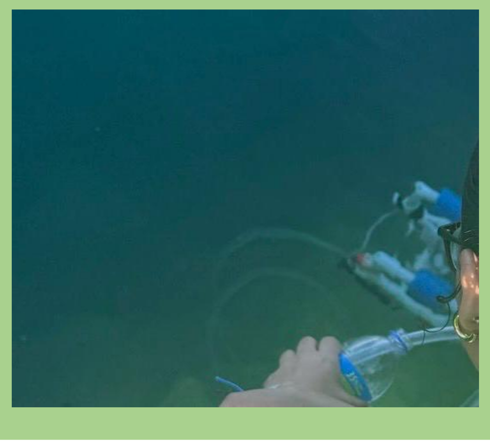
ROV-Driven Analysis of pH and Temperature: Investigating Ocean Acidification



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Abstract

Ocean acidification is an escalating global concern driven by excessive CO_2 absorption, leading to a steady reduction in seawater pH. Rising sea surface temperatures exacerbate this process, threatening marine organisms—especially those requiring stable pH for calcification and metabolic functions. In this study, we developed and deployed a Remotely Operated Vehicle (ROV) equipped with a mini water pump (connected to an Arduino breadboard and activated via an on/off switch) and digital sensors (temperature and distance) to collect water samples at varying depths. The pump channels seawater through a tube into an onboard reservoir for real-time pH measurement and subsequent laboratory validation. Sensor data indicate a measurable decrease in pH compared to historical baselines, correlating with elevated temperatures. These findings underscore the vulnerability of calcifying species such as corals, mollusks, and certain planktonic organisms, whose survival is tied to stable ocean chemistry. By integrating automated sampling with precise temperature and distance measurement, this ROV-based system provides a cost-effective, scalable tool for ongoing monitoring of ocean acidification. The results reinforce the urgency of global strategies to reduce CO_2 emissions, protect marine habitats, and promote research that will inform long-term conservation and mitigation efforts.

Background & Motivation

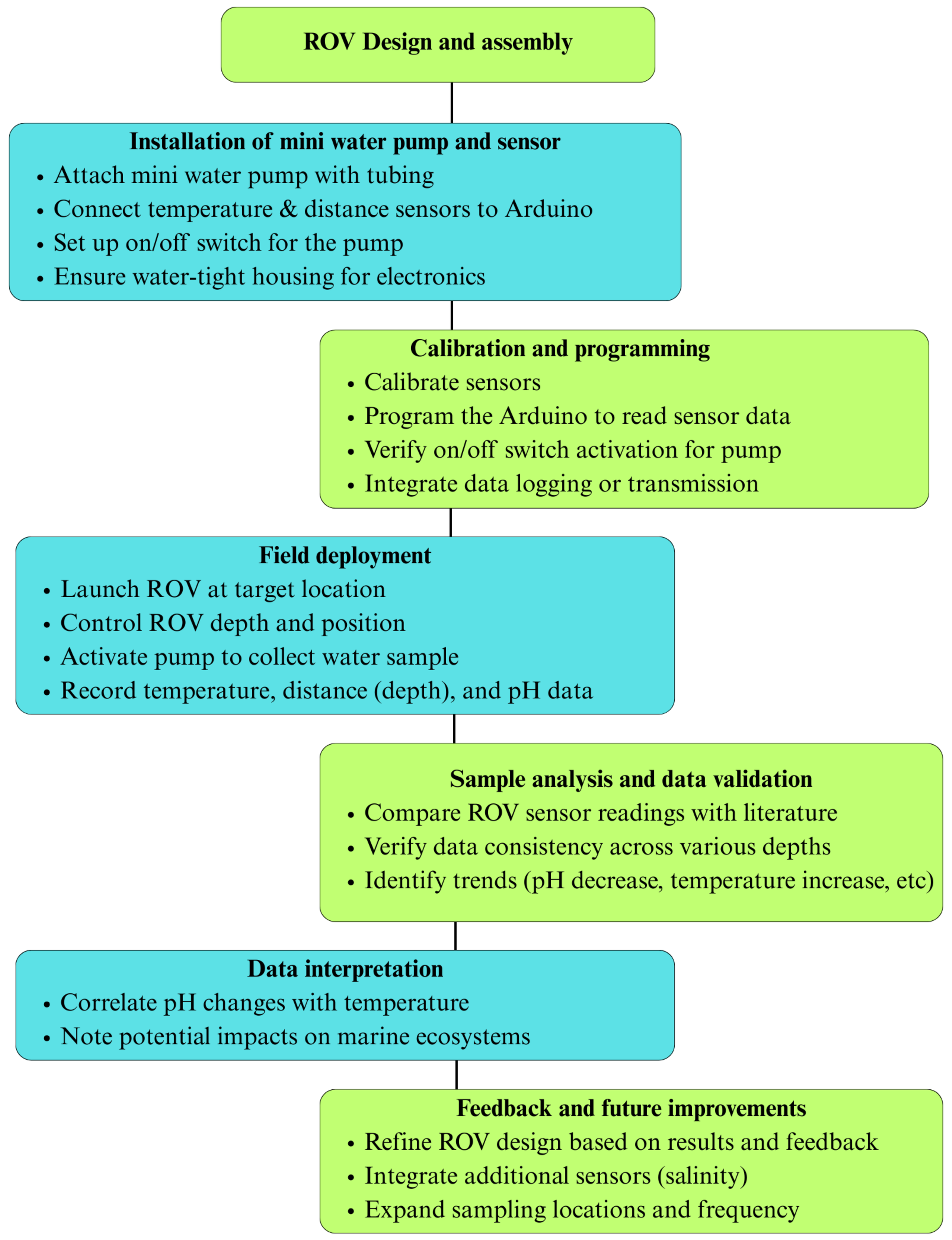
Ocean acidification refers to the decrease in seawater pH primarily due to the absorption of anthropogenic CO_2 from the atmosphere. Since the Industrial Revolution, the average pH of seawater has dropped from approximately 8.2 to 8.1, representing a 30% increase in acidity. Additionally, sea surface temperature has increased by about 0.13°C per decade over the past century, further influencing CO_2 solubility and accelerating acidification. These changes threaten the survival of corals, shellfish, and other marine organisms that rely on stable pH levels for calcification and metabolic processes.

Motivated by these environmental challenges, our project focuses on developing an ROV-based system for real-time measurement of pH and temperature. Through consistent monitoring and data analysis, we aim to better understand how acidification affects marine life and contribute to designing informed, science-based mitigation strategies.

Conclusion

This study confirms that ocean acidification, evidenced by lower pH levels, is a tangible and growing issue in the observed area. Temperature increases further influence acidification dynamics, posing additional risks to marine ecosystems. Implementing this ROV-based monitoring strategy can significantly enhance our understanding of acidification processes and support the development of targeted mitigation measures, such as reducing CO_2 emissions, restoring marine habitats (seagrass, mangroves), and promoting global collaboration to protect vulnerable coastal and oceanic environments.

Methodology



Results & Discussion

Table #1: ROV field measurements

Sample ID	Depth (m)	Distance Reading (m)	Temperature (°C)	pH (Probe)
01	2	2.1	26.7	8.18
02	5	5.0	26.2	8.15
03	10	9.8	25.8	8.12
04	15	15.1	25.3	8.10
05	20	20.2	24.9	8.07
06	25	24.7	24.5	8.05

In **table #1** As depth increases from 2 to 25 meters, the temperature drops by approximately 2.2°C (from 26.7°C to 24.5°C) and the pH decreases from 8.18 to 8.05, indicating a notable increase in acidity. These findings suggest that deeper waters may experience lower temperatures and higher CO_2 concentrations, which can stress marine organisms, particularly those sensitive to changes in pH. The distance readings closely match the intended depths, confirming the ROV's accuracy. Overall, the data highlight the interaction between thermal stratification and shifts in ocean chemistry, underscoring the importance of repeated measurements to monitor the ongoing impacts of ocean acidification.

Table #2: Data on pH, Sea Surface Temperature, and Acidity

Year	Average pH	Sea Surface Temperature (°C)	Increase in Acidity (%)
1850	8.20	15.7	0%
1900	8.18	15.9	4%
1950	8.15	16.2	9%
2000	8.10	16.6	20%
2020	8.05	17.1	30%
2050 *	7.90	18.0	45%

Data presented in **table #2** represents the historical trends from 1850 to 2000. The average pH decreases from 8.20 in 1850 to 8.10 in 2000. This data is obtained from the IPCC (Intergovernmental Panel on Climate Change). Although this is a very small drop in pH, also corresponds to a significant increase in acidity. Sea surface temperature rises from 15.7°C to 16.6°C over the same period, reflecting a gradual warming trend likely due to industrialization and increased greenhouse gas emissions.

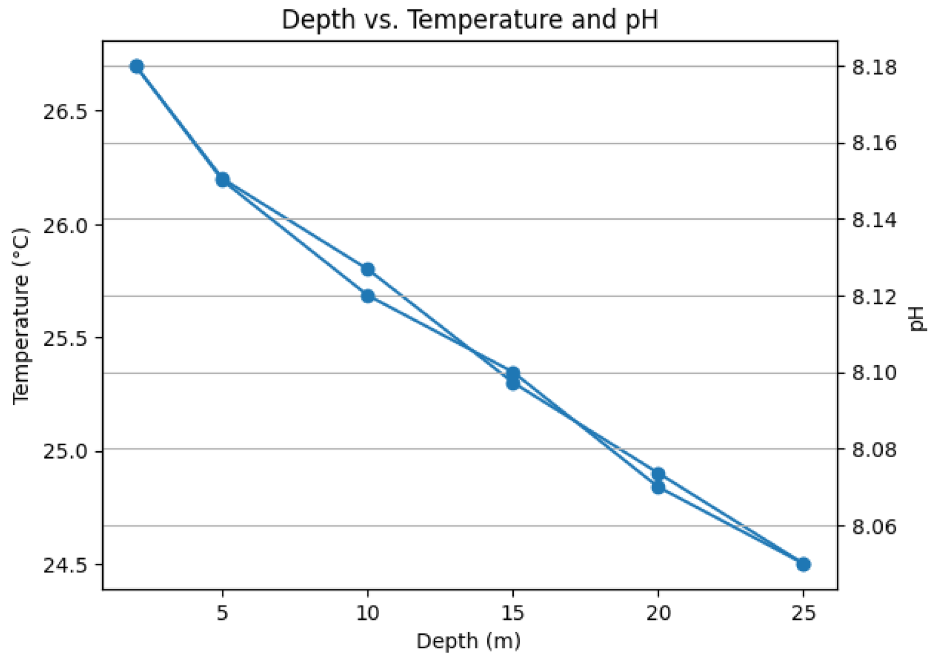
Table #3: Monthly average pH and sea surface temperature

Month	Average pH	Sea Surface Temperature (°C)
September 2024	8.00	28.5
October 2024	7.98	28.3
November 2024	7.97	28.0
December 2024	7.95	27.8
January 2025	7.94	27.5
February 2025	7.92	27.3

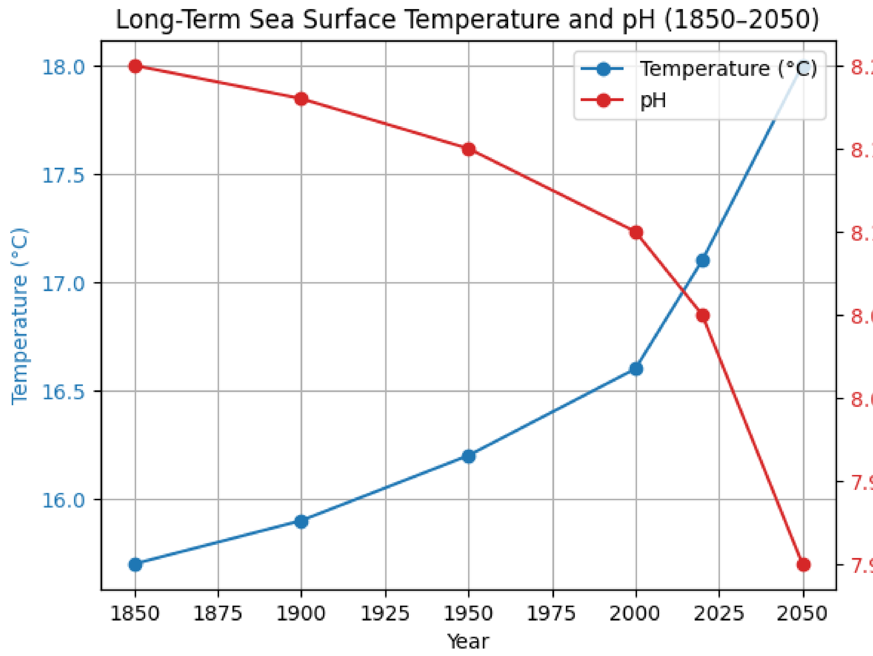
Table #3 the pH decreases gradually from 8.00 in September 2024 to 7.92 in February 2025. These changes may reflect seasonal influences, local water currents, or changes in nearby CO_2 levels. This also can be observed in the sea surface temperature that declines from 28.5°C in September to 27.3°C in February.

Graphs

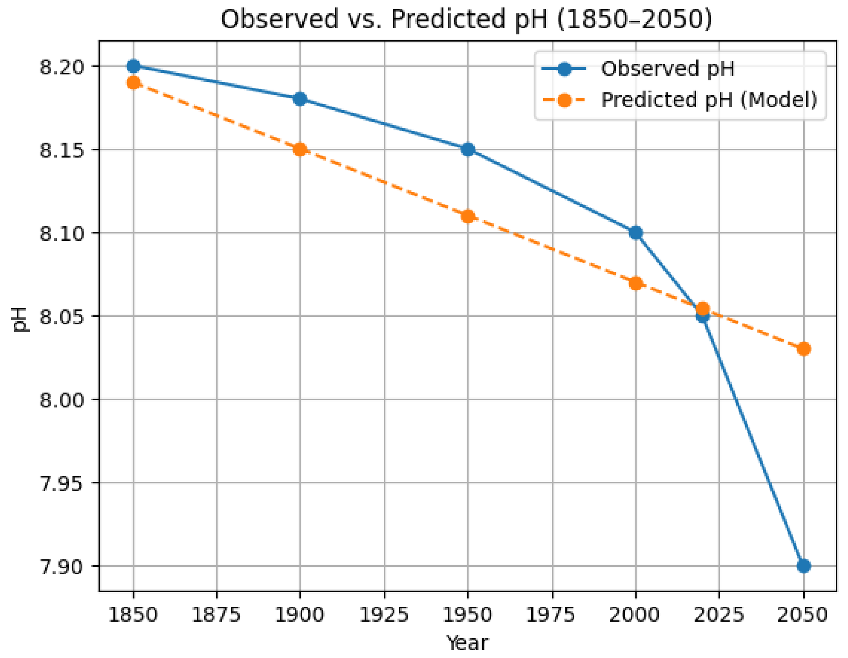
Graph 1: Depth vs. Temperature and pH ROV data



Graph 2: Long term sea surface temperature and pH (1850-2050)



Graph 3: Linear regression of observed and predicted pH using pH (X) = m.X + b where X= year -1850



Next Steps

1. Long- term monitoring of the ROV at regular intervals throughout the year to observe seasonal changes in pH and temperature.
2. Expand sensor array incorporating oxygen sensors and other chemical indicators for a comprehensive water quality assessment.
3. Community and policy outreach to share data and advocate for emissions reduction and marine conservation policies.
4. Technological improvements to the ROV design to increase sampling precision and autonomous operations for extended investigations.

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