Environment and Natural Resources Trust Fund

2022 Request for Proposal

General Information

Proposal ID: 2022-234

Proposal Title: Monitoring wind and boat waves using IoT technology

Project Manager Information

Name: Craig Hill

Organization: U of MN - Duluth

Office Telephone: (218) 726-7412

Email: cshill@d.umn.edu

Project Basic Information

Project Summary: This project demonstrates low-cost long-range IoT sensor and telemetry technology, providing Minnesota communities opportunities to implement affordable methods to monitor water and wave conditions influenced by weather and recreational activity.

Funds Requested: $196,000

Proposed Project Completion: June 30 2024

LCCMR Funding Category: Small Projects (H)
Secondary Category: Water Resources (B)

Project Location

What is the best scale for describing where your work will take place?
Statewide

What is the best scale to describe the area impacted by your work?
Statewide

When will the work impact occur?
During the Project and In the Future

Narrative

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

Unlike affordable and accessible personal weather stations which are heavily integrated into internet platforms, marine observation systems providing real-time lake conditions are not widespread and are typically deployed by state agencies in key locations for lake and river monitoring throughout Minnesota. As watersports activity diversifies and rapidly changing weather patterns increase, on-water conditions can rapidly change nearshore conditions. Expanding nearshore lake monitoring capabilities can provide communities and recreational users key real-time information about spatial variations in wave, water and air conditions, while also establishing information critical for informed policy decisions. Our team seeks to integrate new methods for low-cost, low-power telemetry into marine measurement systems to enable future community-driven IoT (Internet-of-Things) observations. Integrating affordable sensors for marine environments, this nearshore system will utilize LoRaWAN (Long Range Wide Area Network) telemetry, which reliably operates over distances of 5-10km to a WiFi or LTE cellular network connected base station. Across Minnesota, 69% of land falls within 5km of a lake 10 acres in size or larger (90% of land is within 10km of a lake). Existing population density and 5-year state network infrastructure goals provide extensive opportunity to expand community driven wave and water quality monitoring towards affordable and accessible widespread use.

What is your proposed solution to the problem or opportunity discussed above? i.e. What are you seeking funding to do? You will be asked to expand on this in Activities and Milestones.

We seek funding to continue development of a real-time IoT nearshore wave, wind and water measurement station using emerging low-cost, low-power sensing and telemetry for widespread inland water monitoring across Minnesota. This project is structured to include laboratory development, field testing and verification, and analysis to inform pathways towards expanding IoT monitoring of wind-driven and recreation-induced waves and water characteristics. Laboratory system validation focuses on design, development and testing of sensor and telemetry integration. Field observations during the 2023 spring, summer and fall seasons will provide real-time monitoring of on-water weather, recreational activity, waves and water temperatures. Observations will occur in various settings, including tests in urban, rural and remote lakes to verify long-range data telemetry in real-time using LoRaWAN gateway stations connected to either WiFi (urban and rural, if available) or LTE networks (remote, if available). Through this demonstration, we propose to explore the capabilities of these emerging technologies, demonstrate the ability to reliably monitor real-time conditions in nearshore water environments, engage interested citizens in IoT monitoring activities, demonstrate system integration into real-time internet data dashboards, and project statewide coverage potential to implement LoRaWAN telemetry with marine monitoring to accelerate widespread real-time monitoring adoption.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

This project will demonstrate an affordable and reliable method to monitor Minnesota's inland waters and highlight how communities and citizens can engage in widespread real-time marine monitoring utilizing emerging IoT technologies at urban, rural and remote locations across Minnesota. We will demonstrate methods for interested individuals, Lake Associations, educational programs, state agencies, researchers, or others to utilize low-cost sensing and telemetry to expand observations of water and wave characteristics and changes resulting from weather and recreational activity across the state. Implementing these emerging IoT technologies can help monitor Minnesota waters to inform future policy decisions and engage interested citizens.

Activities and Milestones

Activity 1: 1. Validation of nearshore marine measurement station data acquisition and telemetry

Activity Budget: $101,206

Activity Description:

Teams from the University of Minnesota Duluth (UMD) and UMN - St. Anthony Falls Laboratory (SAFL) will collaborate to develop prototype systems integrating sensors and telemetry components. Activities towards milestones will primarily take place in the lab with outdoor testing at UMD and SAFL to verify proper component integration and operation. Specifically, teams will coordinate system design, sensor specifications, power requirements and power management strategies for four measurement stations to be used in Activity 2 consisting of various sensing technologies for monitoring waves. SAFL will lead development of a monitoring platform to measure wind and boat driven wave heights. UMD will lead integration of wide-area LoRaWAN telemetry and ultrasonic systems to provide real-time data. This service uses the global low-cost LoRaWAN cloud service The Things Industries to transmit encoded sensor data to network endpoints, such as Ubidots IoT data platform and data dashboard. A wave buoy for mid-lake monitoring will be built by UMD, integrating LoRa telemetry and water temperature sensing. Open-source software will be used for data acquisition system development. Project teams will have development meetings at both SAFL and UMD (in person, conditions permitting), and decide on urban, rural, and remote test demonstration sites for Activity 2.

Activity Milestones:

Description	Completion Date
Design, specify, and purchase data acquisition, telemetry, and power management system components	October 31 2022
Complete validation of open source data acquisition program and data telemetry pathway from sensor stations	March 31 2023
Identify field deployment locations for Year 2 data collection and field validation activities	April 30 2023
Activity 1 summary report	June 30 2023

Activity 2: 2. Field deployment, data collection and system verification

Activity Budget: $65,164

Activity Description:

This activity will serve as the primary field season for data collection to demonstrate the capabilities of IoT real-time monitoring of wave, water and wind conditions. Three locations will be the primary targets for demonstrating capabilities. Two multi-month deployments will occur at lakes identified near the urban Duluth, MN or Twin Cities, MN area and rural North Central MN location typical for summer vacation homes (i.e. Park Rapids, MN). These systems will utilize at least one wave measurement platform, sending data using LoRaWAN to base stations connected to WiFi infrastructure. A third test deployment will be shorter in a remote region (i.e. Northern MN near BWCA) to demonstrate solar power system management and LoRa communications via Cellular LTE connectivity where WiFi is likely not accessible. Mid-lake wave buoy(s) will be utilized to monitor wave and water conditions away from regions that impact coastline structures and recreation activities to form baseline comparisons. Cloud service data routing to the endpoint data dashboard accessible by the general public will be verified. This activity will verify system operations and demonstrate integrating IoT sensors and telemetry for long-range low-power monitoring in settings typically targeted for monitoring across the state of Minnesota.

Activity Milestones:

Description	Completion Date
Nearshore marine measurement system testing - Location 1 (urban)	October 31 2023
Nearshore marine measurement system testing - Location 2 (rural)	October 31 2023

Nearshore marine measurement system testing - Location 3 (remote)	October 31 2023
Activity 2 field deployment and data collection summary report	December 31 2023

Activity 3: 3. Data analysis, system improvements, and reporting.

Activity Budget: $29,630

Activity Description:

Activity 3 will focus on data analysis from the field deployments in Activity 2. Specifically, wave elevation measurements will be analyzed to identify dominant heights and frequencies associated with weather events (i.e. wind) vs. boat traffic from recreational users (i.e. wake surfing or other activities). Project teams will identify challenges encountered and make improvements to the sensing technologies used, data acquisition software and telemetry utilization. At the outcome of Activity 2, the project team will better understand the capabilities of LoRaWAN telemetry and its ability to integrate marine observations into IoT platforms across urban, rural, and remote regions of Minnesota. As the state looks to expand network infrastructure over the next 5 years, new areas monitoring areas will become available using this low-cost, low-power technology. Once implemented, LoRaWAN base station gateways can aggregate data from hundreds of nearby sensor nodes for widespread "smart-monitoring" IoT implementation without additional network infrastructure costs. UMD will lead assessments for future expansion capabilities using the IoT monitoring system developed during Activity 1 and tested during Activity 2. The final project report will be distributed to state agencies with recommendations for expanding IoT marine monitoring systems across MN.

Activity Milestones:

Description	Completion Date
Analysis of wave measurements identifying space and time variations due to on-water activity and weather	April 30 2024
Map the projected coverage areas for utilizing LoRa wide area network telemetry near Minnesota lakes	May 31 2024
Activity 3 summary report	May 31 2024
Final project report, including data dissemination and recommendations for statewide IoT and citizen marine monitoring.	June 30 2024

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Jeffrey Marr	St. Anthony Falls Laboratory, University of Minnesota	Co-Investigator and Project Manager for wave mast station development at St. Anthony Falls Laboratory.	Yes
William Herb	St. Anthony Falls Laboratory, University of Minnesota	Dr. William Herb is a Research Associate and will provide oversight for data acquisition structure and development and site selection.	Yes
Jessica Kozarek	St. Anthony Falls Laboratory, University of Minnesota	Dr. Jessica Kozarek will provide oversight for measurement system development and site selection.	Yes
Christopher Milliren	St. Anthony Falls Laboratory, University of Minnesota Twin Cities	Mr. Milliren will provide engineering support towards developing sensor and telemetry systems used. He will collaborate and co-mentor the Graduate Student, be responsible for sensor selection, and lead power system development and data acquisition coding.	Yes

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this be funded?

Once deployed, real-time results will be accessible on the project IoT data dashboard, summarized in a project report, and provided to state agencies highlighting IoT monitoring applications for weather and watersport induced waves and implications for nearshore environments and recreation. By demonstrating affordable IoT marine monitoring, we envision expanded citizen and community interest, particularly in regions with impaired waters, competing stakeholder interests and environmental education facilities across the state. Continued funding for future expansion will be actively pursued via state and regional pathways. All project data and designs will be made available on DRUM (Data Repository for U of MN).

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Conserving Minnesota's Native Freshwater Mussels	M.L. 2014, Chp. 226, Sec. 2, Subd. 05k	$350,000
Enhancing Spawning Habitat Restoration in Minnesota Lakes	M.L. 2017, Chp. 96, Sec. 2, Subd. 08e	$294,000

Project Manager and Organization Qualifications

Project Manager Name: Craig Hill

Job Title: Assistant Professor, Mechanical & Industrial Engineering

Provide description of the project manager's qualifications to manage the proposed project.
Dr. Craig Hill is an Assistant Professor in the UMN Mechanical & Industrial Engineering Department and Affiliate Professor with the UMD Large Lakes Observatory and UMN Water Resources Science graduate degree program. His research focuses on the intersection between marine environments and engineered systems, including multi-sensor measurement platforms for marine and atmospheric monitoring, the design, manufacturing, and coupling of composite materials with sensors for marine systems, and fluid-structure interactions of marine and wind energy technologies. He currently receives funding to 1) develop open-source, low-cost wave measurement buoys for drifting and moored measurements on Lake Superior; 2) establish meteorological tower atmospheric condition sensing for community scale wind energy system research and development; and 3) design and build scaled model marine renewable energy technologies for performance and fluid dynamics testing. Prior to his faculty role, Dr. Hill spent nearly a decade at UMN St. Anthony Falls Laboratory (SAFL) as a Research Engineer. He was a marine engineer for the UMD Large Lakes Observatory designing and deploying various surface and subsurface sensor systems for water quality and wave monitoring on Lake Superior. Most recently, Dr. Hill has become involved in the Great Lakes Technology community to explore ways of expanding low-cost, low-power and long-range telemetry systems across the Great Lakes region to engage a broader community in marine environment monitoring systems. As part of this, Dr. Hill has installed a LoRaWAN gateway base station on the UMD campus to test coverage in the Twin Ports region and develop local air and water quality monitoring systems. His combined experiences with research, development and data acquisition systems at the intersection of water resources, renewable energy, and natural resource monitoring suitably position Dr. Hill to successfully manage this proposed project with colleagues at the UMN SAFL.

Organization: U of MN - Duluth

Organization Description:
The University of Minnesota Duluth (UMD) is a highly-ranked regional university offering students a supportive student-centric atmosphere, exposure to research and development challenges at the forefront of society and access to the resources of the larger University of Minnesota (UMN) system. UMD students can choose from more than 93 undergraduate degrees, and from graduate programs in more than 20 different fields, including the project Lead PI's home department and other relevant graduate degrees. The Swenson College of Science and Engineering (SCSE) at the University of Minnesota Duluth is the largest college at UMD and the third largest in the UMN System, with an enrollment of over 3,200 undergraduate and 200 graduate students. This research aligns with SCSE grand challenges to develop an international reputation in areas related to water and sustainability while preparing graduates to contribute meaningful impacts towards regional engineering and economic activities.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Craig Hill		PI - Project Manager to oversee all aspects of project, advise on sensor and telemetry implementation, etc. (73.3% salary, 26.7% fringe).			26.7%	0.08		$11,836
Jeffrey Marr		Co PI - Co-Investigator and Project Manager for wave mast station development at SAFL. (73.3% salary, 26.7% fringe).			26.7%	0.02		$2,530
William Herb		Co PI - Provide oversight for data acquisition structure and development and site selection. (73.3% salary, 26.7% fringe).			26.7%	0.02		$1,726
Jessica Kozarek		Co PI - Provide oversight for measurement system development and site selection (73.3% salary, 26.7% fringe).			26.7%	0.02		$1,689
Christopher Milliren		Engineer - Provide engineering support towards developing systems used. (75.9% salary, 24.1% fringe).			24.1%	0.5		$42,983
Graduate Research Assistant		Graduate Research Assistant - Assistant with design, testing, deployment, and analysis (50.6% salary, 49.4% fringe).			49.4%	1		$80,585
							Sub Total	**$141,349**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Tools and Supplies	Sensors for waves, wind, and water observation stations (Qty = 4)	Ultrasonic and wave gauge, and pressure sensors for measuring wave heights; wind speed and water temperatures sensors for nearshore environment; dataloggers for control and communication with sensors					$9,684
	Tools and Supplies	LoRaWAN gateways, antennas, nodes (Qty = 4)	LoRaWAN (Long Range Wide Area Network) gateway basestations,					$7,665

			antennas, and connections to transmit data from sensors to WiFi or LTE; solar power charging and batteries to maintain signal and data transmission					
	Tools and Supplies	LoRaWAN wave buoy (Qty = 3)	Mid-lake wave buoys with LoRaWAN data communications, temperature strings, wave measurement loggers; mooring supplies (anchor, cable, connections), to measure mid-lake characteristics					$8,435
	Tools and Supplies	Deployment Infrastructure	Sensor tripod masts (Qty = 4); Small trailer for transporting masts and sensor stations to field					$3,278
	Tools and Supplies	Prototyping supplies, wiring, enclosures, consumables	Enclosures for data acquisition systems, power management systems, sensors, datalogger, etc.; Prototyping supplies for in-lab Activity 1 development; laboratory consumable supplies					$8,714
							Sub Total	**$37,776**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	Travel between primary project locations (UMD and UMN-SAFL) for project teams to work on system development and testing (2 people/trip, 4 trips/year, either UMD to SAFL or SAFL to UMD). Costs are for mileage/meals/lodging when applicable. Approx. 320 miles round trip.	Project team members will travel to either UMD or SAFL to work with Engineer and Researchers on system sensing, data acquisition, telemetry, and assembly of field test systems					$5,402
	Miles/ Meals/ Lodging	Travel to field sites for testing (estimated average of 350 miles round trip). Two people per trip, 4 trips total	Travel for 2 people to deploy and recover systems during the 2023 summer field season to both North Central, MN and Northern, MN. Costs					$2,338

			cover mileage/meals/lodging where required.					
							Sub Total	**$7,740**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
		R/V Kingfisher Use	Small UMD watercraft use for deploying mid-lake LoRaWAN buoys in nearshore environments around Duluth, MN. Two days per year.					$3,045
		UMD Engineering Senior Design project supplies	Educational and workforce development supplies to contribute to project designs for UMD Engineering undergraduate Senior Design program over two year project period.					$6,090
							Sub Total	**$9,135**
							Grand Total	**$196,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	University of Minnesota Unrecovered indirect costs at 55%	This is the unrecovered indirect cost amount contributed to the running of the project by the University of Minnesota	Secured	$89,731
			Non State Sub Total	**$89,731**
			Funds Total	**$89,731**

Attachments

Required Attachments

Visual Component

File: ca907bd9-7e5.pdf

Alternate Text for Visual Component

The attached visual illustrates the statewide opportunity for low-cost and low-power long range wide area network monitoring, Internet-of-Things (IoT) LoRaWAN telemetry concept, and a conceptual image demonstrating monitoring sensor systems on lakes to provide real-time monitoring of weather and recreation induced wave conditions. This project seeks to establish a working demonstration of integrating wave sensing technologies with IoT telemetry systems to engage communities in real-time monit...

Optional Attachments

Support Letter or Other

Title	File
Institutional Support Letter	9f749de4-95d.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have potential for royalties, copyrights, patents, or sale of products and assets?

No

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

N/A

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

N/A

Does your project include original, hypothesis-driven research?

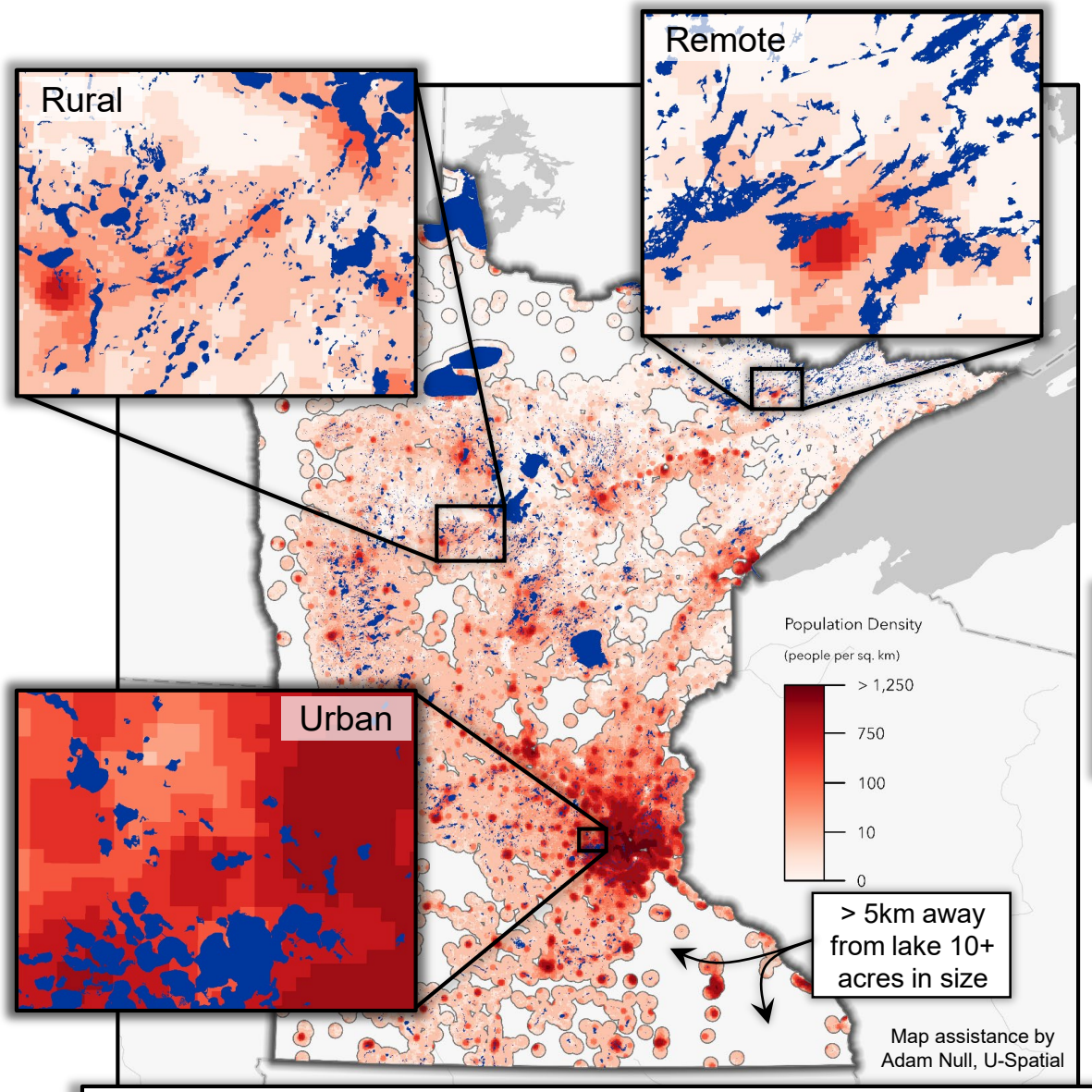
No

Does the organization have a fiscal agent for this project?

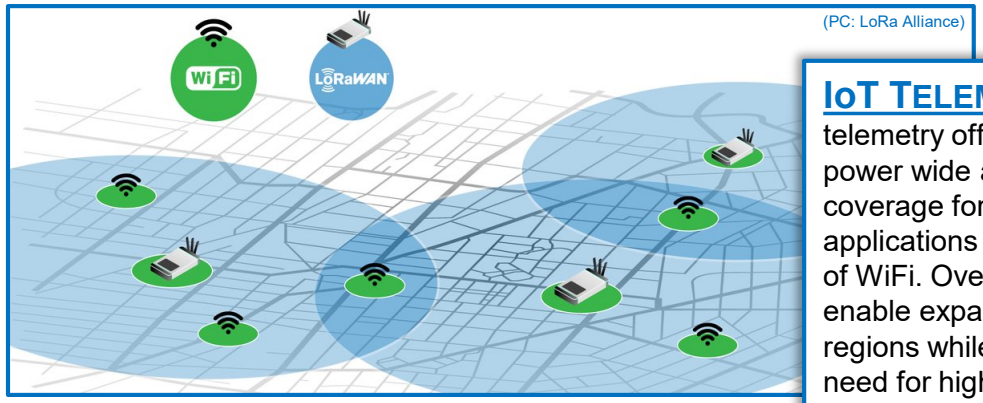
No

Monitoring wind and boat waves using IoT technology

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND 2022



OPPORTUNITY: Buffered zones illustrate 69% of MN lies within 5km of a lake 10+ acres in size. LoRaWAN telemetry typically covers ~10km. Population density can indicate high use marine recreation, interest in water quality, potential for mixed use stakeholders, and network infrastructure to support IoT applications.



IoT TELEMTRY: LoRaWAN telemetry offers low-cost, low-power wide area network coverage for IoT sensing applications beyond the range of WiFi. Overlapping nodes can enable expanded zones to new regions while minimizing the need for higher cost Cellular data or WiFi infrastructure.

OUTCOMES: Community driven marine observations for remote, rural, and urban regions. Opportunities for K-12 integration, regional Lake Association adoption, informed policy decisions, and demonstrating real time technology for IoT integration into statewide wave and water observations.