Ref. No. [UMCES]CBL 2012-052
Alliance for Coastal Technologies Indexing No. ACT-CNUA12-01

Customer Needs and Use Assessment Survey

ALLIANCE FOR COASTAL TECHNOLOGIES

USE OF, SATISFACTION WITH, AND REQUIREMENTS FOR IN SITU pH SENSORS

Conducted by the Alliance for Coastal Technologies

2012

I. OBJECTIVE

The fundamental goal of this survey was to assess user needs and applications and to provide the focus for an Alliance for Coastal Technologies (ACT, www.act-us.info) Technology Verification of in situ pH sensors. The Customer Needs and Use Assessment strives to better understand how pH sensors are used. We hope this information can also assist manufacturers in refining pH sensor technologies to better address user priorities.

II. SURVEY COMPOSITION

From 6 October 2011 to 9 February 2012, ACT conducted a web-based survey to aid in a Customer Needs and Use Assessment of pH sensors. ACT Headquarters and Partner personnel developed the questionnaire. SurveyMonkey.com provided the web-based survey tool. The survey contained a total of twenty-seven questions (listed below along with their responses), divided into three sections: Application, Specifications, and Recommendations.

III. DISTRIBUTION OF SURVEY

Survey participants included both colleagues and vendors. Colleagues were asked to consider the primary in situ pH sensor(s) they used when responding to each question. Unaware if any specific vendor (sensor manufacturer) had its own proprietary statistics collected already, vendors were simply asked to summarize what they felt were the perspectives of their "typical" customers. All participants received emailed requests to participate in this online survey and two follow-up reminders.

IV. PARTICIPANT SELECTION PROCESS

To assure broad geographic coverage, regional outreach personnel at the six ACT Partner Institutions and members of the Technical Advisory committee nominated participants based on their professional interests, background, and expertise. Approximately 173 coastal resource managers, regulatory and environmental health agency representatives, manufacturers, and scientific researchers were targeted to take part in the survey; 24% responded.

Who Participated in this Survey?

- Aquatics NW, Bainbridge Island, WA
- Bangladesh Water Development Board, Dhaka, Bangladesh
- Campbell Scientific, Inc., Logan, UT
- Carlsbad Aquafarm, Carlsbad, CA
- Center for Limnology, University of Wisconsin, Madison, WI
- Chesapeake Biological Laboratory, Solomons, MD
- CICEET, UNH, Durham, NH
- College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR
- Columbus State University, Columbus, GA
- Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
- Department of Natural Resources, MD
- Great Bay National Estuarine Research Reserve, Greenland, NH
- Hawai'i Institute of Marine Biology, University of Hawai'i at Manoa, Honolulu, HI
- Hawai'i Pacific University, Honolulu, HI
- Interfaculty Center for Marine Research, University of Liège, Belgium
- King County Water and Land Resources Division, Seattle, WA
- Laboratoire d'Océanographie, Villefranche-sur-Mer, France
- Marine Science Institute, UCSB, Santa Barbara, CA
- Monterey Bay Aquarium Research Institute, Moss Landing, CA
- Monmouth University/NJDEP, West Long Branch, NJ
- NOAA Northwest Fisheries Science Center, Seattle, WA
- Pacific Marine Environmental Laboratory (PMEL), NOAA, Seattle, WA
- Pacific Shellfish Institute, Olympia, WA
- Penn Cove Shellfish, Coupeville, WA
- San Francisco Bay Regional Water Quality Control Board, Oakland, CA
- School of Freshwater Sciences, University of Wisconsin – Milwaukee, WI
- Scripps Institution of Oceanography, UCSD, San Diego, CA
- Smithsonian Environmental Research Center, Edgewater, MD
- UCSB, Santa Barbara, CA
- Université de La Réunion, Réunion
- Utah Water Research Laboratory, Utah State University, Logan, UT
- University of Victoria, ONCCEE, Victoria, Canada
- University of Washington, Seattle, WA
- USGS, Center for Coastal & Watershed Studies, St. Petersburg, FL
- Virginia Department of Environmental Quality, Richmond, VA
- WET Labs, Inc., Philomath, OR

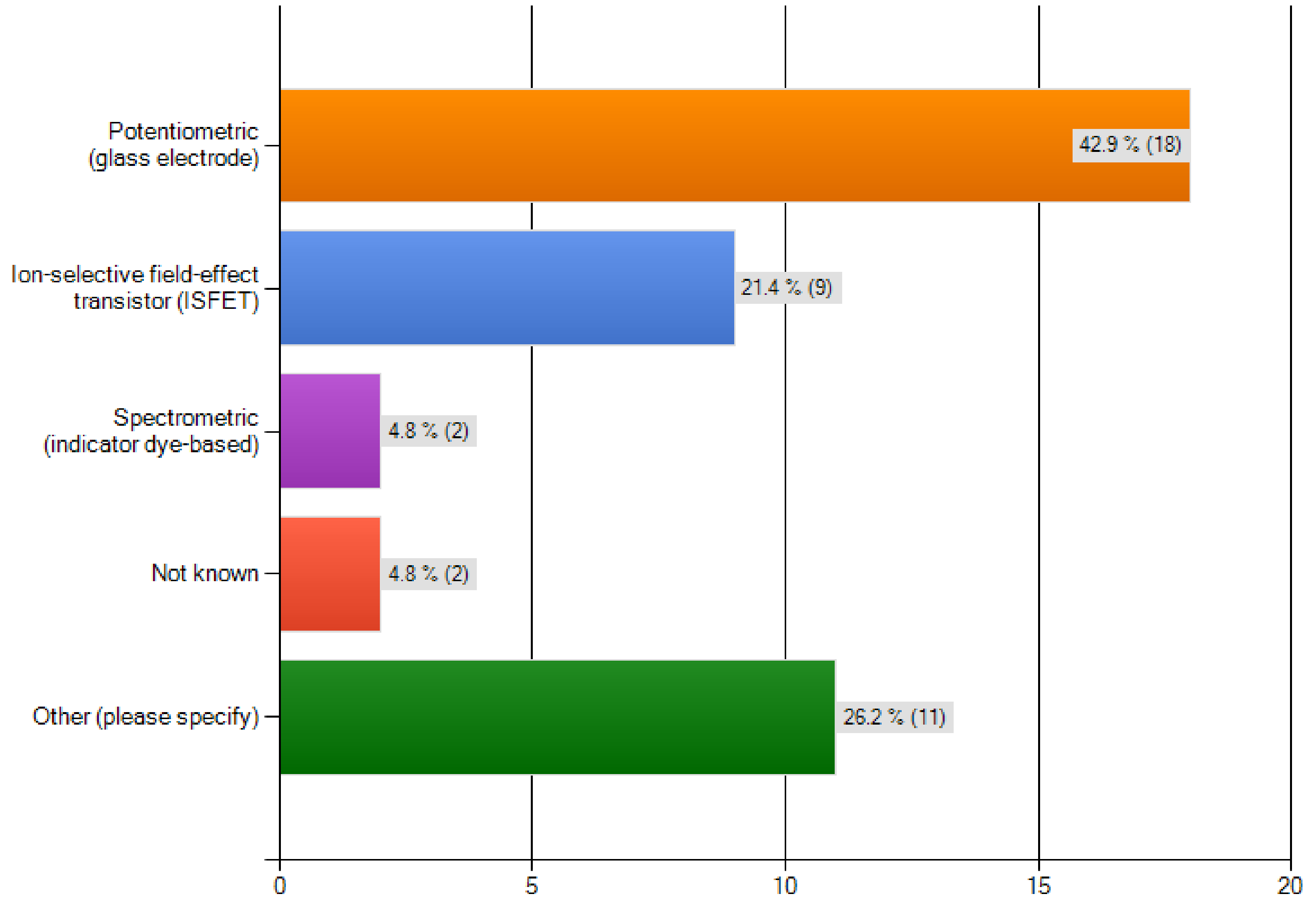
V. SURVEY RESPONSES

This section presents a synthesis of the answers to the survey questions. Survey questions could be answered either quantitatively or as narratives. The results are presented as comprehensibly as possible. Answers with quantitative data are typically shown as bar charts. Each chart shows the percentage of respondents who selected each option. Actual numbers of respondents are shown in parentheses next to the percentages. Simple, quantitative data are at times summarized as narratives and, when applicable, complex narratives summarized and shown graphically. Some answers have both bar charts and narrative summaries below each section. Averages, when used, are shown ± one standard deviation with the number of responses in parentheses.

Understandably, there is bias in such a small, focused survey. Although not comprehensive, we hope that with the careful selection of survey participants, the survey results are exploratory in the way our audience uses in situ pH sensors. ACT hopes to attract as wide an audience as possible while fulfilling our primary mission.

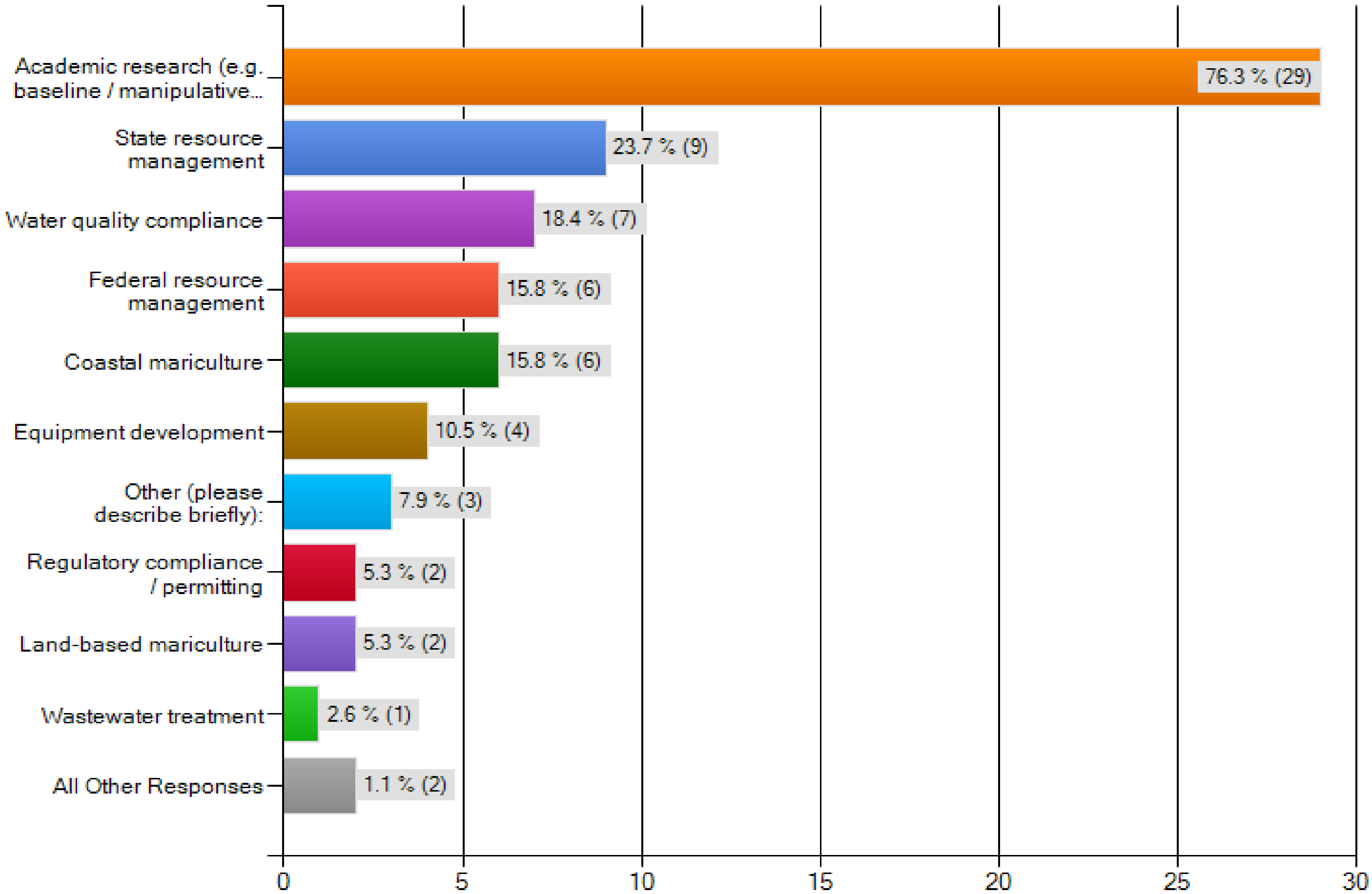
A. Application

1. Indicate the pH instrument technology that you use or anticipate using.



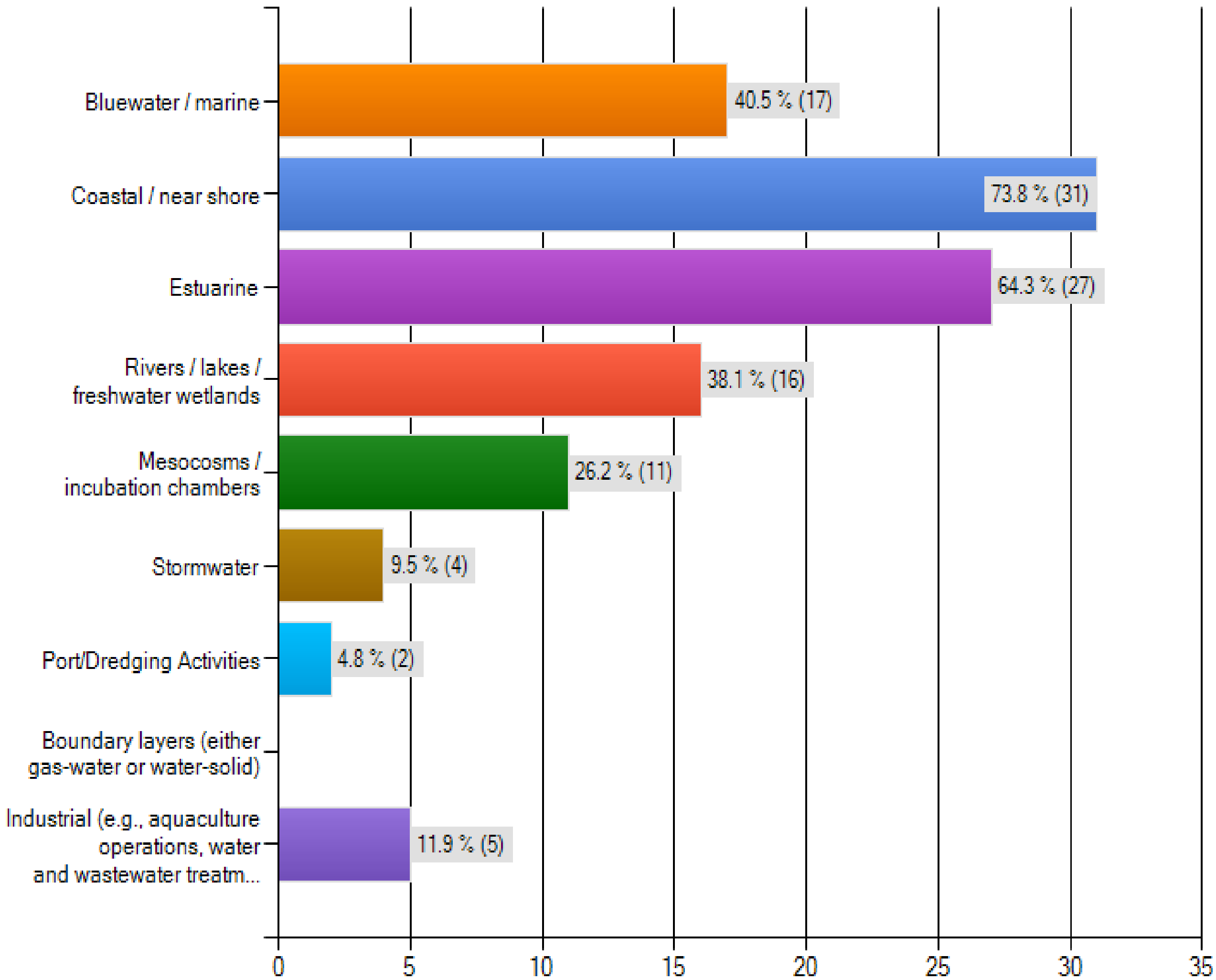
The original survey question allowed respondents to select only one response to this question. This led 11 of 11 respondents in the "Other (please specify)" category to voice this problem and to indicate in the comment section that they used more than one technology. Revising the counts leads to the following corrected results: Potentiometric, 45.0 % (27); ISFET, 31.7 % (19); Spectrometric, 20 % (12); and Not Known 3.3% (2). Corrected, the "Other (please specify)" category now contains 0.0 % (0) responses. Note that the relative order in preference for a given technology did not change as a result of this revision. At present, potentiometric technologies are more common than ISFET, and these are followed by spectrometric technologies. Correcting this problem revealed that more than a quarter of the users surveyed (26.2%) employ multiple units and use more than just one technology.

2. Which two or three activities best represent your intended use of in situ pH data?



"All other responses" combine freshwater aquaculture, effluents and industrial waters, and baseline data acquisition for ocean acidification studies. Contaminant spill response, potable water treatment, and monitoring of dredging and mining operations were not selected

3. In which environments do you collect samples for pH measurement?



Coral reefs and bodily fluids were noted as additional environments.

4. What is your depth range (m)?

The lower depth among the 42 respondents who answered this question averaged 0.2 m (± 0.8 m) and ranged from 0 – 2m with a median depth of 0 meters (surface). The deepest depth averaged 538 m (± 1220 m) with extremes that ranged from 1 to 5000 m; however, the median depth indicated a much shallower depth of only 30 m.

5. What is your salinity range (PSU)?

The main finding with this question is that it is rare among the respondents surveyed to take in situ pH measurements at a single salinity. Those 2.9% (2) respondents who work solely in freshwater understandably work within a narrow range, but another 9.8% (4) reported working either at a single brackish salinity of 16 or within a narrow range of 0 – 8.5 PSU.

The low range of salinities selected by the respondents averaged 14.3 PSU (± 13.9 PSU) with a range from 0 – 36 PSU and a median of 15.0 PSU. The upper high salinity ranged from 5 – 100 PSU, averaging 33.8 PSU (± 14.2 PSU) with a median of 35.0 PSU.

The majority of in situ pH sensor users surveyed (85.3%) appear to work within tiered, discrete salinity ranges, which have in common an end member nominally above oceanic salinities (>36 PSU). Stepping up through the tiers, 31.7% (13) indicated working in a salinity range between 0 – 40 PSU; 14.6% (6) indicated 10 - 35 PSU (although one respondent listed a maximum of 100 PSU). Another 14.6% (6) worked between 20 – 40 PSU. Finally, the remaining 24.4% (10) worked between 30-40 PSU.

6. What is your temperature range (C)?

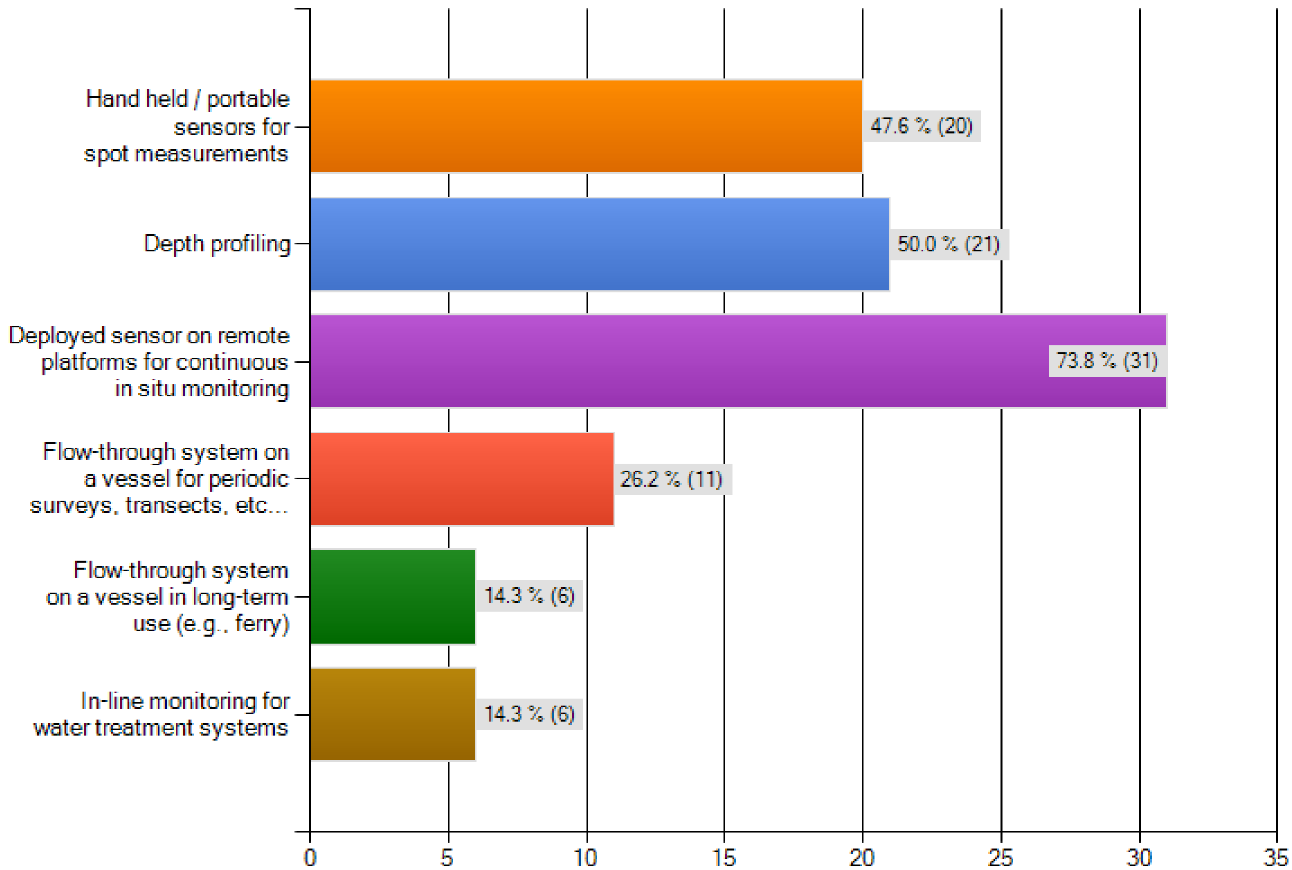
Among the 42 respondents who answered this question, the "low" temperature in their pH working range averaged 4.9°C (± 6.8°C) and ranged from -5–20°C with a median response of 4.0°C. "High" temperature averaged at 27.9°C (± 7.2°C) with extremes that ranged from 15 to 50°C; however, median temperature was 30°C.

7. Please describe the amount and nature of the particles where pH is being measured (e.g. turbid, biological particles, mineral, etc…).

Thirty-nine respondents described the particle load they encountered when measuring pH. One fifth (20.5 %) reported working in clear water with no noticeable turbidity. Two reported the incidence of some biological particles Biofouling was more important than particles in two cases, indicating the similarities in particle-laden water versus relatively clean water but with instruments perhaps fouled, silted and creating a similar sampling environment. CaCO3 from nearby reefs characterized the inorganic particulate load, but this group tended to work in oligotrophic waters. Clays, carbonate silts, aluminosilicates are examples of inorganic particles often encountered. Algae (phytoplankton and crustose algae), invertebrates, and detritus were commonly cited as the most prevalent biological particles.

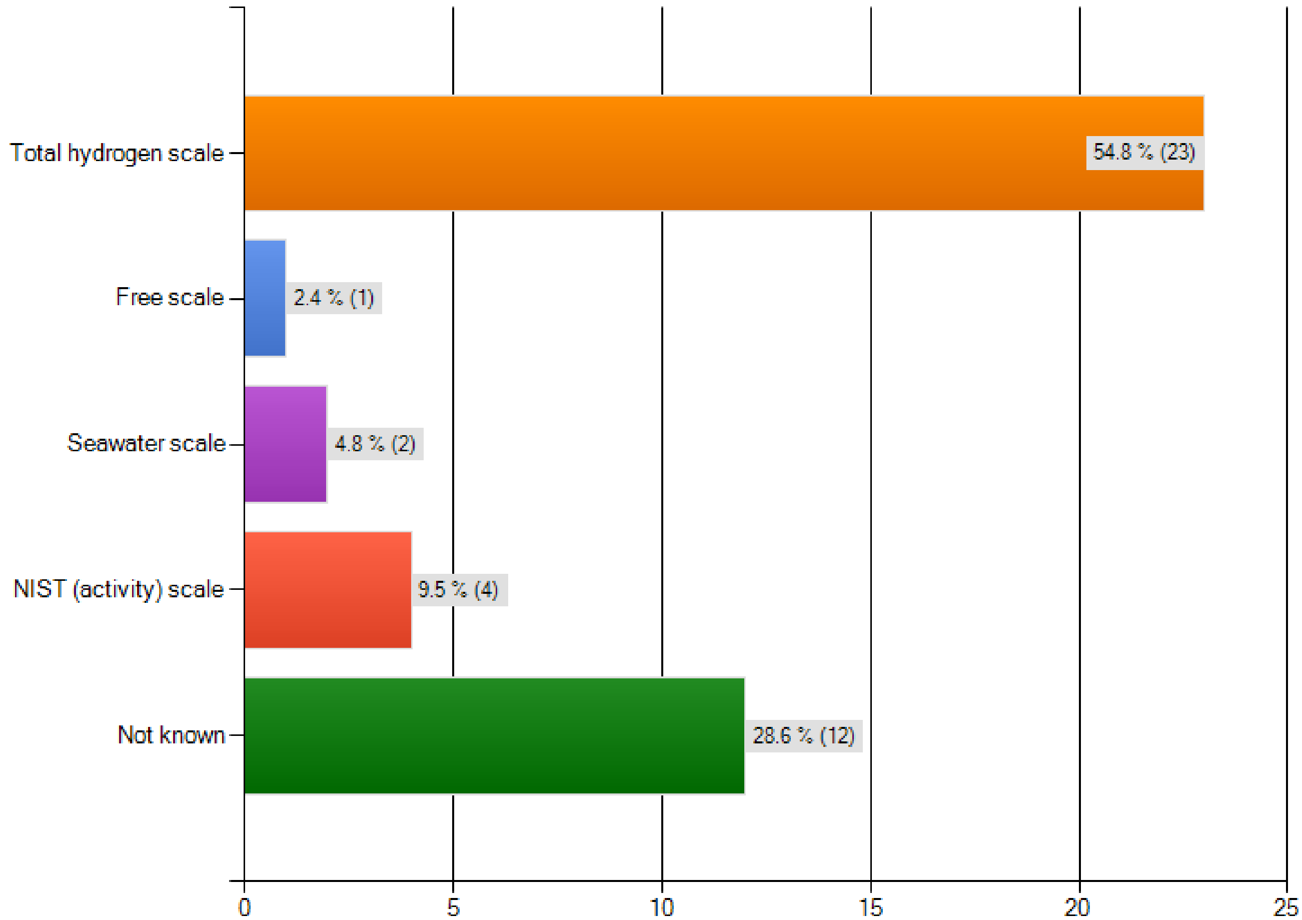
The remaining 79.5% of respondents reported taking pH measurements under turbid conditions, subdivided with 25.6% under consistently turbid conditions and 53.8% under variable turbidity. So, more than half of the respondents surveyed contend with more dynamic conditions such as in estuaries or in waters with short periods of high productivity, blooms, episodes of run-off, near vents, seasonal events, dredging operations, or highly turbid glacial melt. One respondent works in bodily fluids.

8. Which of the following common measurement instrument types apply to how you use pH sensors?

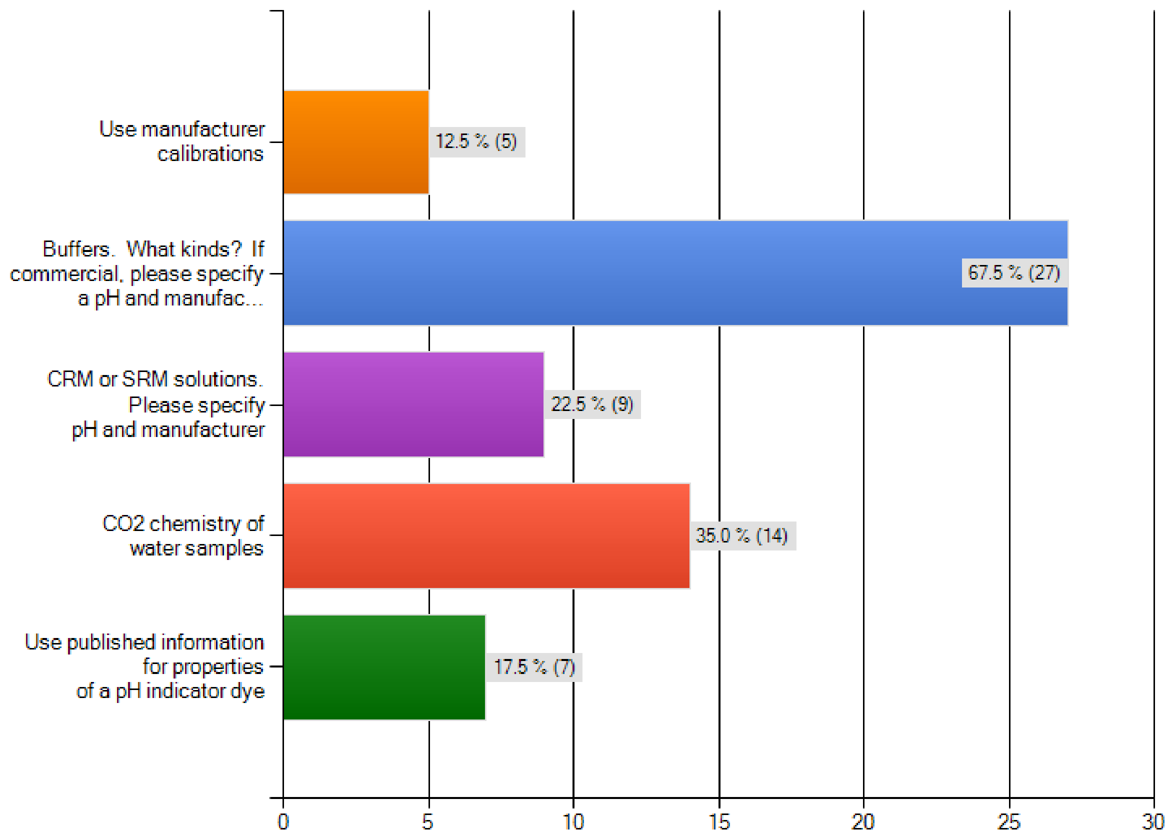


Other. Please describe briefly. Comments included narratives for applications the respondent felt were not easily covered in the survey's choices, although one application was decidedly covered as "depth profiling." One user specified in-line measurement of pH within mesocosms. Another indicated pH sensors used while underway on an AUV. Finally, three users specified more bench-top, laboratory measures for separate samples collected at depth and for general lab analyses for measuring pH of seawater and bodily fluids. While each of these replies could have been shoe-horned into a category above, it is far better to document how pH sensors are actually used. The main point is that in situ pH sensors are clearly used in a number of ways.

9. What pH scale do you use?



10. How do you calibrate your pH measurement?



Twenty-one respondents listed Tris, AMP, recipe-based SOP's, and commercial buffers as standards, although 5 had unknown sources. Some used a variety of solutions and suppliers depending on their application. Combinations of solutions were common. Here is a count based on narratives where a source was given:

Buffers according to Andrew Dickson's (SOP) recipes (5)
Fisher Scientific (3)
Andrew Dickson as a direct source (2)
HACH (2)
VWR (2)
YSI (2)
The Aurical Company (1)
Oakton (1)

11. Do you participate in international, national, or regional pH sensor comparisons?

There were 38 responses to this question: 78.9 % (30) said "yes;" 21.1% said "no." Three of the "no" responses indicate that they have plans to participate, are just beginning a comparison, or anticipate a calibration exercise in the coming year.

12. Do you have records of your calibrations?

Thirty-seven respondents answered this question: 75.7% (28) do have calibration records on file; 24.3% (9) either do not keep calibration records, do not but plan to keep records, or have to check first to see if they keep records on file.

13. Do you have a sensor on a mooring?

This was a very challenging question to translate from the list of 26 who responded and commented; 16 skipped this question. Five respondents claimed not to have a pH sensor mounted on a mooring. The remaining 21 respondents moor and calibrate pH sensors, with the exception of one user (spectrometric) who feels that the calibration is inherent in the properties in the dye used. Deployment and calibration intervals ranged on the scale of years, months, weeks, and days, as respondents tended to answer both mooring and calibration interval questions using these same time scales. No user worked at scales finer than the scale of a day.

Respondents answered both questions in units of years, months, weeks, and days. Assuming a year is 365 days, a month is 30 days, and averaging ranges when given, a rough estimate of both deployment length and calibration interval can be approximated. The overall (a) length of deployment is 561 ± 1202 days with a (b) interval of calibration of 115 ± 136 days. On average, calibration intervals appear to occur at 1/5th the length of a deployment.

Because the data cover such broad time scales, the overall averages and resulting large standard deviations only echo the point that users deploy and calibrate over widely different intervals. We analyzed the patterns and time scales used in the answers and cast the results below into more meaningful data in the context of how our audience uses in situ pH sensors. A very noticeable pattern emerges.

Those who moor at a given time scale tended to calibrate at that same time scale (65%) or they calibrated on next more frequent scale (25%). For example, those who moored pH sensor on a yearly time scale calibrated also within the scale of year; and, if not yearly, then on monthly time scales. Those who had moorings that lasted months tended to calibrate on monthly intervals, or on weekly time scales, and so on. Two users (10%) were the exception to this rule and had moorings out for 1-15 years but calibrated every 2-4 weeks. Generally speaking, however, it is perhaps useful to recognize that among 90% of those surveyed, moored deployments and calibrations take place over similar time frames regardless of whether these time frames are narrow or broad. This does raise the fundamental question of how often an in situ pH sensor should be calibrated and how long they can last in the field and still yield meaningful data?

The same question answered from the overall data above is broken down into yearly, monthly, weekly and daily categories below. In summary, the answer to both questions of mooring length and the interval of calibration is not straightforward. Even when subdivided into finer time scales, the variability in answers is often as large as the means.

If yes, what is

(a) the length of deployment?
Yearly: 4.1 ± 4.4 years (8)
Monthly: 4.7 ± 2.4 months (9)
Weekly: 3.0 ± 1.4 weeks (2)
Daily: 6.3 ± 6.1 days (2)
Overall: 561 ± 1202 days

(b) the interval of calibration?
Yearly: 1.6 ± 1.2 years (4)
Monthly: 3.6 ± 2.1 months (8)
Weekly: 3.4 ± 1.2 weeks (5)
Daily: 4.1 ± 3.0 days (3)
Overall: 115 ± 136 days

14. Do you have a sensor on a profiler? How often is it used, and how often is it calibrated?

Twelve survey participants answered this question; 30 skipped this question. Five of the respondents do not profile; 7 do. Actual responses are given randomly below in the order of how often the profiler is used; how often it is calibrated.

once a year; every use
frequently; frequently
every 5 days; 4 years
2 hourly for 30 minutes; monthly
2 days a month; annually
1-4 times a year; 1-4 times a year
1 time per week; Daily when in use

As in Question 13, profiling occurs on scales of years, months, weeks, and days. By its nature, we expect profiling to yield data on the scales of hours and minutes, but actual profiling intervals appear to vary widely among users. In 4 cases the time frame for calibration is less than or matches the profiling intervals; however, in contrast to moored applications, calibration intervals are much longer in 3 of the cases. In summary, as with Question 13, the answer to both questions of profiling frequency and the interval between calibrations is not straightforward. Converting the responses into units of days and averaging the data does not yield meaningful answers. Again, this raises the question how frequently in situ pH sensors have to be calibrated?

B. Specifications

15. What is the typical pH range for your application?

Forty-one responded to this question with only one respondent skipping it. The low end of the typical users' pH scale fell between a minimum of 4.00 and a maximum of 7.80 with an average pH of 6.60 < 1.09 and median of 7.00. The high end of the range had a minimum pH of 8.00 and a maximum of 11.00, an average pH of 8.47 ± 0.71, and a median of 8.25.

16. What level of overall uncertainty do you require for this application?

0.1: 31.6% (12)
0.01: 39.5% (15)
≤ 0.01: 28.9% (11)
Other. Please describe:

The comments left by 4 respondents are echoed in the response statistics above, but they indicate finer intervals or more defined levels of uncertainty: 0.1-0.01, 0.02 – 0.05, 0.05, and 0.005.

17. What level of reproducibility do you require for this application?

0.1: 30.8% (12)
0.01: 41.0% (16
≤ 0.001: 28.2% (11)
Other. Please describe:

Two respondent comments specify 0.002 and 0.005.

18. Is your pH sensor part of an instrument package?

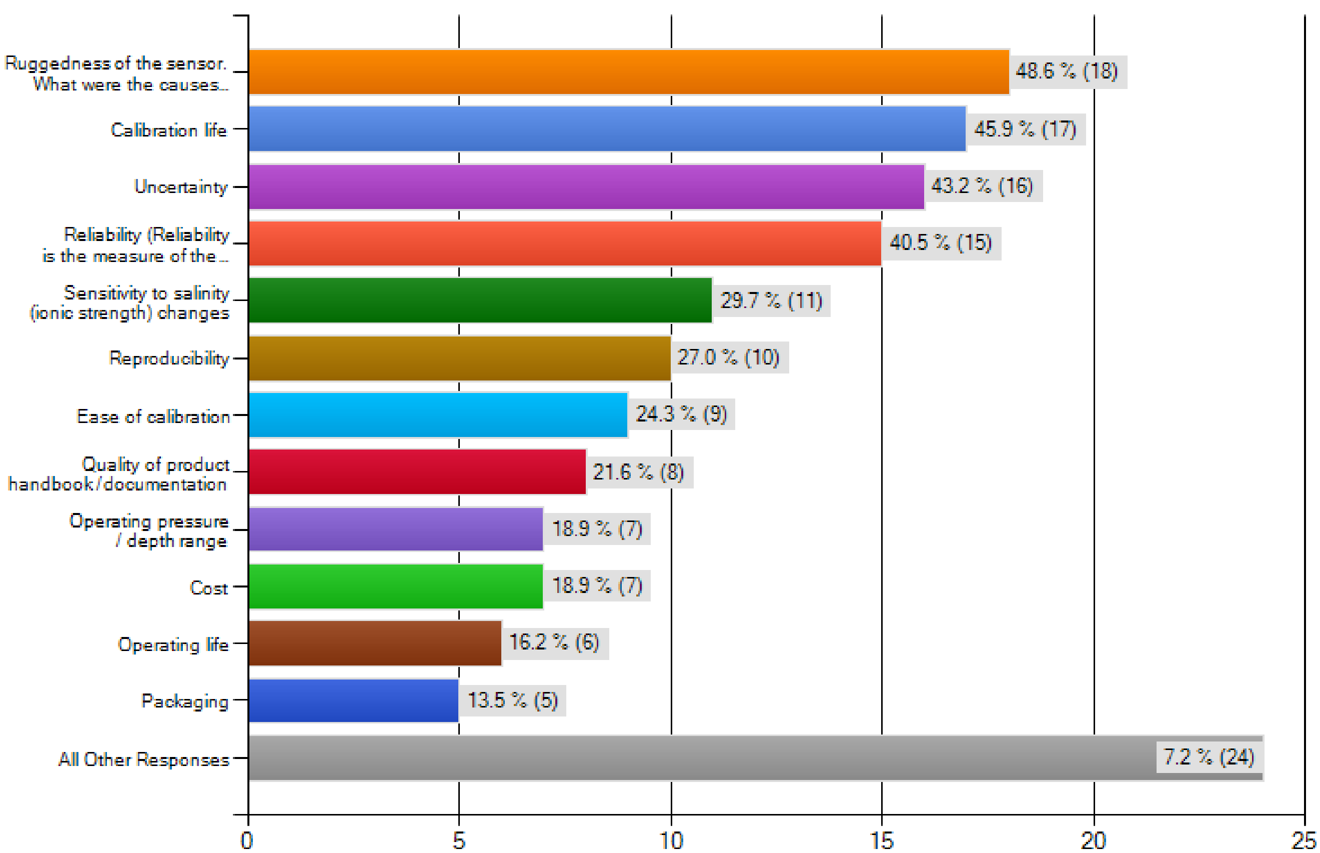
Forty respondents answered; 60.0% (24) indicated that their pH sensor was part of a suite of water quality instruments while 40.0% (16) describe their instrument as a stand-alone.

19. Is your pH sensor a commercial product? a design you developed yourself?

Out of 39 responses 94.9% (37) classify their pH sensor as a commercial product and only 5.1% (2) as a design developed themselves.

20. In which of the following areas do in situ pH sensors that you are currently using have significant limitations? (not performing up to specifications or expectations, nor meet your needs?

The top 12 categories with the most significant limitations are shown in descending order in the figure below.



Range/detection limits, Specificity or Interferences (the ability to separate a pH signal from other signals), Automatic calibration, and I/O Interfaces each received 4 responses. Real-time sensor data display and In-field maintenance each received 2 responses. Sampling Interval and Flow Sensitivity received no responses for in situ pH sensors currently in use.

Actual User Responses (edited):

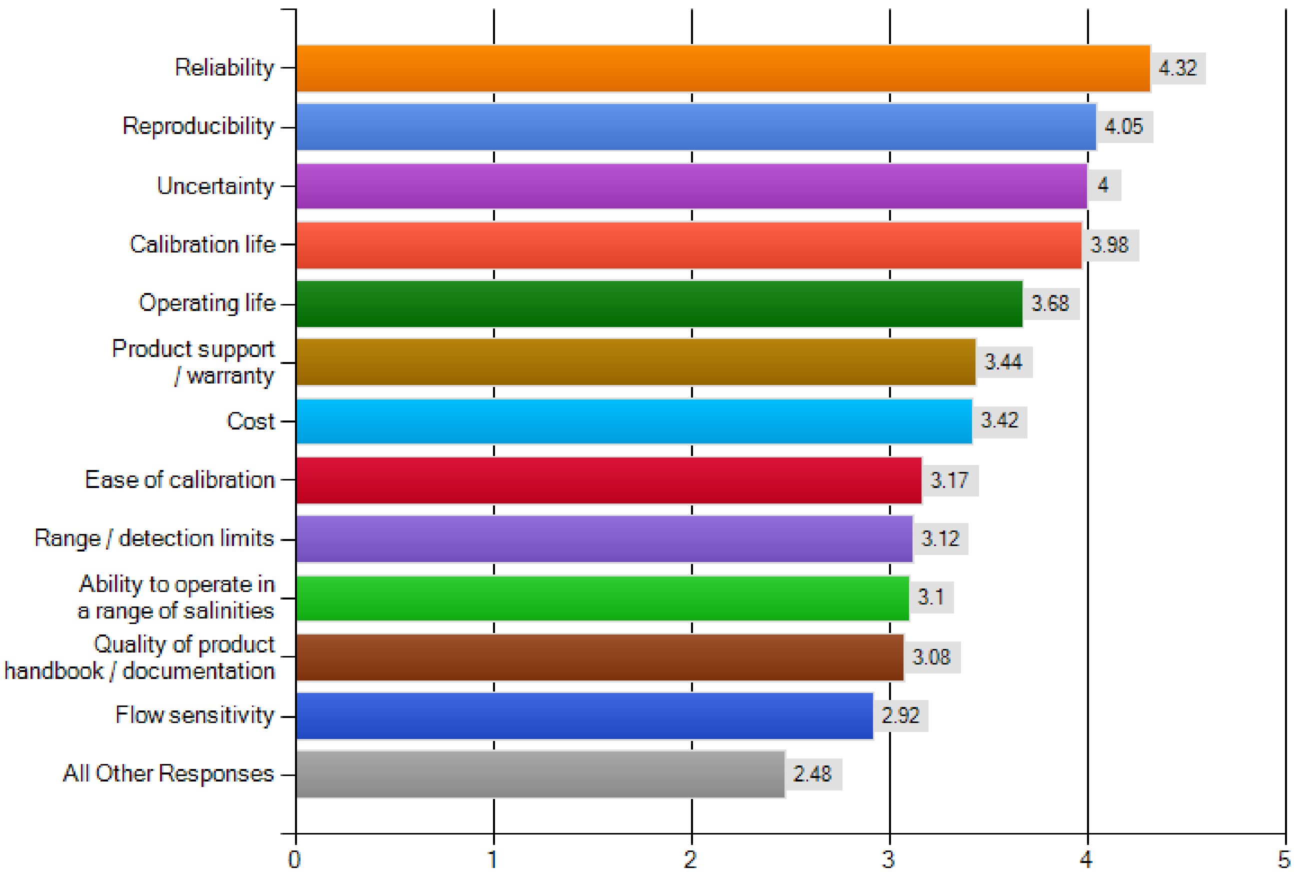
- We'd like to have better accuracy and precision to at least 0.01 as we seldom use our existing pH data due to the sensor's poor resolution and accuracy.
- Unsure as to the causes of sensor failure, but we have had sensors that would not calibrate correctly and had to be replaced by the manufacturer.
- Over 6 months of use: clogging of the intake tubing due to suspended sediment in shallow areas.
- One instrument noisy due to LED quality or low life time (?)
- Poor packaging (replacing the battery is difficult).
- No way in software to adjust the calibration (for example after replacing the dye), no way in software to post-process the data with salinity given by another instrument.
- We observe an increased difference in pH between probe data and spec measurements with increased depth. It seems there is a non-linear relationship between pressure and probe pH. Currently trying to resolve this issue. Furthermore, we have had difficulty keeping our sensors working for more than 2 years before the housing leaks, the probe fails, etc...
- Calibration techniques and standards.
- We know very little about the uncertainty and reproducibility of these sensors in the real environment. We know less about responses characteristics in changing temperature, pH and salinity which is the real world.
- Commercially available seawater buffers for calibration have been the biggest issue for use.
- "We have used pH sensors at depth, which were pretty poor. Large pH drift, short (<days) calibration confidence due to drift. Deployment depth of ~3000 m. There wasn't anything else available.
- We are now using ISFET pH sensors in the lab - they are fantastic. We have also deployed a coupled on small benthic moorings at 100 m depth - this is near or over their max depth range. Hope to see great data when they are recovered!
- Sensor is frustratingly slow to calibrate and VERY slow to stabilize in low ionic strength waters. I recently was introduced to a new pH probe at a workshop in 9/2011 at University of Michigan Biological Station. This sensor appears to not have many of the problems associated with traditional ISE pH sensors (e.g. calibration frequency, life expectancy) and I may use this in the future.
  I do not have any sensors yet, but wish to deploy pH sensors at my coral calcification monitoring stations on the outer reef tract, Florida Keys, USA
- Availability-sensors are being custom built by one lab (not truly commercially available). There are reliability issues in that as a small production group, not every sensor has proven to work in the field consistently.
- Been using the glass bulb technology with is very sensitive and needs to be calibrated/cleaned often. Accuracy is the real issue.
- Our current favored pH system for the ship-of-opportunity measurements that I do would be an ISFET pH system. However, we pretty much need to collect and measure discrete samples for DIC and TA to standardize our measurements. This seems to work adequately in bluewater settings, but is definitely an issue in coastal and estuarine environments in that calculated pH values will be off where dissolved organic matter changes alkalinity.
- Biofouling

C. Recommendations

21. How important are the following characteristics to you when using pH sensors in the field? Please enter a value between 1-5 for each box, where:

1 = not at all important
5 = very important

The top 12 characteristics are scored, sorted, and shown in descending order in the figure below:



All other responses cumulatively averaged a score of 2.48 in importance and included 8 categories; however, In-field maintenance tied with Flow sensitivity for a score of 2.92.

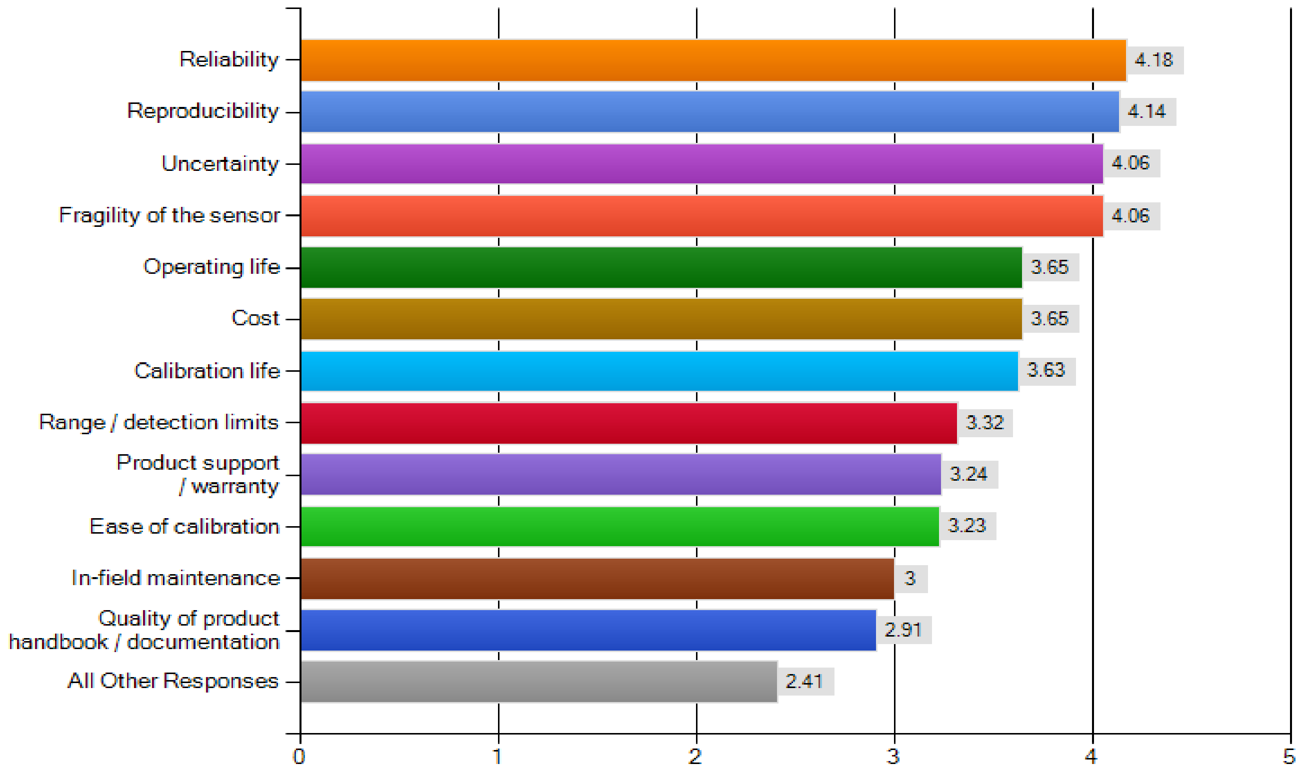
The scores for the remaining 7 categories are:
Sampling interval / frequency, 2.82; Operating pressure / depth range, 2.68; Real-time sensor data display and/or analysis, 2.46; Packaging, 2.31;Input / output interfaces (e.g., computers, alarms, etc....), 2.26; Automatic calibration, 2.23; and Off-sensor telemetry, 2.13. No single category stood out as "not at all important." All scores were greater than 2.

Other(s). Please describe briefly: Comments left by 5 respondents merely echoed the categories given above.

22. How important are the following characteristics to you when deciding which pH sensor to purchase? Please enter a value between 1-5 for each box, where:

1 = not at all important
5 = very important

The top 12 characteristics are scored, sorted, and shown in descending order in the figure below:



The scores for the remaining 8 categories are:
Sampling interval / frequency, 2.76; Operating pressure / depth range, 2.67; Flow sensitivity, 2.53; Real-time sensor data display and/or analysis, 2.48; Automatic calibration, 2.39; Input / output interfaces (e.g., computers, alarms, etc), 2.21; Packaging, 2.21; Off-sensor telemetry, 2.06. As in Question 21, no single category stood out as "not important at all." All scores were greater than 2.

Two respondents commented and asked how Question 22 was fundamentally different from Question 21? Both questions contain a number of categories we ask our participants to attempt to prioritize and somehow rank. Both questions are clearly exploratory in their primary objectives. We paired the questions to look for major shifts in point value among identical categories as the respondents prioritized characteristics in what they actually use versus what they desire. In this survey, cost, predictably, became more of a concern and climbed 0.22 points, but none of the paired categories moved more than a half a point. Note that pH sensor reliability, data reproducibility, and data uncertainty remain unchanged as the top three most important characteristics in using or choosing to purchase an in situ pH sensor. It is interesting to note that one respondent felt that this question was also irrelevant, but for a different reason. As a resource manager, he was required to use specific pH sensor and did not have a choice, so he did not answer this question.. If you build sensors either as a sensor developer or as a manufacturer, or you are an administrator gathering recommendations on what to buy, we hope this data is of value as end users are often not included in the decision process.

23. Relative to the above (Questions #21 and #22) sensor system characteristics, are any of your sensor needs or requirements "non-standard" or custom made? If yes, please describe.

Yes : 18.9 % (7)
No: 81.1% (30)

Four respondents left comments. Two recognize that ISFET sensors could have a greater working depth for profiling applications, and those systems that do work at depths greater than 500 m are hard to find and thus mostly nonstandard. Another respondent uses an ISFET pH system that has been augmented with custom electronics allowing an external reference sensor. These systems are built in the laboratory of an academic colleague. Another non-standard sensor requirement is the need to develop protocols or calibration standards that would allow easier pH measurements across changing ionic strengths. A final sensor need that is non-standard involves mounting in situ pH sensors on non-standard platforms (such as on plankton nets).

24. Are you happy with your present pH sensor?

Yes : 47.4 % (18)
No: 52.6% (20)

25. Do you plan on acquiring new commercial sensors within the next 2 years?

Yes: 75.0% (30)
No: 25.0% (10)

Nineteen respondents of the 30 who said that they do plan on acquiring new commercial sensors went on to answering the following question:

If yes, will you consider a different sensor type than the one you are currently using to measure pHs?

Fourteen respondents said yes; two on the condition that the different sensor type still fit either their existing sonde or CTD. Two respondents were decidedly not happy with their existing potentiometric sensors and were searching for new technologies and/or manufacturers. One respondent is looking specifically for better accuracy and precision so they can actually use their data. The remaining respondents were in large part imply interested in trying out new sensors and trying to find something better, particularly those pH sensors employing spectrophotometric and ISFET technologies, or they were purchasing multiple field-deployable sensors and perhaps could afford to evaluate other sensor types. Finally, two respondents specified that any newer model be based on field robust design with increased reliability, rapid response and the capability of operating over a good depth range. Both specifically cited sensors built around a small form-factor response; one user cited the smallest form factor for use on a mobile sensing platform (AUV).

Five respondents said they would not consider a different sensor type than the one they are currently using to measure pH. Reasons include the fact that their current sensors work well, particularly those favored to be used in seawater. This group tended to use ISFET technology and is pleased with the accuracy and stability these offer. One respondent is very happy with the group that is helping design their sensors.

26. How much are you willing to pay for a new sensor?

Prices among the 26 who answered this question ranged from $200 to $20,000, spanning three orders of magnitude. This broad data pattern reveals the many levels of in situ pH sensor users. Note that a $1.30/Euro exchange rate (as of 12/31/11) was applied to the international responses to normalize all results to US dollars.

Breaking down responses according to order of magnitude, 23.1 % wanted to spend no more than $1000 for an in situ pH sensor ($500 ± $253), 50.0% were willing to pay between $1000 but no more than $10,000 ($2731 ± $1943), and 26.9 % were willing to pay $10,000 or more ($13,643 ± $4130). This latter group was most likely to add conditionals to a higher price, such as the requirement that the sensors possess superb performance characteristics, or that they have the funding in place to afford the gain in performance.

27. Based on your experience with in situ pH sensors, are there any modifications or design additions that you would recommend?

Comments from 21 respondents on in situ pH sensor user recommendations were captured as narratives and are summarized below. Note that references to specific makes and models of in situ pH sensors were not mentioned, so some of the recommendations may not apply to all sensors.

Modification and design modifications fell into several broad categories of areas for improvement. Users typically cited more than one area, and most of these areas are somewhat inter-related. Improvements in calibration, for instance, was the largest category, and recommendations here overlapped with biofouling and design recommendations. Users want to be able to perform in situ calibrations and to be able to cover a broad range of oceanic salinities, temperatures, and pressures. Most would at least like to be able to do easy reliable calibrations out in the field if not in situ. Calibration functions should be built into the units and calibration procedures available to the users. Selectable pH scales would be a desirable feature.

Adding biofouling control was a chief design recommendation. Sensors could be encased in copper as standard practice in biofouling environments. The aforementioned improvements in active biofouling control are linked to improved calibration in the sense of extending calibration life. Long life expectancy in a sensor includes a slow loss in calibration.

Design recommendations include more durable construction for field use and sensors designed for deep water use. Divers have complained about positively buoyant in situ sensors. Perhaps these sensors could be housed in packages that are neutrally buoyant or slightly negatively buoyant underwater to prevent the units from floating away from divers. Pumps could be added to units to provide flow-through measurements. More data offload options like real-time data transmission or telemetry are needed.

Better protection of the reference electrode from seawater intrusion to avoid significant drift. One respondent recommends that a sensor have a more straightforward way to be grounded (if necessary) during calibration. In this instance, during calibration the user was advised to ground the sensor with a wire. However, the output voltage changed depending on how the wire was grounded (fully in solution versus only the end of the wire in solution).

General recommendations to improve accuracy/repeatability in pH sensors rounded out the comment section, often tied in with the aforementioned design modifications and steps to improve overall longevity. Finally, performance recommendations of accuracy include increased consistency of measurements between sensors.

Ref. No. [UMCES] CBL 2012-053

ACT Headquarters
c/o University of Maryland Center of Environmental Science
Chesapeake Biological Laboratory
Post Office Box 38
Solomons, Maryland 20688-0038
Email: info@act-us.info