Implementation of an ROV to test a predictive model relating bioluminescence perception and abiotic factors in Mosquito Bay, Vieques

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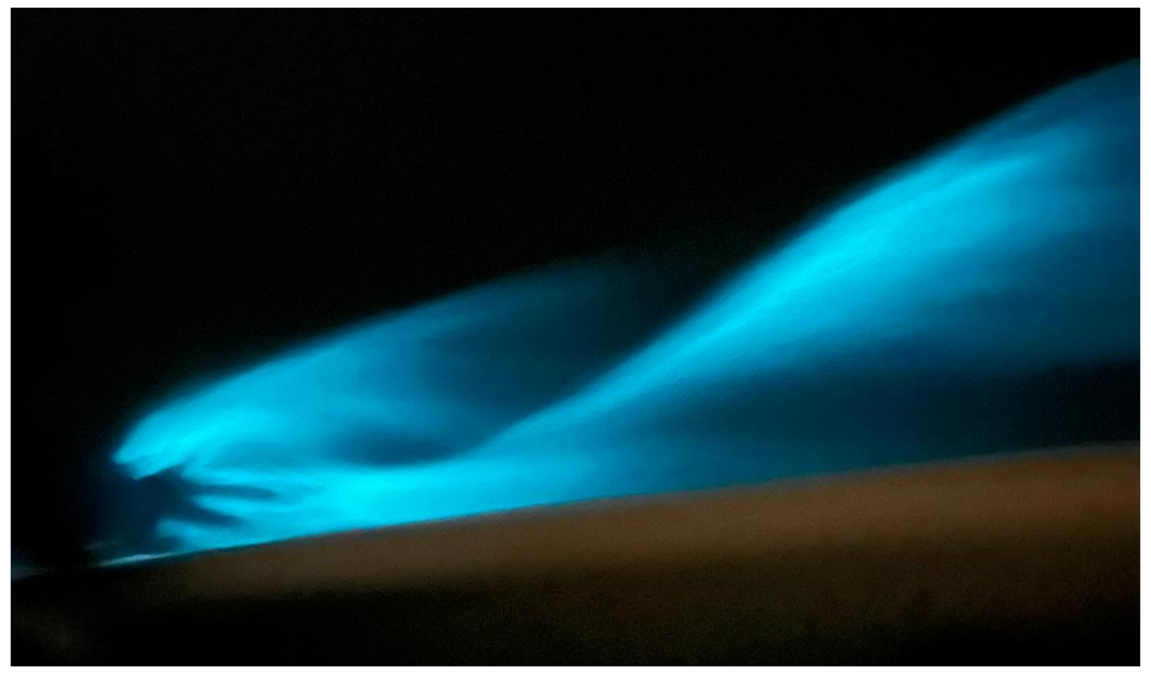
Abstract

Mosquito Bay, located in Vieques (an island from the Puerto Rican archipelago), is the brightest bioluminescent bay in the world, thanks to its populations of the dinoflagellate *Pyrodinium bahamense*. Although it displays bioluminescence year-round, its intensity varies as several factors affect *Pyrodinium* abundance. To help identify these, the Vieques Conservation & Historical Trust shared a data set collected in the bay since 2014. The dates of the three annual maximum and minimum dinoflagellate populations from July 2019 to June 2024, in three different stations across the bay, were selected as the study's sample. Scales from 1 (minimum) to 10 (maximum) were then created to represent each of the variables studied. The probability that each individual factor, at each level of its scale, would cause a spike in *P. bahamense* was calculated. Different relationships were found; lower monthly precipitation and higher salinity helped *Pyrodinium* reproduce more quickly. Local temperature and winds did not significantly affect the populations. Some additional variables which affect our perception of bioluminescence were considered; a moonless and cloudless sky is favorable to appreciate the bay's glow. Bringing all this together, an empirical model was created to predict bioluminescence perceptibility at Mosquito Bay. Finally, two visits to the bay were made to test the model, collecting samples with our research ROV. In the future, it could help scientists study the area and tourists decide their visit dates.



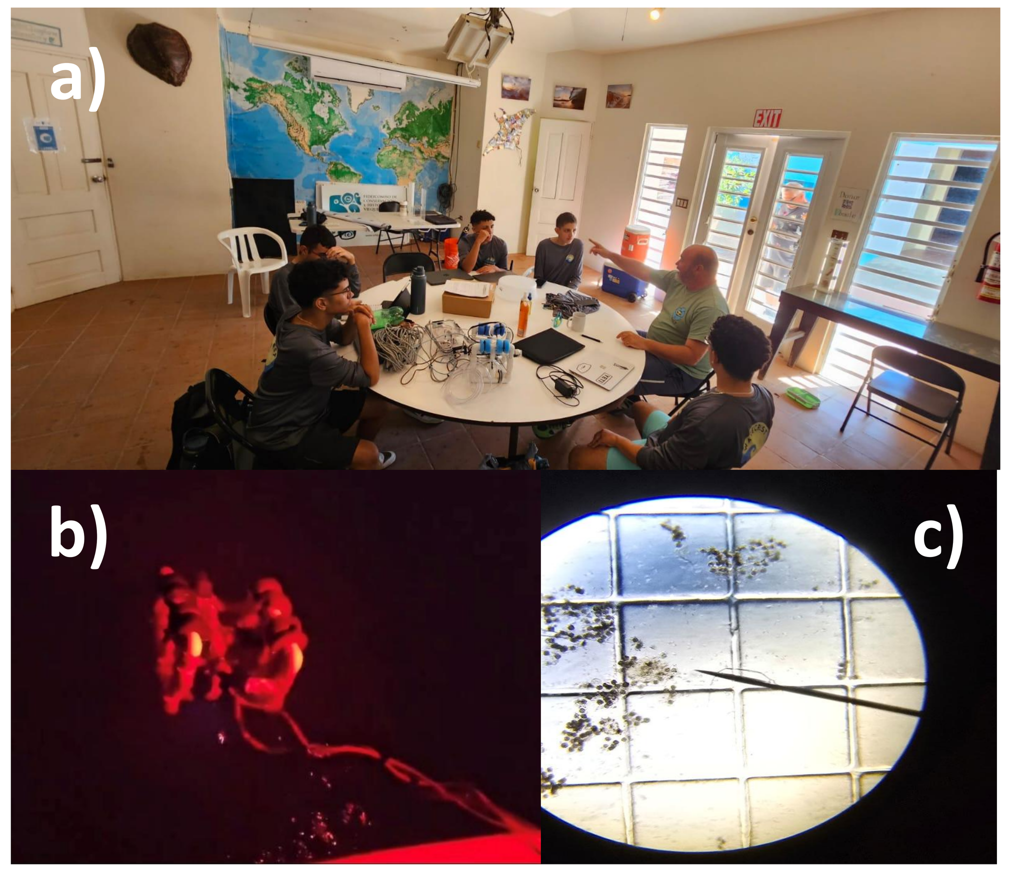
Bioluminescence display in Mosquito Bay, caused by the hand of one of Wavecrest's team members activating the dinoflagellates' defense mechanism.

Background & Motivation

- Bioluminescent bays are bodies of water where water glows because of large populations of the dinoflagellate *Pyrodinium bahamense*. Mosquito Bay, located in Vieques, Puerto Rico, is the brightest in the world, and attracts many tourists.
- *Pyrodinium* populations oscillate depending on various abiotic factors, such as precipitation, affecting bioluminescence. Wavecrest decided to study them to try and predict bioluminescence.
- This research would help visitors decide which nights to go and would benefit the island economically and socially by attracting even more people to these areas.
- Additionally, this research would be one of the few that help scientists understand the nature of bioluminescent bays and the dinoflagellate *P. bahamense*.
- It has been found some chemical substances, such as insect repellents, damage the dinoflagellates in the water. Remotely operated vehicles (ROVs) could be used to get water samples from the bay, without significantly altering them.

Methodology

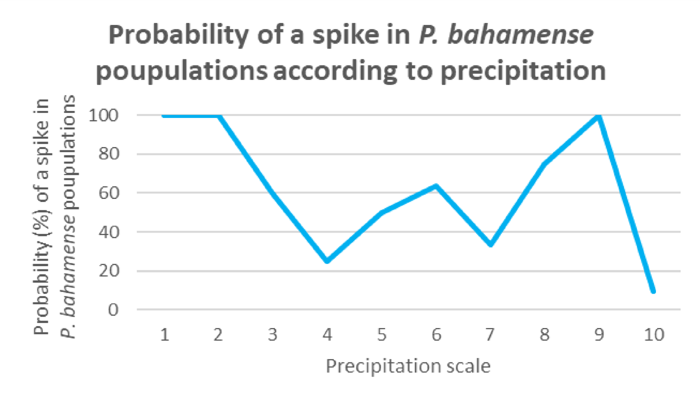
- Prior to field and laboratory research, abiotic factors recorded during three annual maximum and minimum *P. bahamense* population dates, in three different points across the bay, during the last 5 years, were analyzed.
- A scale of 1 (least) to 10 (most) was created for each variable to facilitate the analysis process.
- To finalize the analysis, patterns were sought between abiotic factors and bioluminescence on the selected dates, and an empirical model was created.
- To test the model, two visits to the bay were made: one in November and one in January.
- Sampling took place between 7:00 p. m. and midnight. The intention was for moonlight not to interfere with the perception of bioluminescence.
- Temperature and salinity were measured with a multi-parameter sonde.
- Two samples, one collected manually and the other with our ROV, were taken from each of three different points in Mosquito Bay:
  - Point 1: Eastern part of the bay.
  - Point 2: Deepest point, center of the bay.
  - Point 3: Southern part of the bay.
- ROV samples were taken at a depth of 0.3 meters using a small water pump to deliver it via a plastic tube to the boat. Manual samples were taken using graduated cylinders. Whether collected manually or by ROV, samples had an original volume of 5 liters.
- Each sample was filtered through a 25 µm mesh, to catch *P. bahamense*. Then, the pump was used to wash away the dinoflagellates with filtered water and collect them in glass bottles.
- The samples in the glass bottles were composed of approximately 47.5 mL of saltwater (with microorganisms) and 2.5 mL of Lugol's iodine, a preservative.
- The Sedgwick-Rafter method involves using a compound microscope to count the dinoflagellates in a special gridded slide with 1 mL capacity. The Wavecrest Robotics team used this method.
- The Utermöhl method is based on the sedimentation of a water sample and counting of the dinoflagellates in the bottom using an inverted microscope. The Vieques Conservation & Historical Trust used this method.
- Monthly precipitation, wind, and tide data for the day of the visit were collected from local weather stations.
- Microsoft Excel was used to analyze all collected data.



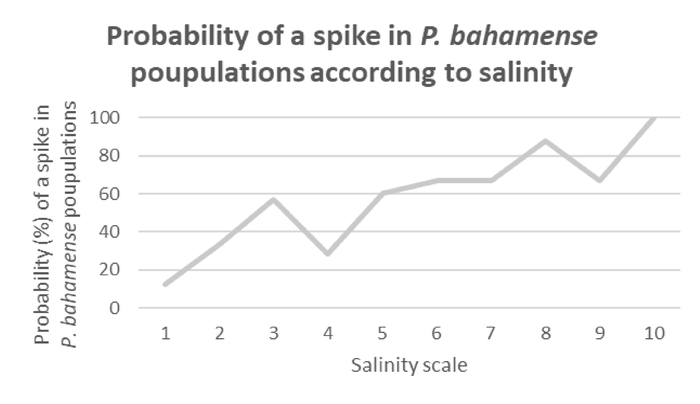
a) Meeting between the Wavecrest Robotics team and Mark Martin, who helped us plan for our trip and provided us with equipment and a boat.
b) Wavecrest's ROV submerged in Mosquito Bay's waters, collecting samples.
c) Preserved P. bahamense from the ROV's sample in a Sedgwick-Rafter cell under a light microscope's 5x lens.

Results & Discussion

- We found a 2 on the monthly precipitation scale means there is a 99.99% probability of a spike in *P. bahamense* populations. On the other hand, a 10 has a 9.52% probability of causing a spike.
- Influenced by the above precipitation, salinity had a generally positive correlation with *P. bahamense* populations.
- Local winds and temperatures did not significantly affect *P. bahamense* populations.
- To better perceive bioluminescence, there must be high *Pyrodinium* populations and reduced light pollution; it is best to visit the bay on a moonless, cloudless night. However, if there is moonlight, it is preferable to have a cloud-covered sky to block it.
- As for the dinoflagellate count on January 22, 2025, Point 2 had the highest populations, followed by Point 1. Point 3 had a surprisingly low *P. bahamense* count.
- The Vieques Conservation & Historical Trust's counts were significantly higher than ours. This was probably due to the differences in counting methodology.
- ROV samples looked cleaner than manually collected samples, making *P. bahamense* easier to identify without having to search through sediment accumulations. Also, ROV samples had more *P. bahamense* clusters.
- In Point 1, ROV samples had a higher count, probably due to the ROV submerging more than it was supposed to.
- In Point 2, manually collected samples had a higher count.
- In Point 3, ROV and manual samples had similar counts.



Monthly Precipitation (in inches)		
1	0.00	0.56
2	0.57	1.39
3	1.40	2.23
4	2.24	3.06
5	3.07	3.90
6	3.91	4.73
7	4.74	5.57
8	5.58	6.40
9	6.41	7.24
10	7.25	Infinity



Salinity (in psu)		
1	0.00	33.41
2	33.42	34.00
3	34.01	34.59
4	34.60	35.18
5	35.19	35.77
6	35.78	36.36
7	36.37	36.95
8	36.96	37.54
9	37.55	38.13
10	38.14	Infinity

Fig. 1: Graphs depicting the probabilities of a P. bahamense spike occurring according to the precipitation and salinity scales. For the precipitation graph, there was not enough evidence to support the probability at levels 1 and 9; for the salinity graph, there was not enough evidence to support the probability at levels 2 and 10.

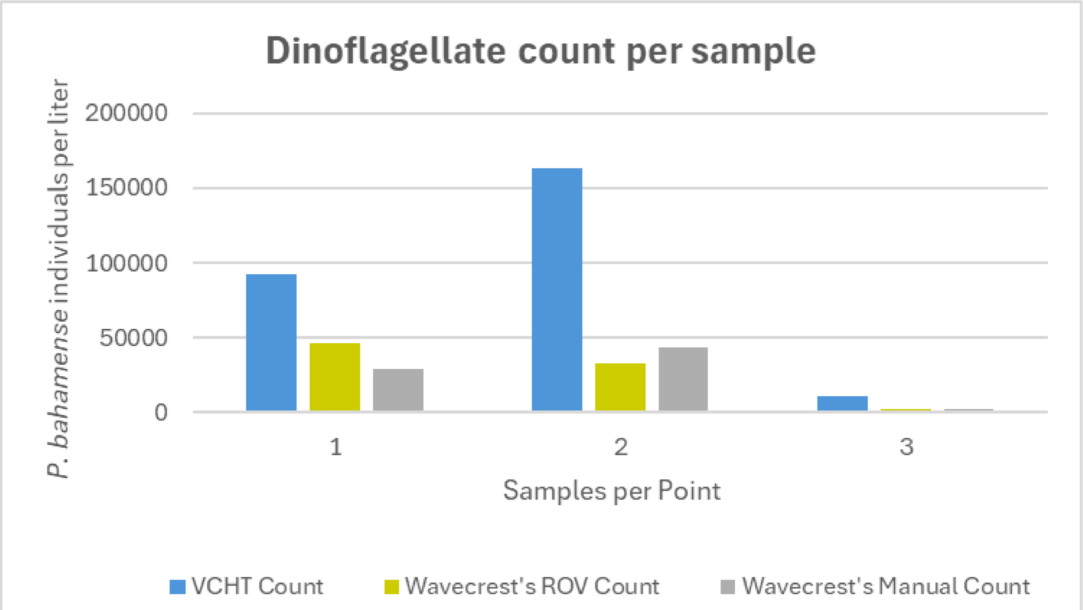


Fig. 2: Graph comparing each sample's P. bahamense count.

Conclusion

- Our research had two main goals, which we accomplished:
  - Create an empirical model that links abiotic factors to the perception of bioluminescence caused by *P. bahamense* in Mosquito Bay, Vieques.
  - Prove ROVs can be used to collect saltwater samples in Mosquito Bay, Vieques, without significantly affecting dinoflagellate count.
- Bioluminescent bays are still not fully understood ecosystems; however, with the available data, an empirical model was created to help predict bioluminescence.

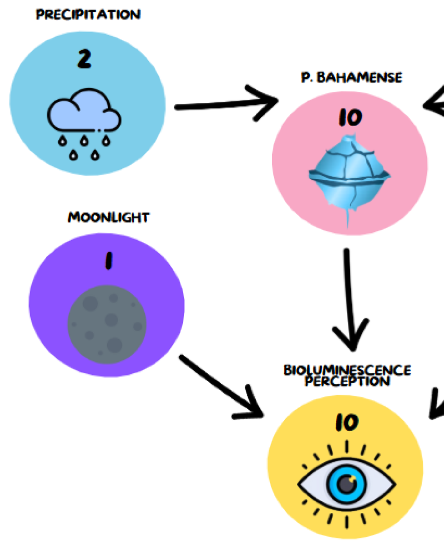


Fig. 3: Example of the empirical model showing one of the best possible bioluminescence perceptions, only including the variables that had a significant impact. The numbers are taken from the scales; 1 is the minimum, while 10 is the maximum.

Next Steps

- Our empirical model could be later improved to predict other bioluminescence levels by increasing sample size and considering other variables.
- Additionally, another model could be created to predict the location in the bay where the greatest bioluminescence may occur.
- Deeper ROV samples could be obtained in the future to compare dinoflagellate populations in the surface and the depths.
- ROVs with underwater cameras could be used to record the bay's marine life and rich ecosystems.
- Stations which obtain dinoflagellate count, and measure salinity and bioluminescence perception could be installed at different points.
- Finally, further studies, such as a daily *P. bahamense* census, should be conducted to make more accurate predictions.

Acknowledgements

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