

# Measuring Protons with Photons: A hand-held, spectrophotometric pH Analyzer for Ocean Acidification Research, Community Science and Education

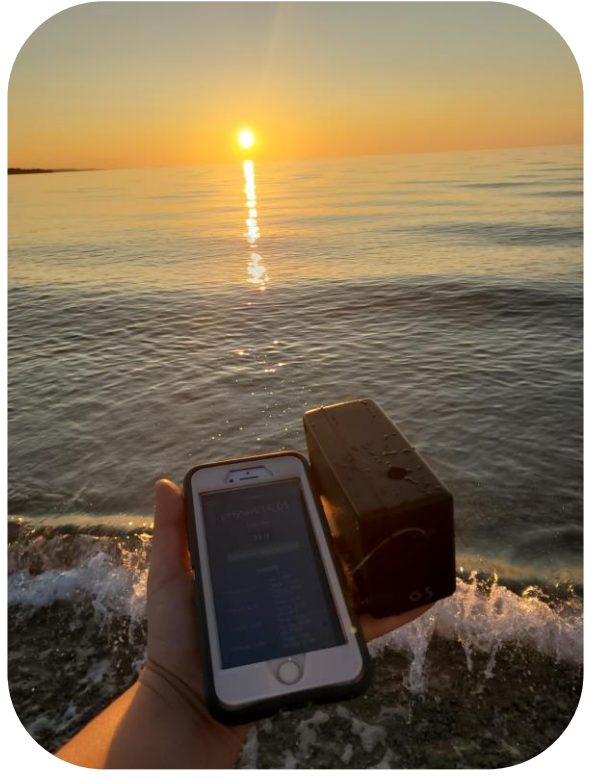


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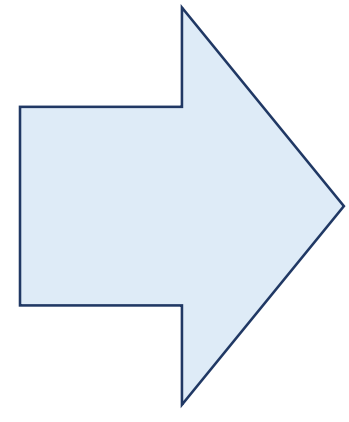
Kalina C. Grabb<sup>1,2</sup>, William Pardis<sup>3,4</sup>, Michael D. DeGrandpre<sup>5,6</sup>, Reggie Spaulding<sup>5</sup>, James Beck<sup>5</sup>, Jonathan A. Pfeifer<sup>2,4</sup>, and David M. Long<sup>4,7</sup>

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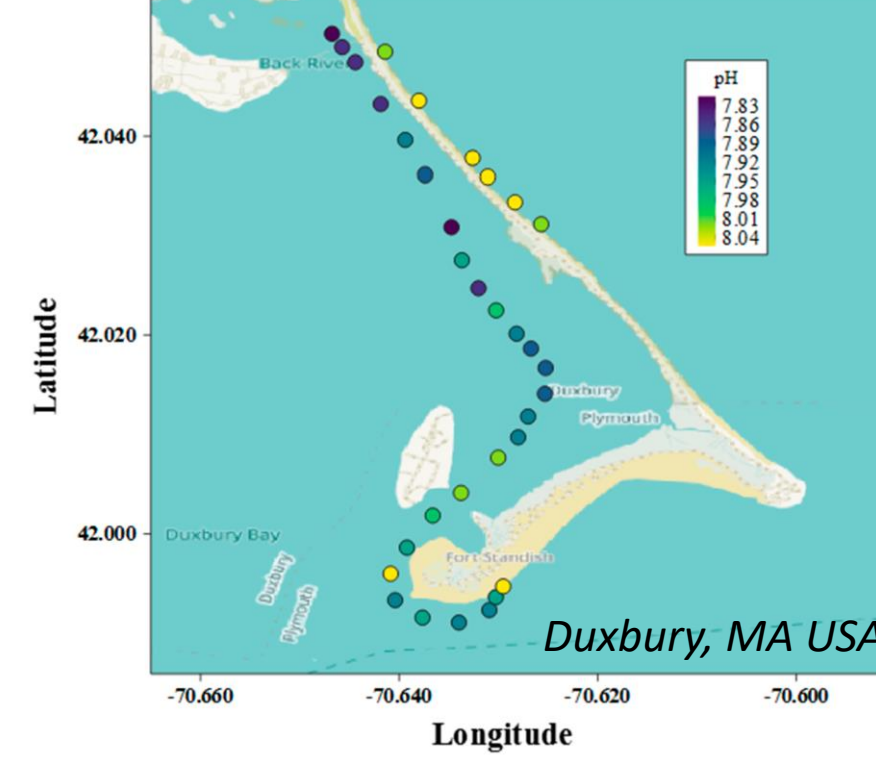
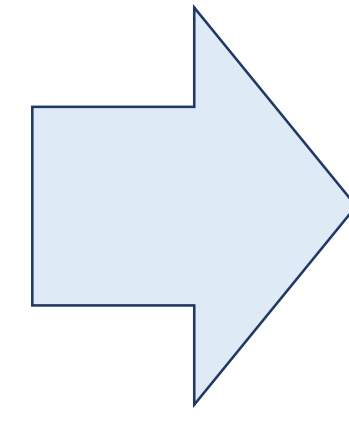
## The Power of the pHyter



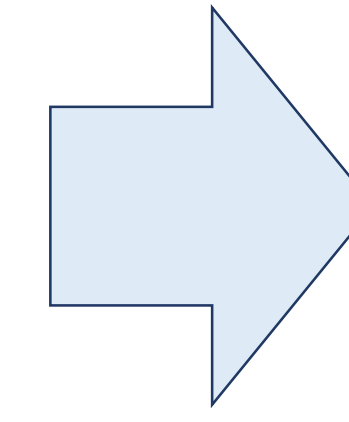
**Measures pH reliably** with a known accuracy and requires minimal training



**Enables STEM and OA education programs** to encourage and stimulate students to learn about local and global environmental issues



**Provides people around the world** with a **tool to measure pH** in their local environments to observe spatial and temporal pH trends



**Empowers global communities** to use their own **science to inform** local government, policy, and societal decisions

## What is the pHyter?

- **Hand-held, affordable, field-durable, easy-to-use** pH instrument (Fig. 1)
- Controlled through **smartphone app** with data in under 1 minute (Fig. 2)
- pH measurements are **spec-based** with indicator dye (Fig. 3)
- **Accuracy comparable** to uncertainties in benchtop spectrophotometric pH measurements (Table 1, Fig. 4, Fig. 5)
- Designed for **community-based science** and used with minimal training
- Ideal for **spatial and temporal sampling**, while highlighting small-scale variations across large regions



Fig. 1



Fig. 2

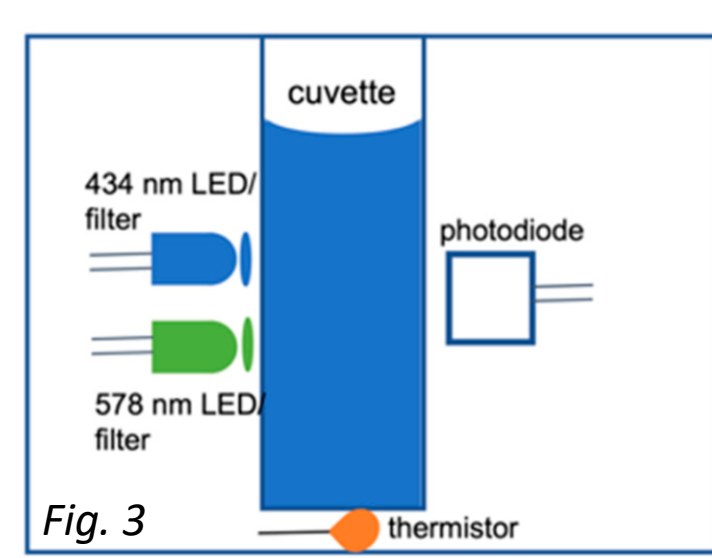


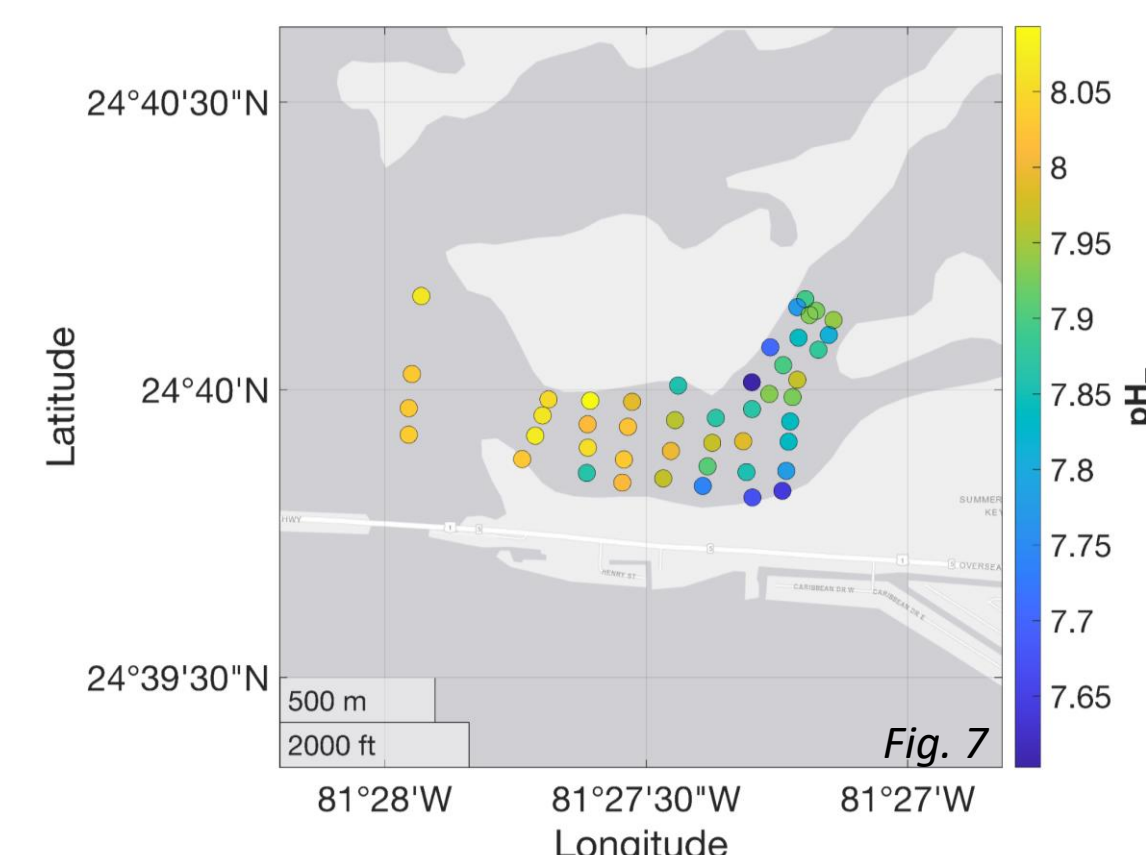
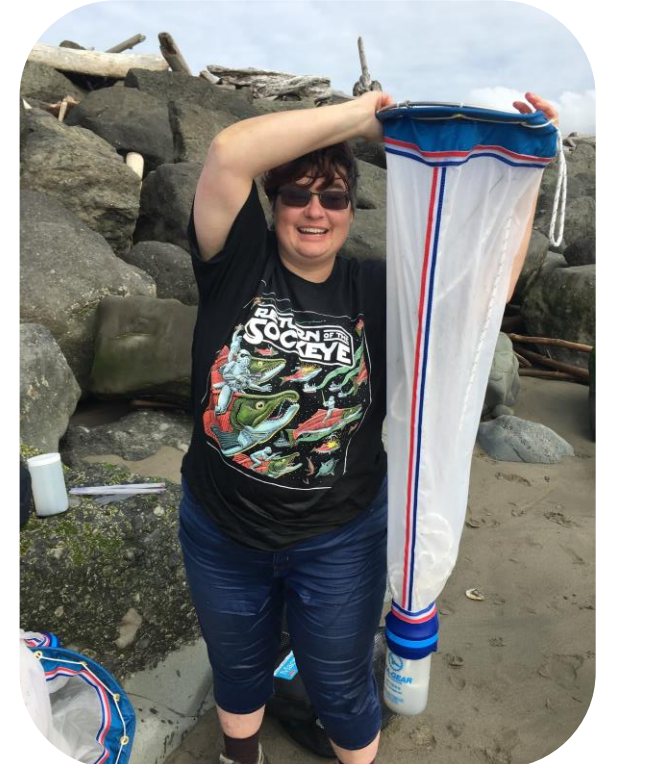
Fig. 3 (Right): pHyter optical design

Fig. 1 (Left): pHyter diagram  
Fig. 2 (Center): pHyter smartphone app  
Fig. 3 (Right): pHyter optical design

## The pHyter in Action



NOAA West Coast Region National Marine Sanctuaries developed a **plankton curriculum** that utilized the **pHyter to educate about OA**. Teacher Alice Ryan (right) taught this curriculum at the **Quileute Tribal School** (top), who proceeded to win the Nickelodeon Get Dirty! Ambassadors award for their work in science



SEA students collected **pH data from water carousels** in the Gulf of Mexico, showing pH depth trends across three stations (Fig. 8)



**Sea Education Association (SEA)** students measured **pH within mangroves** using the pHyter while on kayaks, highlighting the small-scale variation (Fig. 7)

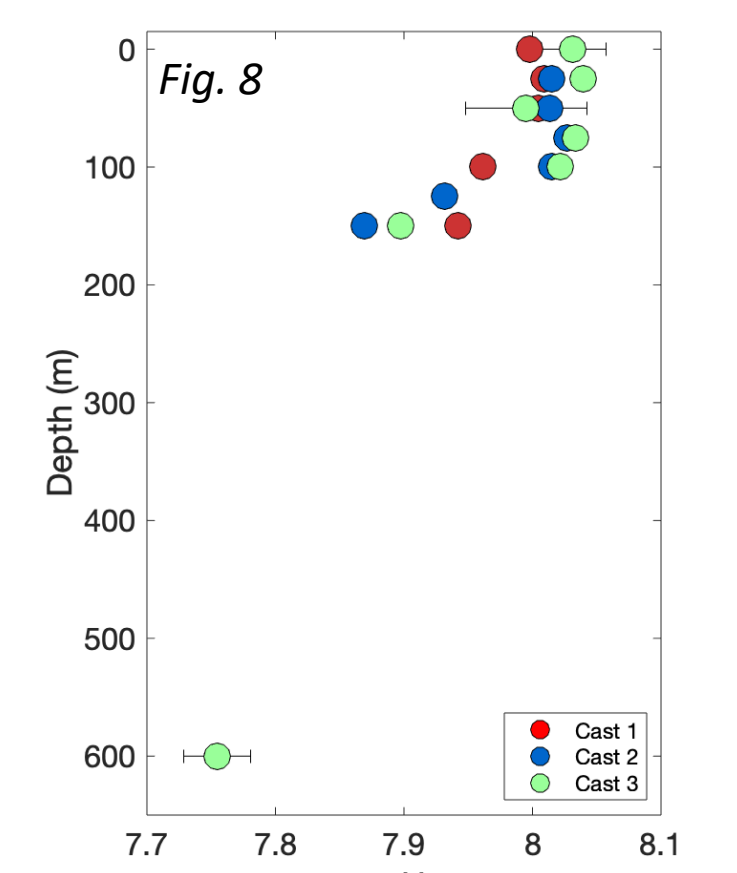


Fig. 8



## Testing, Verification, and Accuracy



Measuring Protons with Photons: A Hand-Held, Spectrophotometric pH Analyzer for Ocean Acidification Research, Community Science and Education

William Pardis<sup>1,2</sup>, Kalina C. Grabb<sup>1,2</sup>, Michael D. DeGrandpre<sup>3,4,5,6</sup>, Reggie Spaulding<sup>5,6</sup>, James Beck<sup>5</sup>, Jonathan A. Pfeifer<sup>1,2,4</sup>, and David M. Long<sup>4,7</sup>

Read the Sensors Paper

The pHyter was **tested and verified** against known methods (Pardis et al., 2022, above)

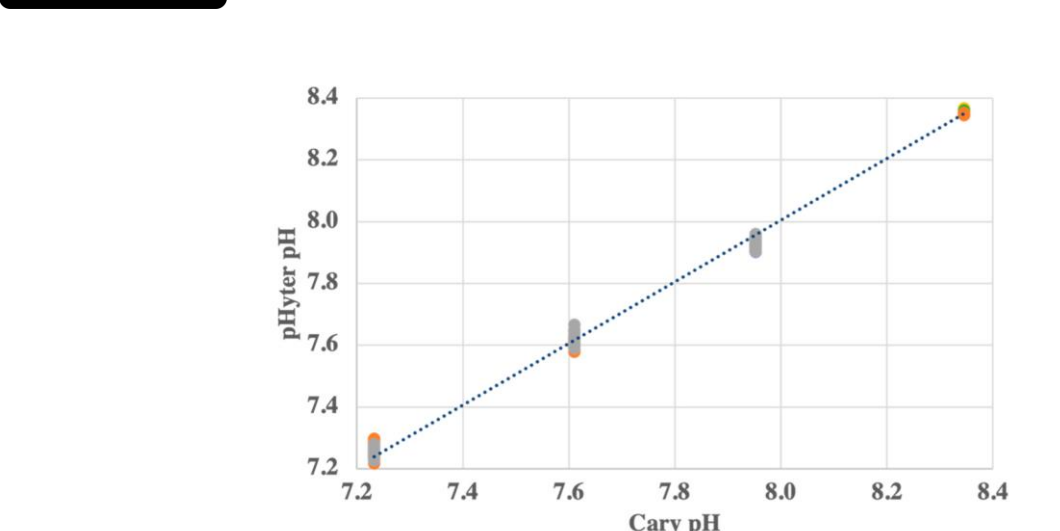


Fig. 4: Seawater pH measurements collected on benchtop **Cary UV-Vis** and **pHyter** (linear fit 0.997, R<sup>2</sup> = 0.998, n=69)

Table 1: pHyter accuracy and precision on Tris Certified Reference Material (CRM) was  $+0.026 \pm 0.045$

Temperature (C)	Tris pH	pHyter 1	pHyter 2	pHyter 3	pHyter 4	pHyter 5	Average Offset	Standard Deviation
24.74 ± 0.09	8.107 ± 0.005	8.130	8.120	8.120	8.110	8.120	+0.013	±0.007
22.09 ± 0.35	8.190 ± 0.011	8.230	8.220	8.230	8.190	8.200	+0.024	±0.010
27.72 ± 0.19	8.016 ± 0.006	8.030	8.189	8.010	8.013	N/A	+0.046 (+0.002)	±0.086 (0.011)

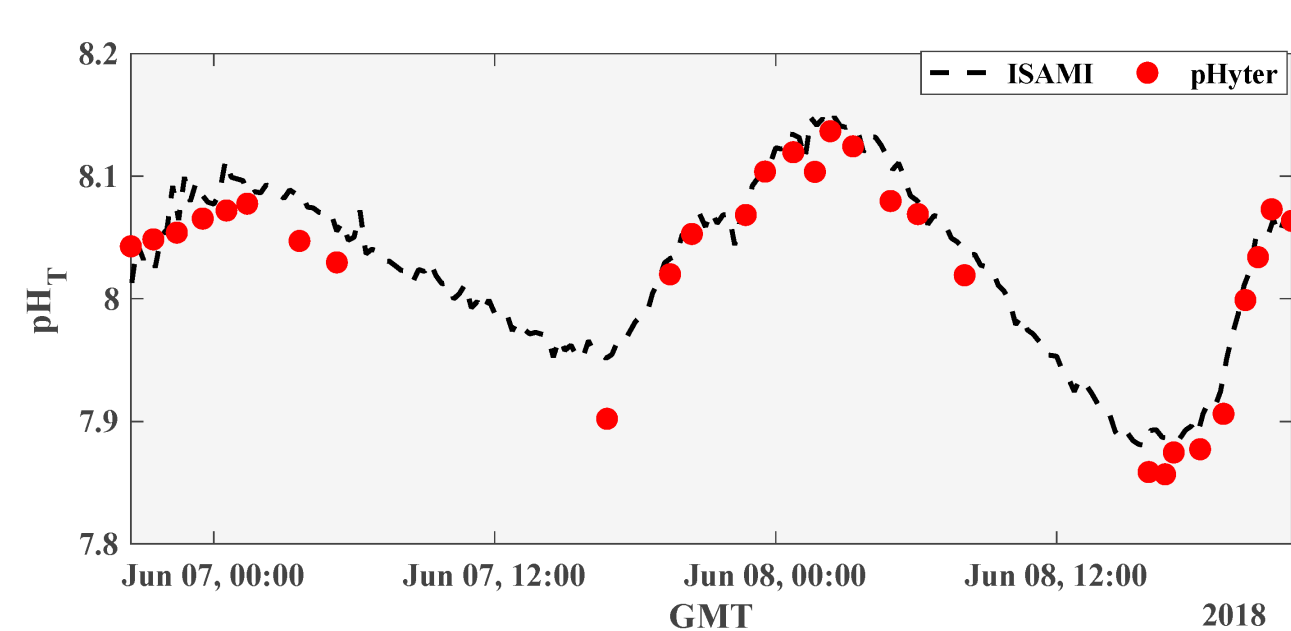


Fig. 5: Compared to **iSAMi**, pHyter measured pH  $-0.033 \pm 0.066$

Did the pHyter motivate you to learn more about pH chemistry?

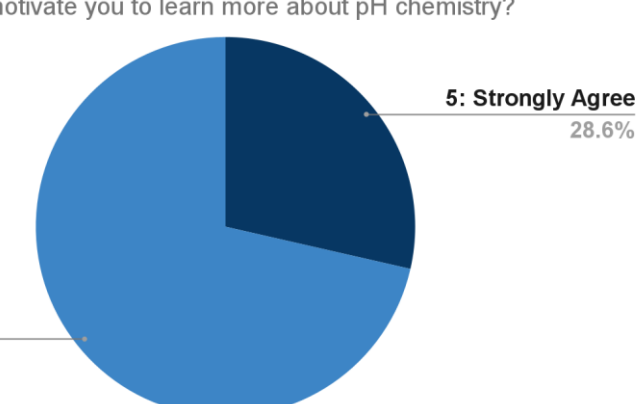


Fig. 9

In a user-feedback survey, SEA students say (Fig. 9):

- The pHyter **inspired them to learn more**
- The pHyter was **easier to use** than the benchtop spec
- They **felt competent** using the pHyter after a few times
- They were **comfortable teaching peers** how to use the pHyter
- They **enjoyed** using the pHyter

## Additional Interested Partners



### Education & Outreach

Cabrillo College  
Chesapeake Bay Governors School for Marine and Environmental Science  
Flathead Valley Community College  
Quileute Tribal School  
Ocean Guardian School  
Montana American Indians Math & Science  
University of North Carolina, Wilmington  
Woods Hole Oceanographic Institution (WHOI)

### International Networks

Global Ocean Acidification Observing Network (GOA-ON)  
Ocean Acidification Alliance

### Community Science

Buzzards Bay Coalition  
National Phytoplankton Monitoring Network  
Surfrider Foundation

### Local Industries

Aquaculture  
Fishermen

### Governmental Agencies

US Environmental Protection Agency (EPA)  
US National Oceanic and Atmospheric Administration (NOAA)

### Scientists

University (Cal Poly, UH, VIMS)  
Research Institution (WHOI)

### Non-government Orgs

The Ocean Foundation

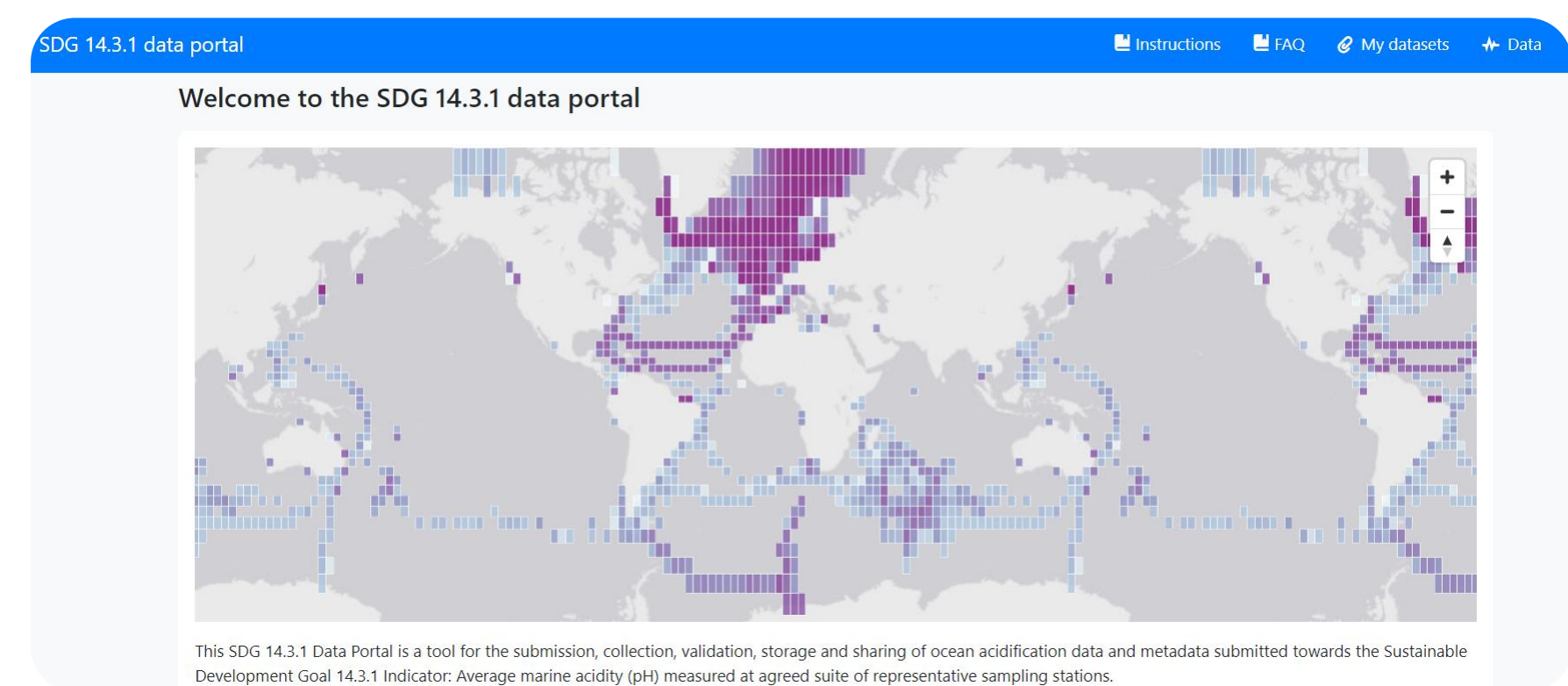
## The Future of the pHyter



The pHyter can provide communities, such as **Indigenous nations**, with opportunities in **science and education** (Quileute Tribal School, left; teacher training on Makah Indian Reservation, right)



**Global OA networks** can distribute pHyters and support users to increase **OA monitoring capacity** and **build international collaborations** (Pacific Islanders training in Fiji, left; Chile, right)



**pHyter measurements** will enable countries to meet **UN mandate to submit data to global pH databases** such as Sustainable Development Goal 14.3.1 Data Portal and GOA-ON Data Explorer

