beach visitation (Honolulu)



Multi-Resolution Land Characteristics Consortium (MRLC) 2011 Hawaii land cover

Methods: Analyses

- Principal Component Analysis (PCA)
  - Coral cover data and land cover data → synthesize & simplify multiple measures of coral status
- Correlation Analysis
  - Screen for surrogate variables that may impact interpretation of Boosted Regression Trees (BRT)
- BRTs
  - Combination of two methods: decision-trees & boosting methods (e.g., machine learning)[4]
  - Advantages[5]:
    - Can use a wide array of response types (binomial, normal, Poisson)
    - Stochastic, which improves predictive performance
    - Robust to missing values and outliers
    - Model represents the effect of each predictor after accounting for the effects of other predictors

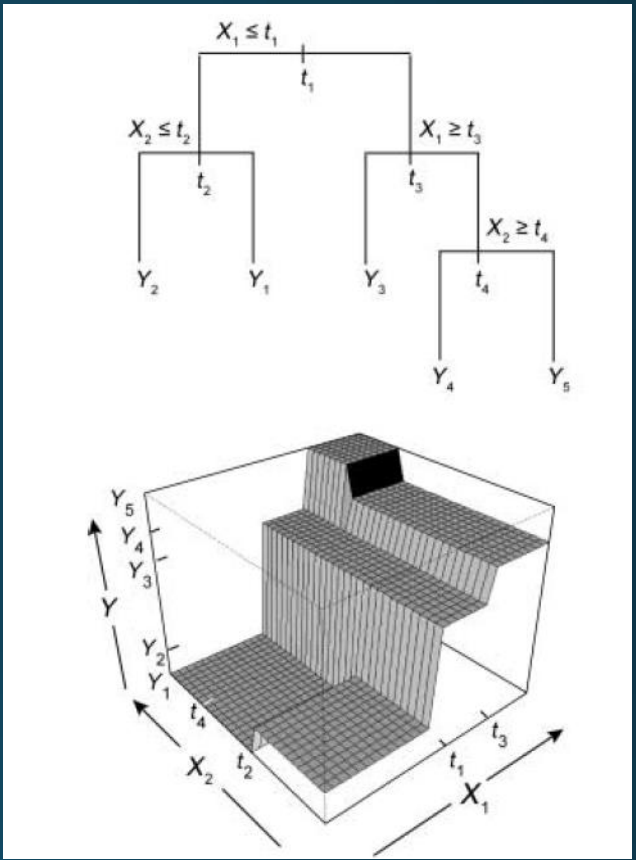


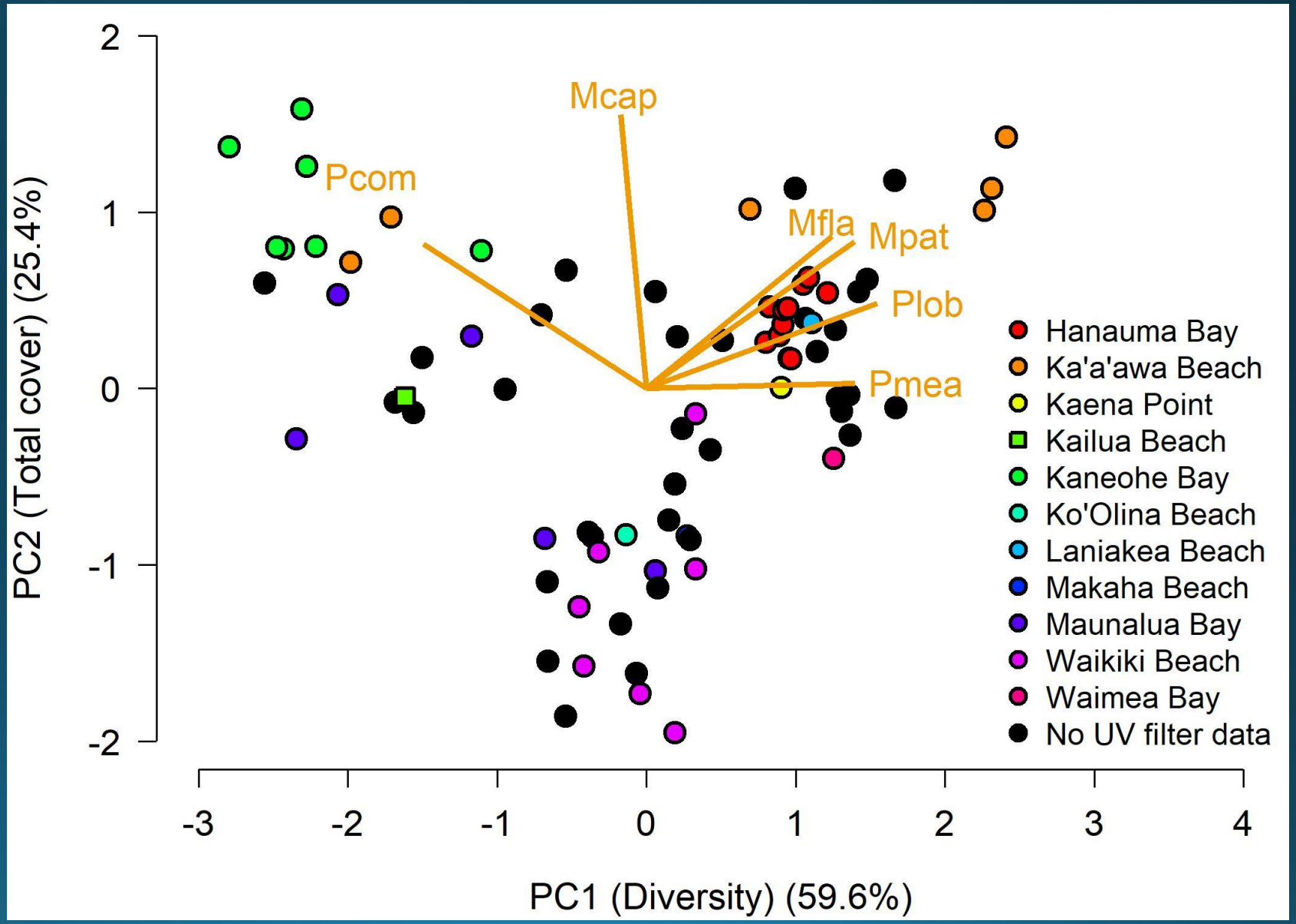
Image: Elith et al. (2008). Journal of Animal Ecology 77: 802-813, Fig. 1

[4] Elith J, Leathwick JR, Hastie T. 2008. A working guide to boosted regression trees. Journal of Animal Ecology, 77: 802-813. DOI: https://doi.org/10.1111/j.1365-2656.2008.01390.x

[5] https://support.bccvl.org.au/support/solutions/articles/6000083202-boosted-regression-tree#header-page5

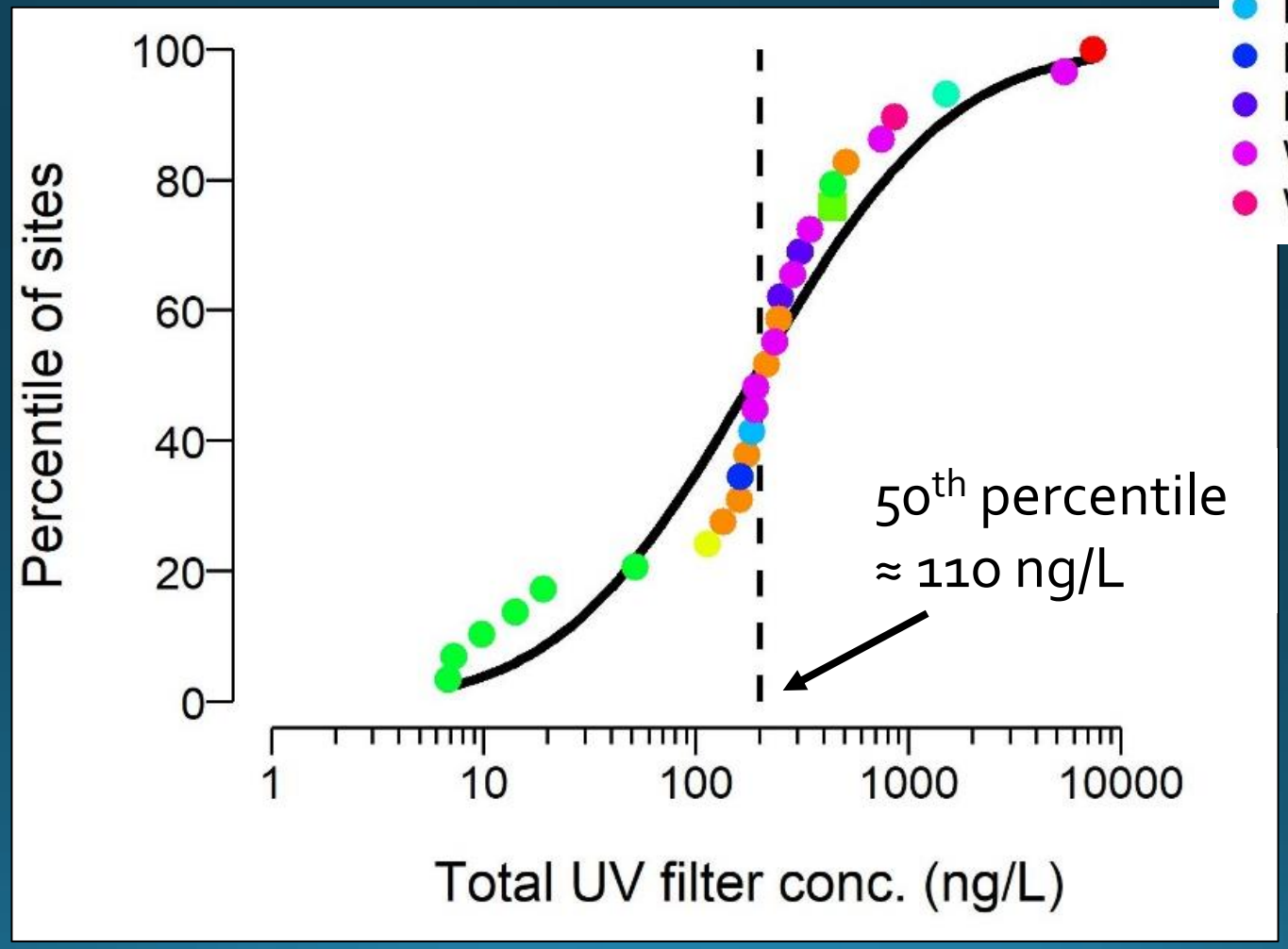
Results: Coral data

- Two PCs explain ~85% of variation in coral cover
- PC1 represents a diversity gradient
- PC2 represents an abundance gradient
- Coral PC1 and PC2 used as *response variables* in subsequent statistical analysis

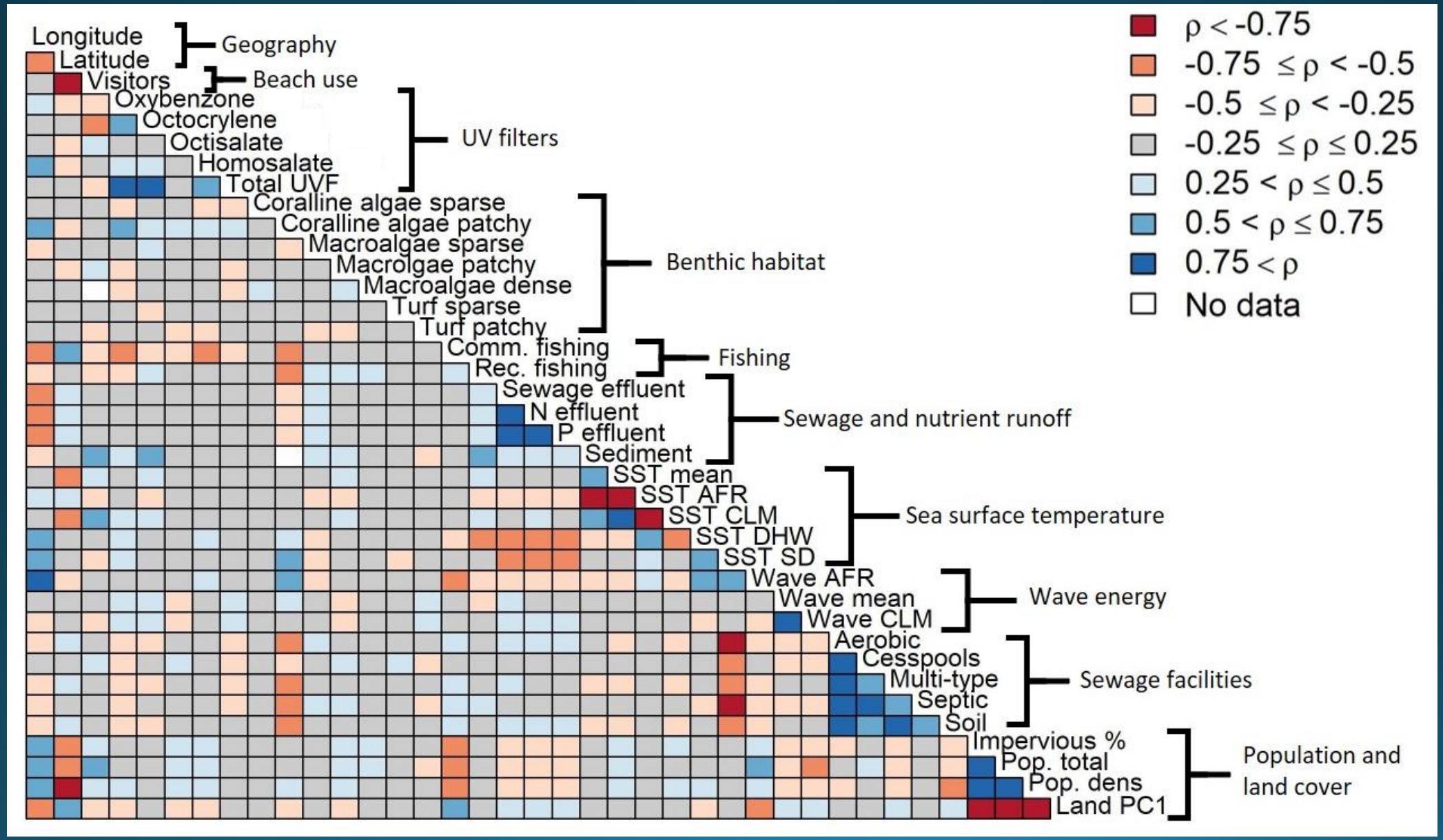


Results: UV filter concentrations

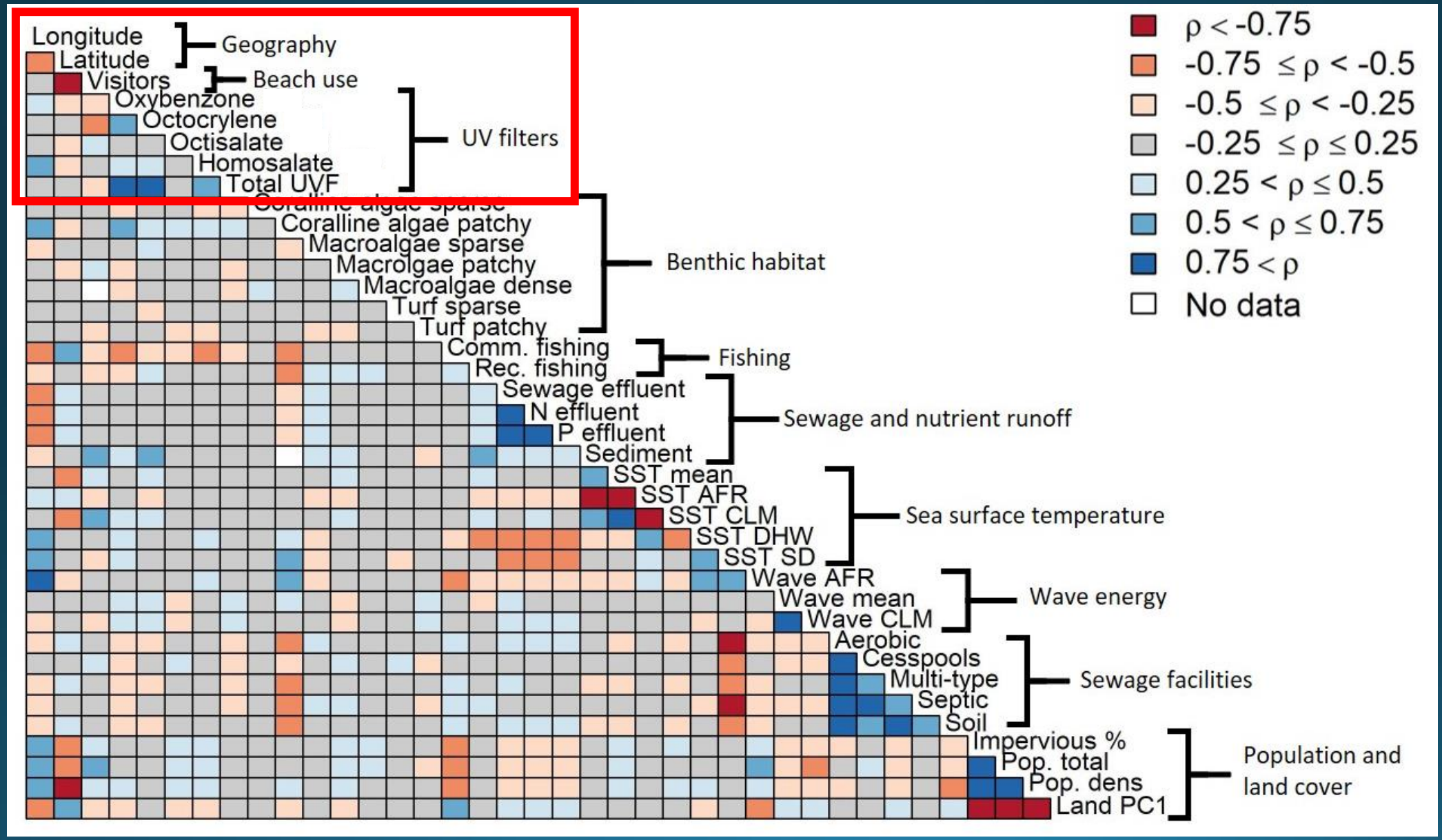
- Total UV concentrations ranged over 3 orders of magnitude



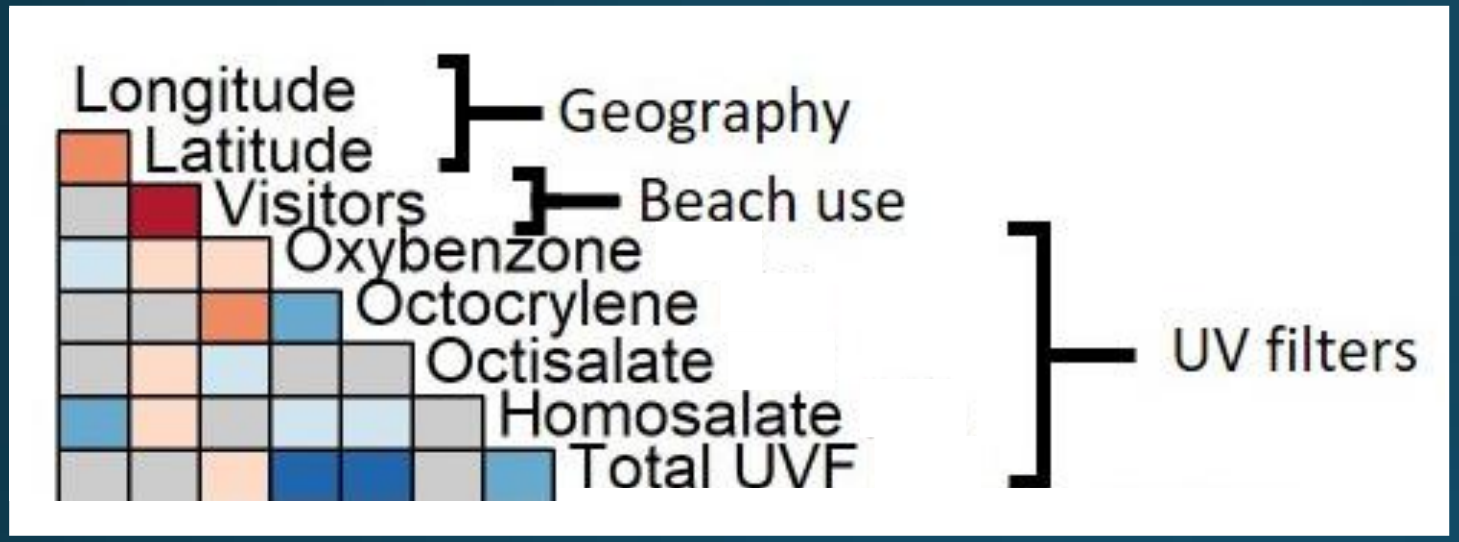
Results: Correlations of Indep. Variables

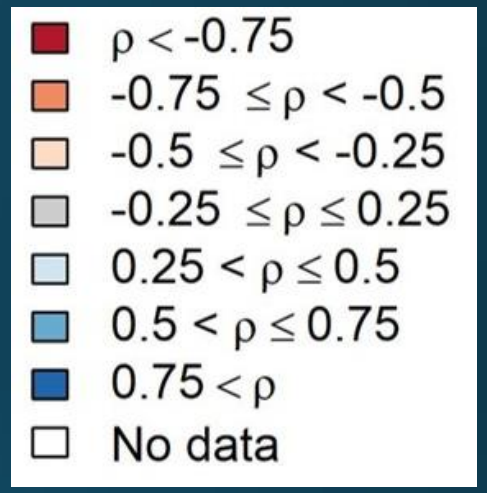


Results: Correlations of Indep. Variables



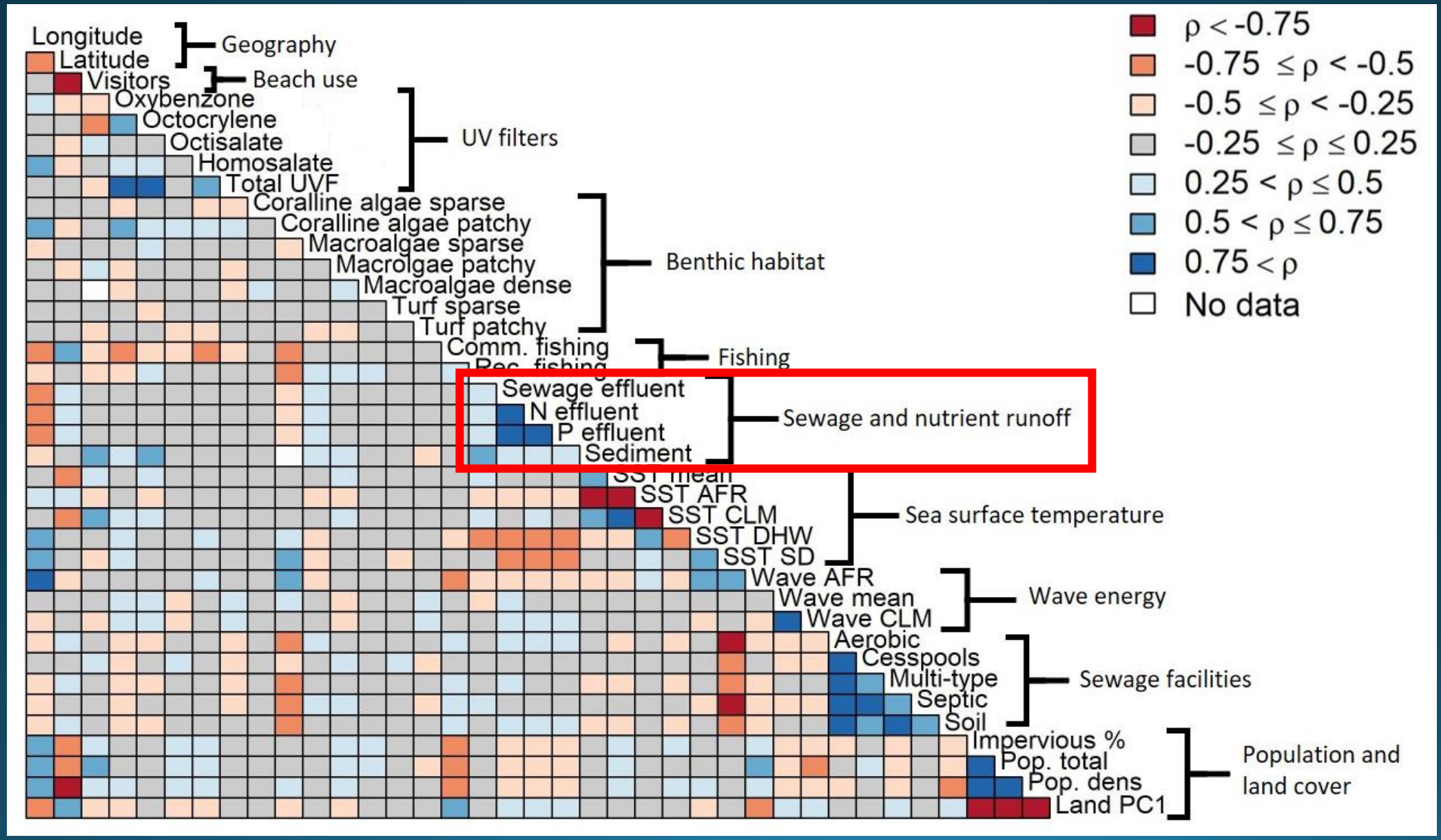
Results: Correlations – UV Filter Focus





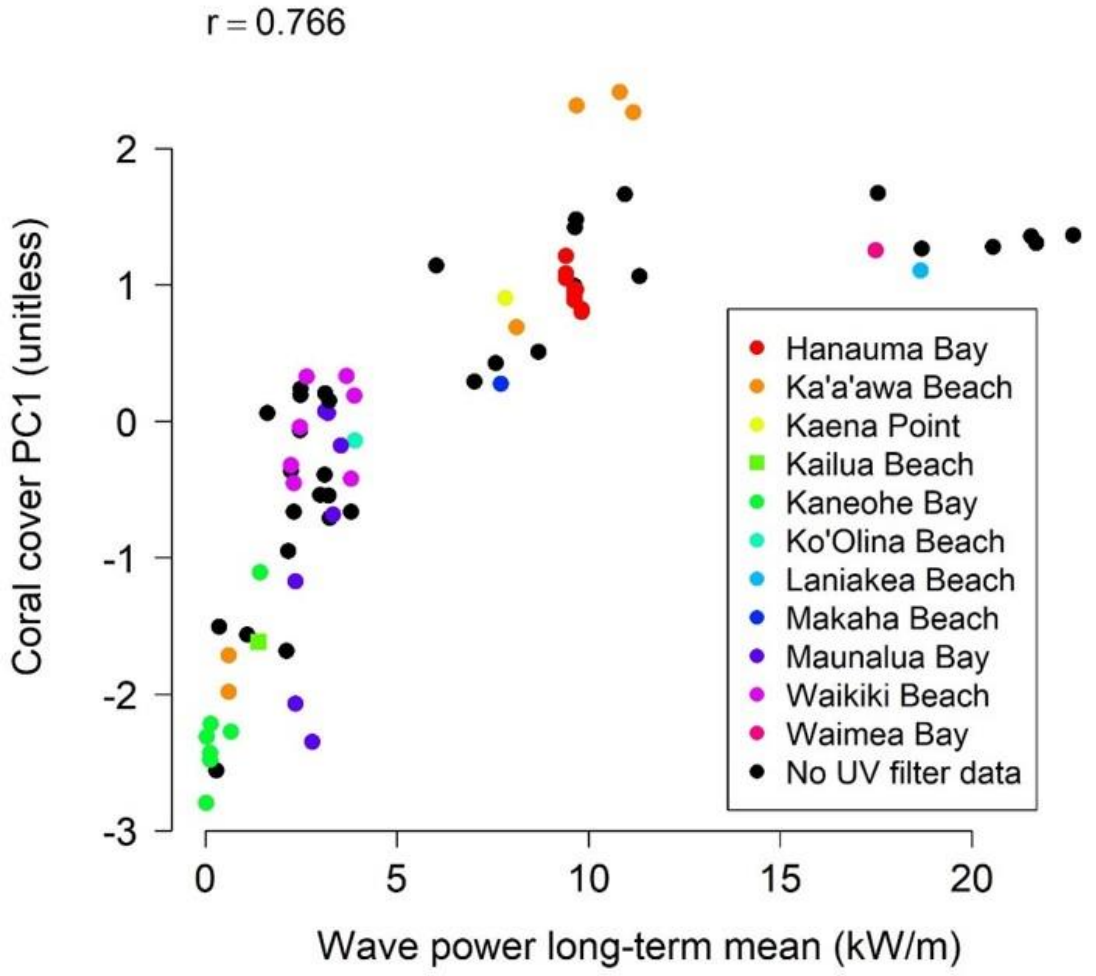
- Visitation and latitude strongly negatively correlated
  - Lower latitudes = urbanized/major tourist areas
- Visitation and UV Filters: inconsistent and counter-intuitive correlations
  - Indicates more work is needed on Visitation data
- UV filters generally positively correlated with each other

Results: Correlations – Sewage Focus



Results: Correlates of Coral Diversity (PC1)

More diversity

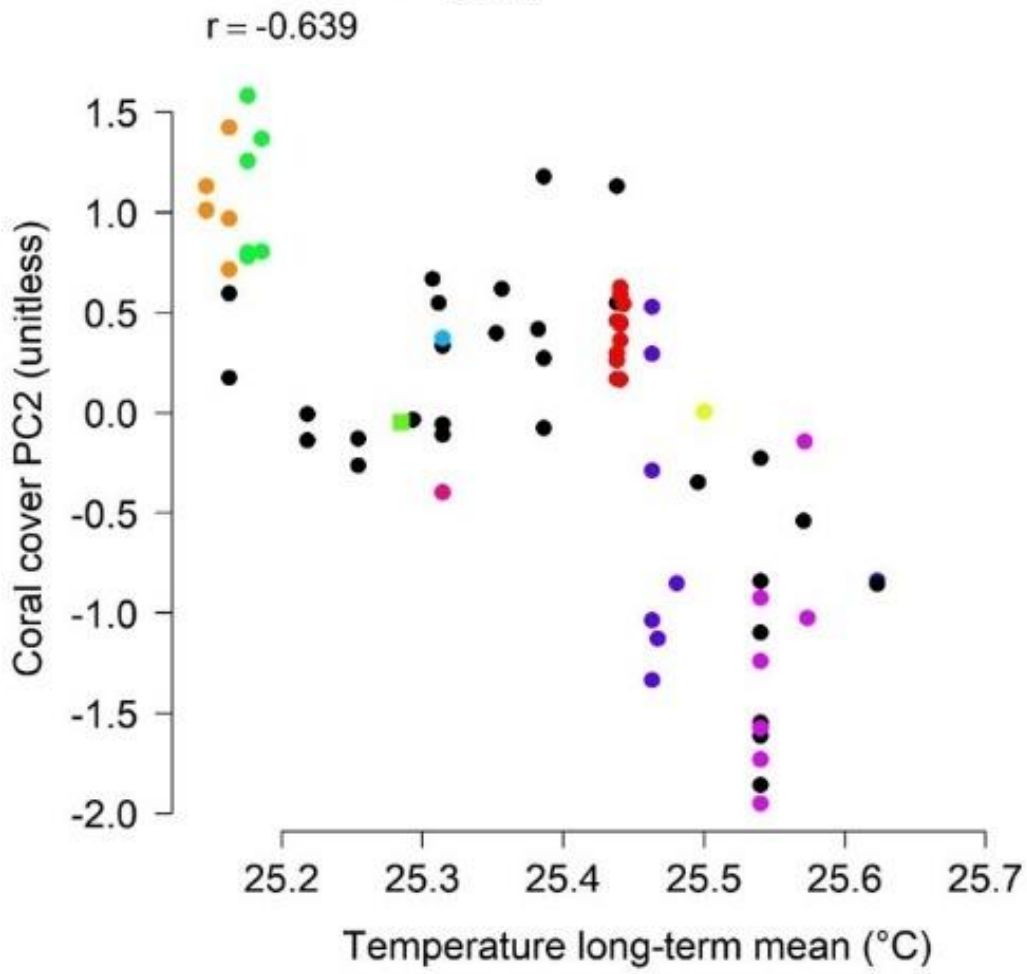


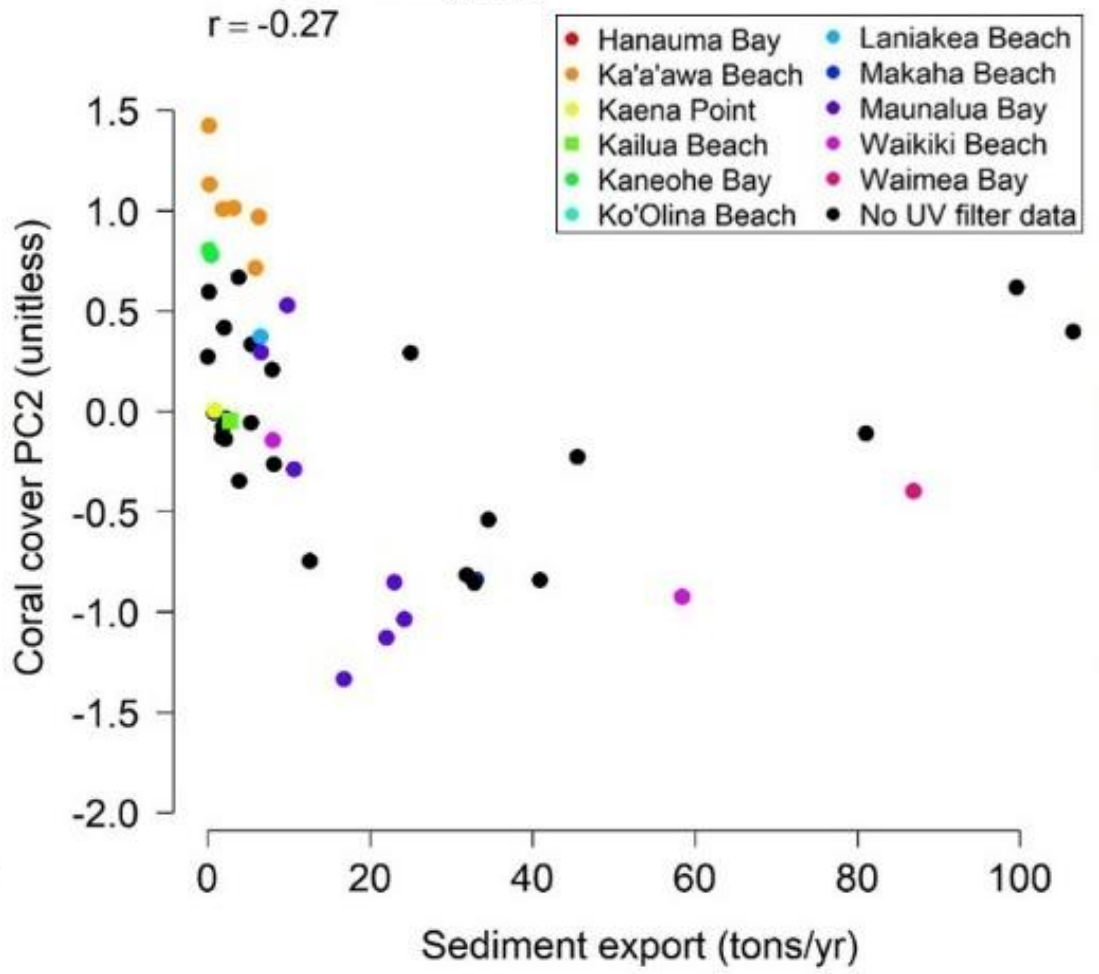
Less diversity

Results: Correlates of Coral Cover (PC2)

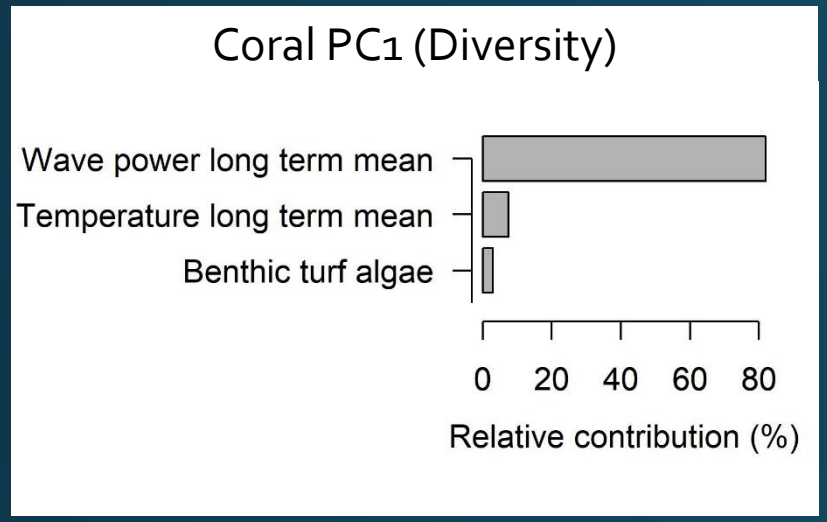
More total cover

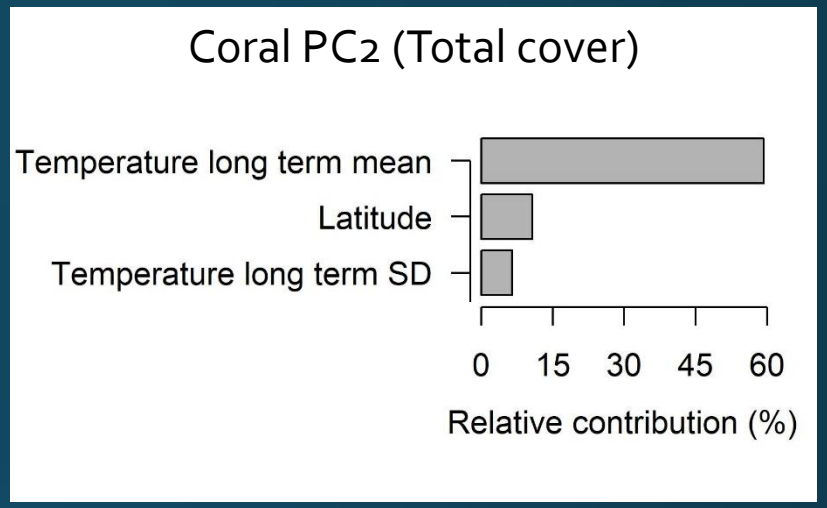
Less total cover





Results: Variable Importance in BRTs





- Wave power, Temperature (long-term mean) and Benthic Turf Algae addressed nearly 90% of the variance in the BRT model
- Remaining 10% included (listed alphabetically)

Beach Visits
Benthic Macroalgae
Commercial Fishing Harvest
HUC 12 Cesspool Systems
HUC 12 Population Density
Land Cover
Longitude, Latitude
Oxybenzone
Recreational Fishing Harvest
Sediment Export
Temp Long-Term SD
Total Sewage Effluent
Total UV Filters

- Temperature (long-term mean), Latitude (i.e., North-South) and Temperature (long-term SD) addressed about 75% of the variance of the BRT model
- Remaining 25% included (listed alphabetically) :

Beach Visits
Benthic Macroalgae
Commercial Fishing Harvest
HUC 12 Cesspool Systems
HUC 12 Population Density
Land Cover
Longitude
Oxybenzone
Sediment Export
Total Sewage Effluent
Total UV Filters
Wave Power (long-term mean)

Discussion

- UV filter concentrations covered a wide range of values across sites
- Conceptually, there was a sufficient range of UV filters to assess their relative importance to coral diversity & cover
- Estimated coral cover and diversity mostly driven by sea temperature, wave power, geography

Hanauma Bay, Oahu

Photo: https://hanaumabaystatepark.com

Conclusions

- Based on the eco-epidemiological analysis, UV filters were not a key driver of coral ecological status
  - Doesn't support effectiveness of highly restrictive regulatory actions
- Needs
  - More UV filter monitoring data needed to confirm the relative importance to coral community status
  - Update coral cover dataset
  - Update Visitation data

Coral photo: NOAA

Acknowledgements

- **Study sponsor:** Personal Care Products Council (PCPC)
- **Collaborators:** C. Holmes (Applied Analysis Solutions), G. Hoogeweg (Waterborne Environmental, Inc.)
- **Science advisors:** S. Raimondo (USEPA); C. Mitchelmore (U. Maryland); I. Davies, E. Burns (PCPC)
- **Data and assistance:** S. Enright, City and County of Honolulu

Thank You

https://www.earth.com/news/resilient-coral-reefs-north/