How Tourism Shapes Hawaiʻi's Coastal Waters

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Abstract

This study investigates whether fluctuations in monthly visitor numbers influence coastal water quality in South Oahu. Focusing on chlorophyll, turbidity, and enterococcus levels, this analysis draws conclusions between water-quality measures by deploying time-series analysis and an autoregressive integrated moving average (ARIMA) model. The results indicate visitors are not a significant predictor of water quality.

Background

Chlorophyll measures the amount of algal blooms and cyanobacteria in the water whereas Turbidity measures the water's clarity. Enterococcus is a type of fecal indicator bacteria, signalling fecal contamination in ocean water. SARIMAX is a type of ARIMA model that examines seasonal trends while accounting for various exogenous variables. SARIMAX specifically accounts for seasonality, which are cyclical patterns in data. This can reflect predicted trends such as environmental cycles, spikes in tourism, and biological processes.

Research Question

How do fluctuations in visitor numbers influence Hawaii's coastal water quality over time?

Methods, Data, and Programs

- Data was collected from both a NOAA water sensor and by the Blue Water Task Force in South Oahu
- Cleaned and visualized data via Jupyter Notebook through the TACC Supercomputer
- Graphed correlation matrix to quantify how visitor numbers relate to each water-quality variable
- Created regression plots to visualize how visitor numbers relate to turbidity, chlorophyll, and enterococcus levels
- Deployed a SARIMAX time-series model to account for trends, seasonality, and autocorrelation

Results & Visuals

	N	Mean	Std	Range
Visitors	89	399317.179775	156183.048011	595385.000000
Water Temperature (degF)	90	79.793254	1.908892	8.296642
Salinity (PSU)	90	33.009835	0.788929	3.639467
Turbidity (NTU)	88	6.670479	9.881740	48.014862
Chlorophyll (ug/L)	88	3.210614	1.893409	12.208972
Enterococcus (mpn/100mL)	73	155.372146	334.566434	1958.000000

Fig.1 Descriptive statistics summarizing sample size/variability
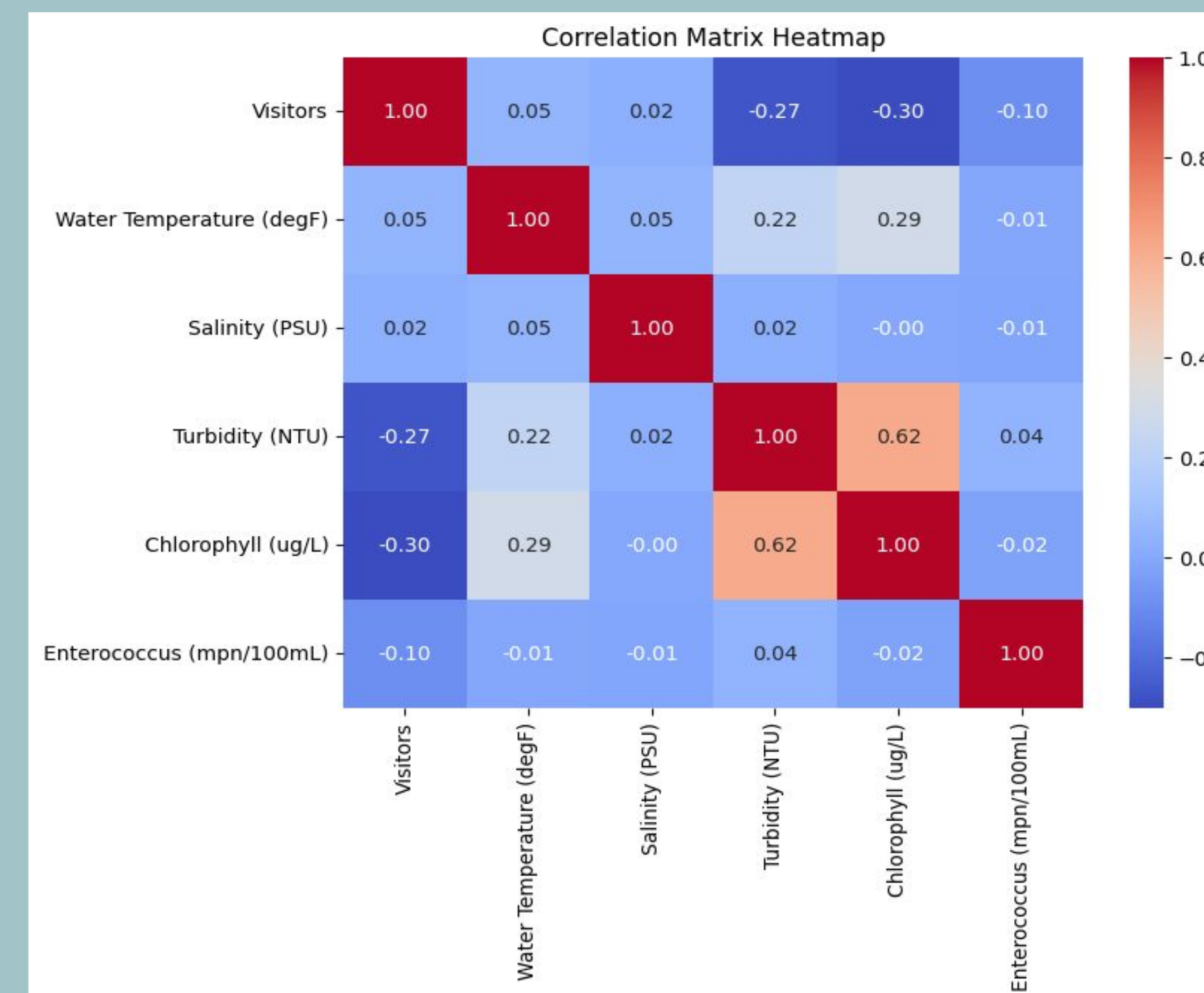

Fig. 2 Correlation matrix comparing visitor and water quality data
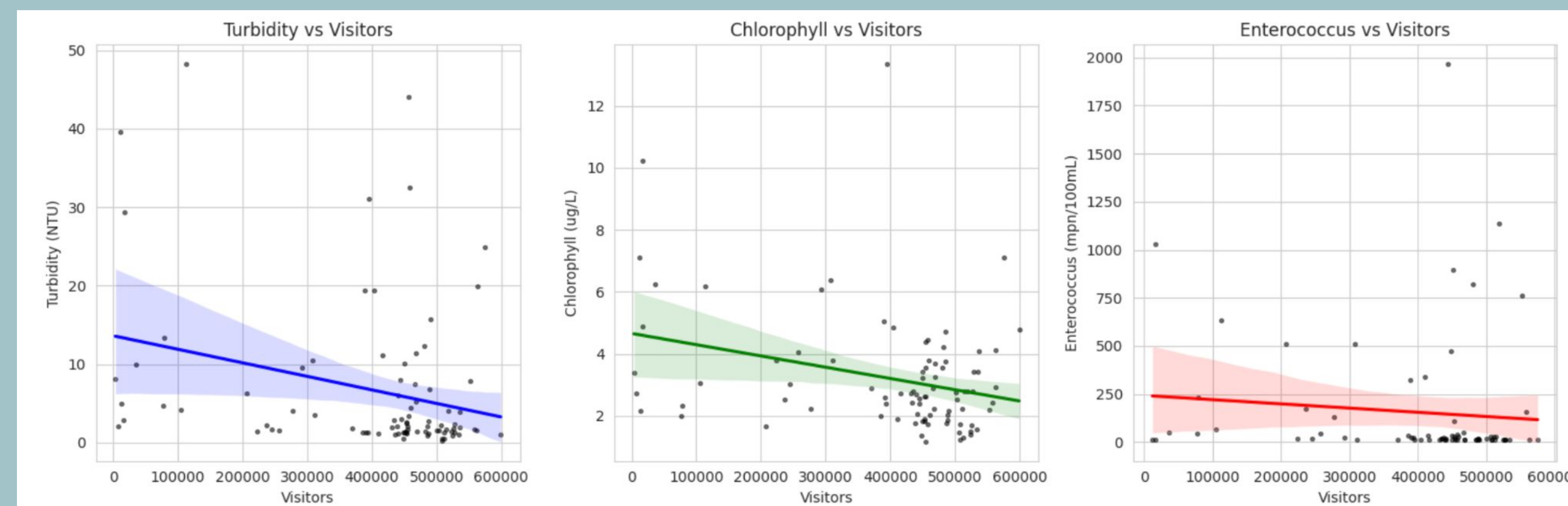

Fig. 3 Regression plots illustrating the relationships between visitors and two water-quality indicators (Turbidity and Chlorophyll)

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                              SARIMAX Results
==============================================================================
Dep. Variable:               Turbidity (NTU)   No. Observations:           87
Model:             SARIMAX(1, 1, 1)x(1, 1, 1, 12)   Log Likelihood       -239.206
Date:                    Thu, 04 Dec 2025   AIC                     490.412
Time:                            15:18:29   BIC                     502.978
Sample:                                 0   HQIC                    495.327
                                     - 87
Covariance Type:                      opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
Visitors     -3.097e-06   2.09e-05     -0.148      0.882   -4.41e-05    3.79e-05
ar.L1           0.1839      0.276      0.667      0.504      -0.356       0.724
ma.L1          -0.6461      0.242     -2.673      0.008      -1.120      -0.172
ar.S.L12        0.0715      0.279      0.256      0.798      -0.475       0.617
ma.S.L12       -0.2278      0.364     -0.627      0.531      -0.940       0.485
sigma2        192.1950     35.595      5.400      0.000     122.430     261.960
==============================================================================
Ljung-Box (L1) (Q):                   0.06   Jarque-Bera (JB):         6.90
Prob(Q):                              0.81   Prob(JB):                 0.03
Heteroskedasticity (H):               0.07   Skew:                     0.27
Prob(H) (two-sided):                  0.00   Kurtosis:                 4.57
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Fig.4 SARIMAX Analysis

Discussion & Limitations

- Fig.1: Presents the sample size, average values, variability, and the range. Enterococcus levels can be found to be unstable and spike dramatically.
- Fig.2: Shows a weak relationship between visitors and all water-quality indicators in the data, with the strongest association found between turbidity and chlorophyll.
- Fig.3: Plots the relationship between the selected three indicators (Chlorophyll, Turbidity, and Enterococcus). Chlorophyll and Turbidity are shown to have slight, negligible correlation. Enterococcus did not have any correlation.
- Fig.4: Showcases the results of the SARIMAX model. Visitors do NOT significantly affect turbidity (along with chlorophyll and enterococcus levels) even when accounting for seasonality. Even with extreme fluctuations, there was no significant effect on the quality of water.
- Limitations include a lack in consistent and detailed data in all aspects.

Conclusion & Future Works

While there was a slight correlation, overall, an increased amount of visitors was not shown to influence water quality in South Oahu. This is likely because many of these factors are strongly dependent on cyclical patterns in nature, such as rainfall and wind among other factors. Next steps could include testing other sensors around the island to compare and contrast results.

References

Berg, C. J., Alderete, J. P., & Alderete, E. A. (2023). Human wastewater tracking in tropical Hawaiian island streams using qualitative and quantitative assessments of combined fecal indicating bacteria and sucralose, an organic micropollutant of emerging concern. Environmental Monitoring and Assessment, 195, 966.

CNN. (2022, August 18). How Hawaiʻi's tourism boom affects islands' future. CNN. https://www.cnn.com/2022/08/18/us/hawaii-tourism-impact-united-shades-cec

Gazta, K. (2018). Environmental impact of tourism. AGU International Journal of Professional Studies & Research, 6(6), 7-17.

Luxury Yacht Owner to Pay $100,000 for Coral Damage. (2020, September 2). Maui Now. https://mauinow.com/2020/09/02/luxury-yacht-owner-to-pay-100000-for-coral-damage

National Oceanic and Atmospheric Administration. (2014, October 28). NOAA removes 57 tons of marine debris from Northwestern Hawaiian Islands. https://www.noaa.gov/media-release/noaa-removes-57-tons-of-marine-debris-from-northwestern-hawaiian-islands

Pacific Islands Ocean Observing System. (n.d.). Hawaiʻi Yacht Club nearshore sensor observations. https://www.pacioos.hawaii.edu/water/sensor-hawaiiyachtclub

State of Hawaii, Department of Business, Economic Development & Tourism. (n.d.). Tourism data warehouse. https://dbedt.hawaii.gov/visitor/tourismdata

Surfrider Foundation. (n.d.). Blue Water Task Force: Oʻahu water quality monitoring. https://oahu.surfrider.org/bwtf

Wiener, C. S., Needham, M. D., & Wilkinson, P. F. (2009). Hawaiʻi's real life marine park: Interpretation and impacts of commercial marine tourism in the Hawaiian Islands. Current Issues in Tourism, 12(5–6), 489–504.