Responsive Management

USE OF, SATISFACTION WITH, AND REQUIREMENTS FOR IN-SITU NUTRIENT SENSORS

Conducted for the Alliance for Coastal Technologies

by Responsive Management

2005

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EXECUTIVE SUMMARY

This study was conducted for the Alliance for Coastal Technologies (ACT) to gather data about the use of in-situ nutrient sensors. The study entailed a telephone survey of professionals in the coastal resources field, such as biologists, researchers, and coastal managers, who are currently involved in measuring nutrients. For the survey, telephones were selected as the preferred sampling medium because of the universality of telephone ownership. The telephone survey questionnaire was developed cooperatively by Responsive Management and the ACT. Responsive Management conducted a pre-test of the questionnaire, and revisions were made to the questionnaire based on the pre-test.

Interviews were conducted Monday through Friday from 9:00a.m. to 9:00p.m., Saturday noon to 5:00p.m., and Sunday from 3:00p.m. to 9:00p.m., all local time. The survey was conducted in February 2005. Responsive Management obtained a total of 56 completed interviews. The software used for data collection was Questionnaire Programming Language 4.1. The analysis of data was performed using Statistical Package for the Social Sciences software as well as proprietary software developed by Responsive Management.

NUTRIENTS AND AQUATIC ENVIRONMENTS OF INTEREST

- Overwhelmingly, respondents listed their primary area of interest as research (79%), while 14% listed their primary area of interest as resource management; however, the question asked for the *primary* area of interest and allowed only one response, and some of those who listed their area of interest as research indicated that they also had resource management responsibilities.

- Respondents who indicated that they are currently measuring nutrients can be categorized as follows: those who use in-situ nutrient sensors and those who do not use in-situ nutrient sensors. Those who do not use in-situ nutrient sensors were asked about the use of in-house sample analyses, outside laboratory for analyses, or both for measuring nutrients.

- The nutrients most of interest/concern are nitrates/nitrites (98% said they are interested/ concerned with these), phosphates (98%), ammonium (88%), and silicate (70%).
  - An overwhelming majority of respondents (88%) are measuring nitrates/nitrites.
  - A large majority of respondents (79%) are currently measuring phosphates.
  - A large majority of respondents (70%) are currently measuring ammonium.
  - A slight majority of respondents (55%) are currently measuring silicate.
  - A fifth of respondents (20%) indicated that they are currently measuring other nutrients (other than nitrates/nitrites, phosphates, ammonium, and silicate). Other nutrients of interest include nitrogen, carbon, and various metals.

- The top aquatic environment of interest is estuarine, followed by coastal/nearshore, open ocean, and rivers/lakes/freshwater wetland/groundwater. Water depths of interest appear to be evenly distributed among shallow, intermediate, and deep water.

REASONS FOR NOT MEASURING PARTICULAR NUTRIENTS OR NOT USING IN-SITU SENSORS

- Cost, lack of time, and technical expertise limitations are three important constraints to use of in-situ sensors, among those not currently measuring a nutrient of interest.

- Cost and lack of confidence in data are the top constraints to use of in-situ nutrient sensors, among those not using an in-situ nutrient sensor.
  - In a related question, when respondents were asked if they had plans to purchase new commercial sensors within the next 2 years, those who did not have plans most commonly cited lack of need and cost.

SPECIFIC PROCEDURES/ASPECTS OF MEASURING NUTRIENTS

- About half of the sample of coastal professionals (48%) currently use in-situ nutrient sensors, and these are typically commercial products, although a substantial percentage are a combination of commercial and custom-made.

- The most common application for nutrient sensors is as a deployed sensor on a remote platform for continuous in-situ measurements.

- A majority of those who use in-situ nutrient sensors take measurements hourly (59%), by far the leading answer.

- About a third of respondents (34%) are required to use specific approved analytical techniques and procedures, most commonly EPA-approved methods.

- Nearly a third of respondents (29%) said their sensor needs or requirements are non-standard.

- In-situ nutrient sensors are used by majorities of respondents for absolute concentrations (73%) as well as for relative changes (55%) in the nutrient(s) being measured.

- A majority of coastal professionals (68%) measure nutrients in µM (micromolars), while 40% measure nutrients in mg/l (milligrams per liter); these percents include the 11% who measure using both.

- Nearly a fifth of respondents (18%) indicated that there are detection limits for nutrients that they measure that are set by regulations or other needs of the data.

- An overwhelming majority of respondents conduct their own absolute calibrations (83%).

- An overwhelming majority of coastal professionals (81%) use in-house sample analyses to measure nutrients at least some of the time, with most of those using in-house sample analyses exclusively; 38% contract with a laboratory to conduct analyses at least some of the time, with about half of those using an outside lab exclusively.

- The performance characteristics of most importance are reliability, accuracy, precision, range/detection limits, and key operational parameters.

- The overwhelming majority of those who plan to purchase new commercial sensors within the next 2 years (85%) will have a trained person on staff to operate the new sensor.

LIMITATIONS OF SENSORS

- Cost, reliability, and in-field maintenance are the top areas in which current in-situ nutrient sensors have limitations, do not meet expectations, or do not meet needs.

- Ease of calibration, reliability/durability/maintenance, analytical time, hardware, software/data management, and range/detection limits are the top areas in which in-house sample analyses have limitations, do not meet expectations, or do not meet needs—all of these responses had more than 20% giving the answer (of those who use in-house sample analyses as opposed to those who use an outside subcontract laboratory for analyses).

- Analytical time is the top limitation on contracted laboratory analyses.
  - 40% indicated that their contracted laboratory analyses had no significant limitations.

PURCHASING NEW SENSORS

- A little less than half of respondents (46%) indicated plans to purchase new commercial sensors within the next 2 years.
  - The overwhelming majority of those who plan to purchase new commercial sensors within the next 2 years will have a trained person on staff to operate the new sensor.
  - Many respondents indicated that they will consider a different type of sensor type than the one they are currently using.
  - Common reasons for planning to purchase new commercial sensors include an interest in new technology/new technology will address needs, facility/program expansion, and for replacement (other answers added a caveat regarding availability of funding).
  - Common constraints to purchases of new commercial sensors are lack of need and cost.

- Regarding what respondents (those who plan to acquire/purchase new equipment and will consider a different sensor type) require or would like to see in terms of customer support:
  - 16 of the 20 respondents mentioned the need for training of some kind, and 11 of them specifically said *on-site* training
  - 4 respondents specifically mentioned on-site set-up (these 4 also said on-site training).
  - 7 mentioned ongoing support (4 wanted telephone support, 1 wanted on-line support, 2 did not specify medium of support).
  - 3 mentioned a good manual.

TABLE OF CONTENTS

INTRODUCTION AND METHODOLOGY

This study was conducted for the Alliance for Coastal Technologies (ACT) to gather data about the use of in-situ nutrient sensors. The study entailed a telephone survey of professionals in the coastal resources field, such as biologists, researchers, and coastal managers, who are currently involved in measuring nutrients. Specific aspects of the research methodology are discussed below.

For the survey, telephones were selected as the preferred sampling medium because of the universality of telephone ownership. In addition, a central polling site at the Responsive Management office allowed for rigorous quality control over the interviews and data collection. Responsive Management maintains its own in-house telephone interviewing facilities. These facilities are staffed by interviewers with experience conducting computer-assisted telephone interviews on the subjects of natural resources. The telephone survey questionnaire was developed cooperatively by Responsive Management and the ACT. Responsive Management conducted a pre-test of the questionnaire, and revisions were made to the questionnaire based on the pre-test.

To ensure the integrity of the telephone survey data, Responsive Management has interviewers who have been trained according to the standards established by the Council of American Survey Research Organizations. Methods of instruction included lecture and role-playing. The Survey Center Managers conducted project briefings with the interviewers prior to the administration of the survey. Interviewers were instructed on type of study, study goals and objectives, handling of survey questions, interview length, termination points and qualifiers for participation, interviewer instructions within the survey instrument, reading of the survey instrument, skip patterns, and probing and clarifying techniques necessary for specific questions on the survey instrument. The Survey Center Managers randomly monitored telephone workstations without the interviewers' knowledge to evaluate the performance of each interviewer. After the surveys were obtained by the interviewers, the Survey Center Managers and/or statisticians edited each completed survey to ensure clarity and completeness.

Interviews were conducted Monday through Friday from 9:00a.m. to 9:00p.m., Saturday noon to 5:00p.m., and Sunday from 3:00p.m. to 9:00p.m., all local time. A five-callback design was used to maintain the representativeness of the sample, to avoid bias toward people easy to reach by telephone, and to provide an equal opportunity for all to participate. When a respondent could not be reached on the first call, subsequent calls were placed on different days of the week and at different times of the day. The survey was conducted in February 2005. Responsive Management obtained a total of 56 completed interviews.

The software used for data collection was Questionnaire Programming Language 4.1 (QPL). The survey data were entered into the computer as each interview was being conducted, eliminating manual data entry after the completion of the survey and the concomitant data entry errors that may occur with manual data entry. The survey instrument was programmed so that QPL branched, coded, and substituted phrases in the survey based on previous responses to ensure the integrity and consistency of the data collection. The analysis of data was performed using Statistical Package for the Social Sciences software as well as proprietary software developed by Responsive Management.

Note that some results may not sum to exactly 100% because of rounding.

NUTRIENTS AND AQUATIC ENVIRONMENTS OF INTEREST

- Overwhelmingly, respondents listed their primary area of interest as research (79%), while 14% listed their primary area of interest as resource management; however, the question asked for the *primary* area of interest and allowed only one response, and some of those who listed their area of interest as research indicated that they also had resource management responsibilities.

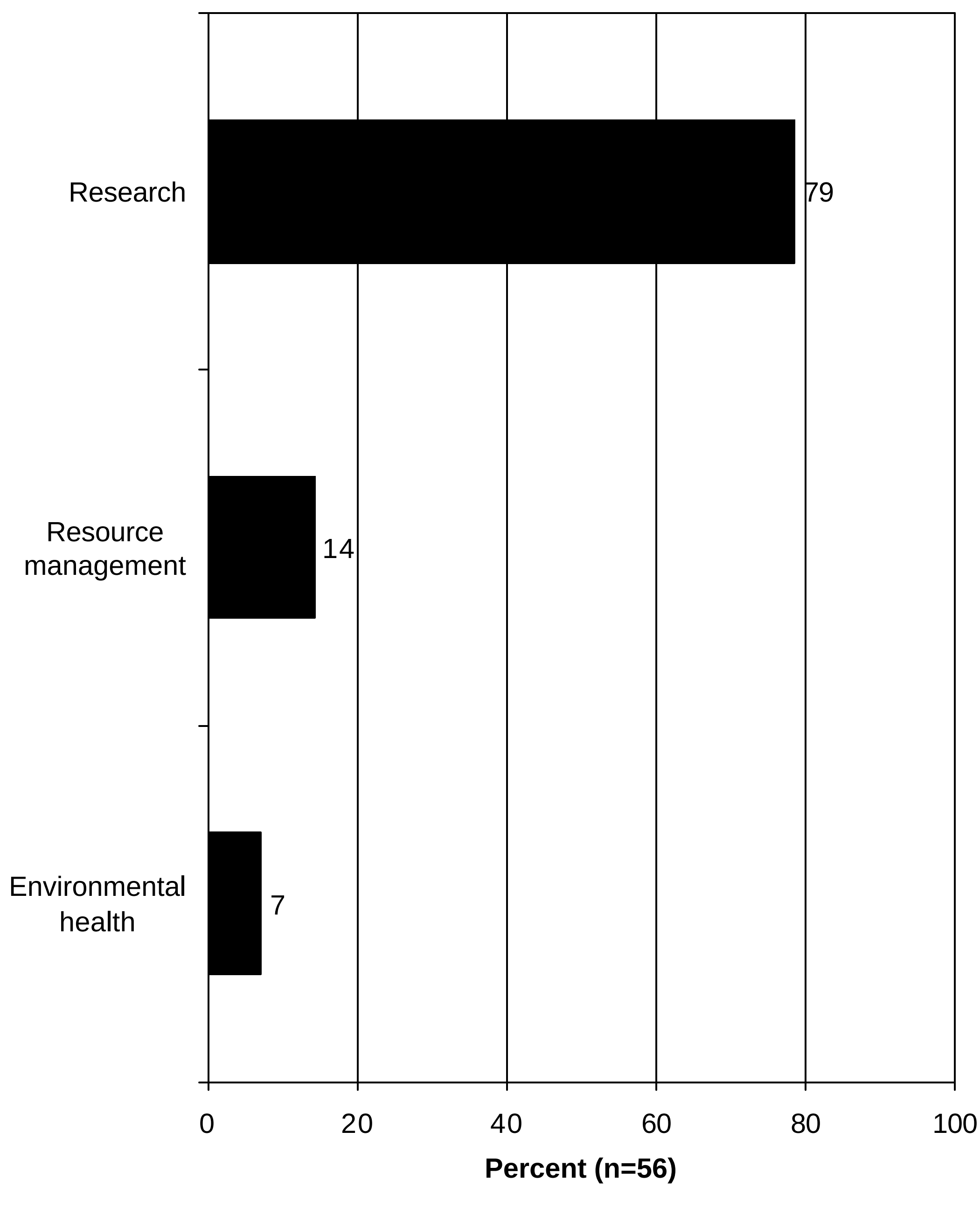
- Respondents who indicated that they are currently measuring nutrients can be categorized as follows: those who use in-situ nutrient sensors and those who do not use in-situ nutrient sensors. Those who do not use in-situ nutrient sensors were asked about the use of in-house sample analyses, outside laboratory for analyses, or both for measuring nutrients. A small percentage of those who do not use in-situ nutrient sensors indicated that they use a method other than in-house or outside laboratory analyses (these graphs are shown in the section of the report titled, "Specific Procedures/Aspects of Measuring Nutrients").

- The nutrients most of interest/concern are nitrates/nitrites (98% said they are interested/ concerned with these), phosphates (98%), ammonium (88%), and silicate (70%).

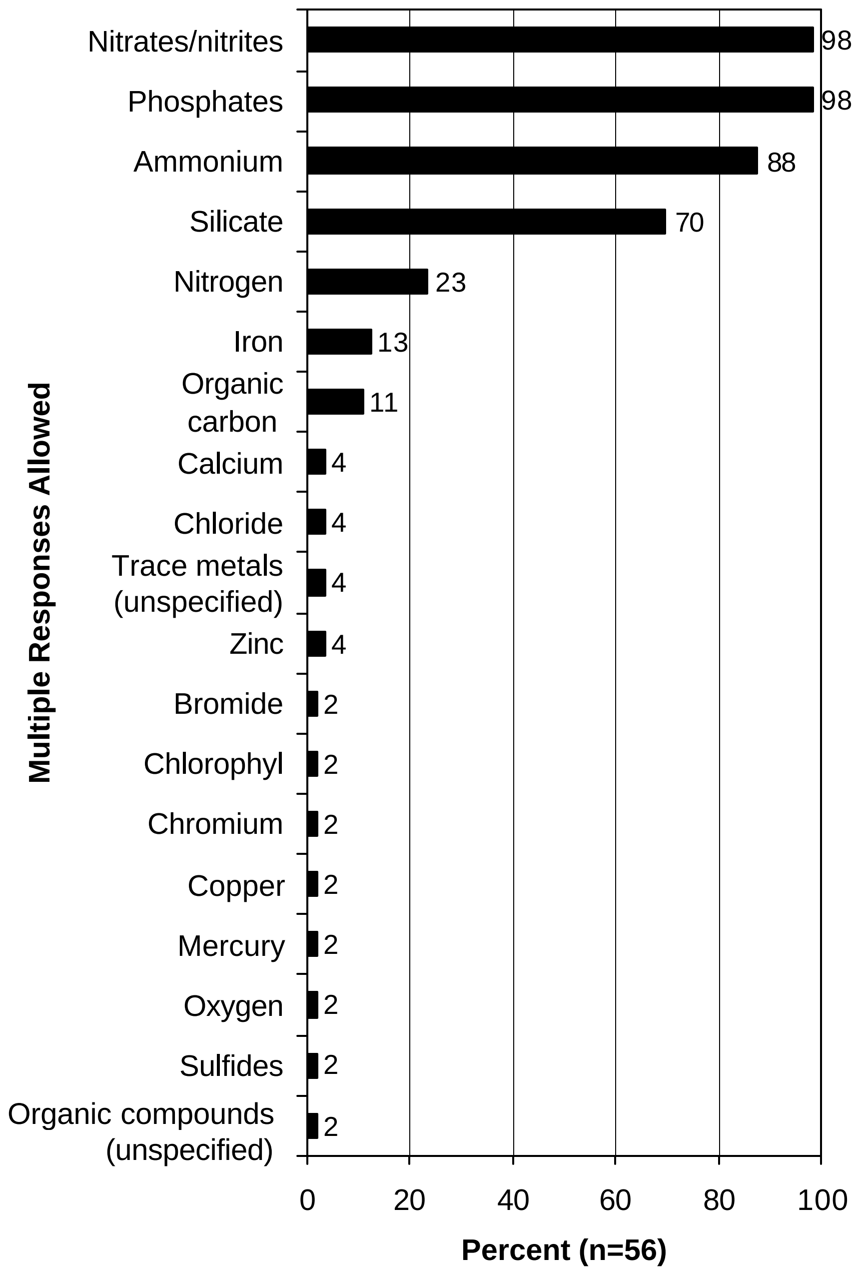
- The top aquatic environment of interest is estuarine, followed by coastal/nearshore, open ocean, and rivers/lakes/freshwater wetland/groundwater. Water depths of interest appear to be evenly distributed among shallow, intermediate, and deep water.

- The organizations of the respondents are listed in the section of this report titled, "Characteristics of Sample."

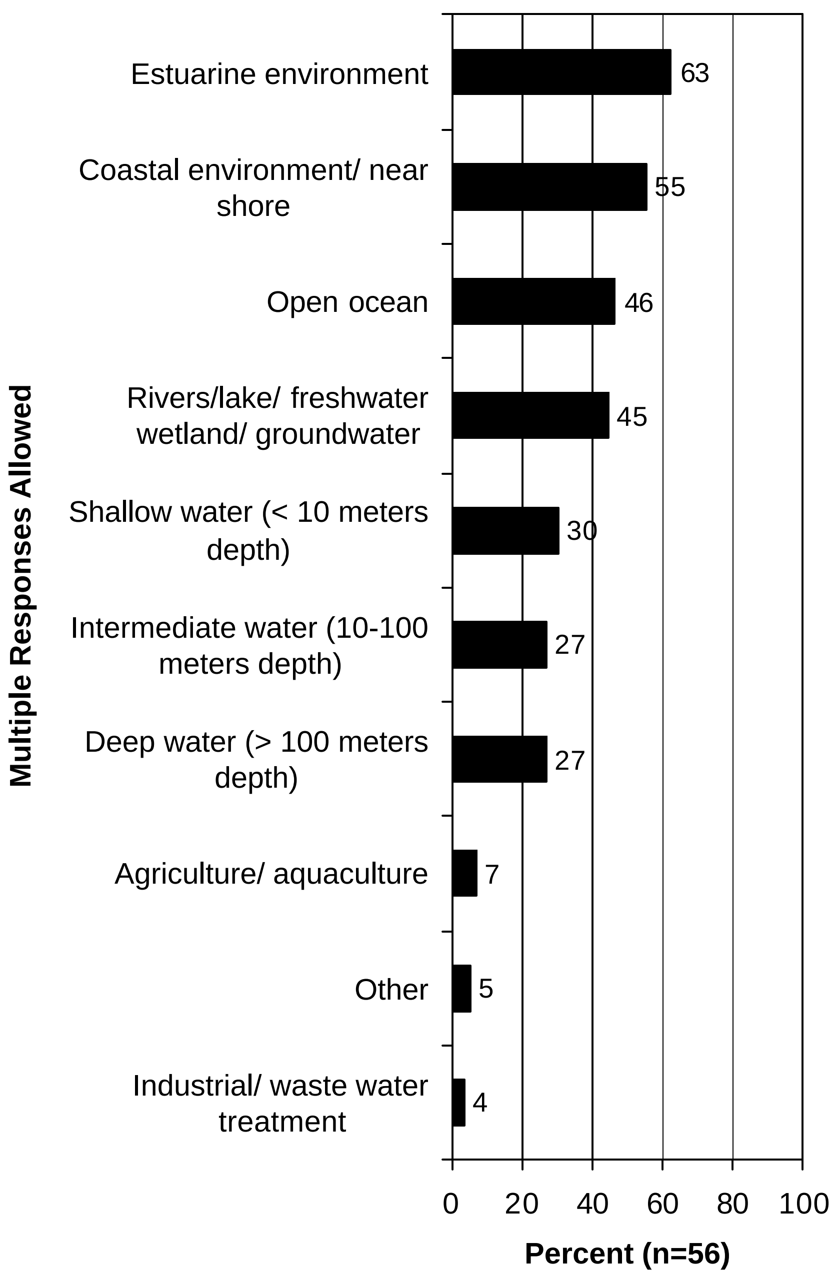
Q6. Which of the following best describes your primary area of interest or application concern?



Q9, 10, and 12-16. Which of the following nutrients are of interest or concern for you?



Q101. Which of the following describes your primary investigated/monitored aquatic environment?



NITRATES/NITRITES

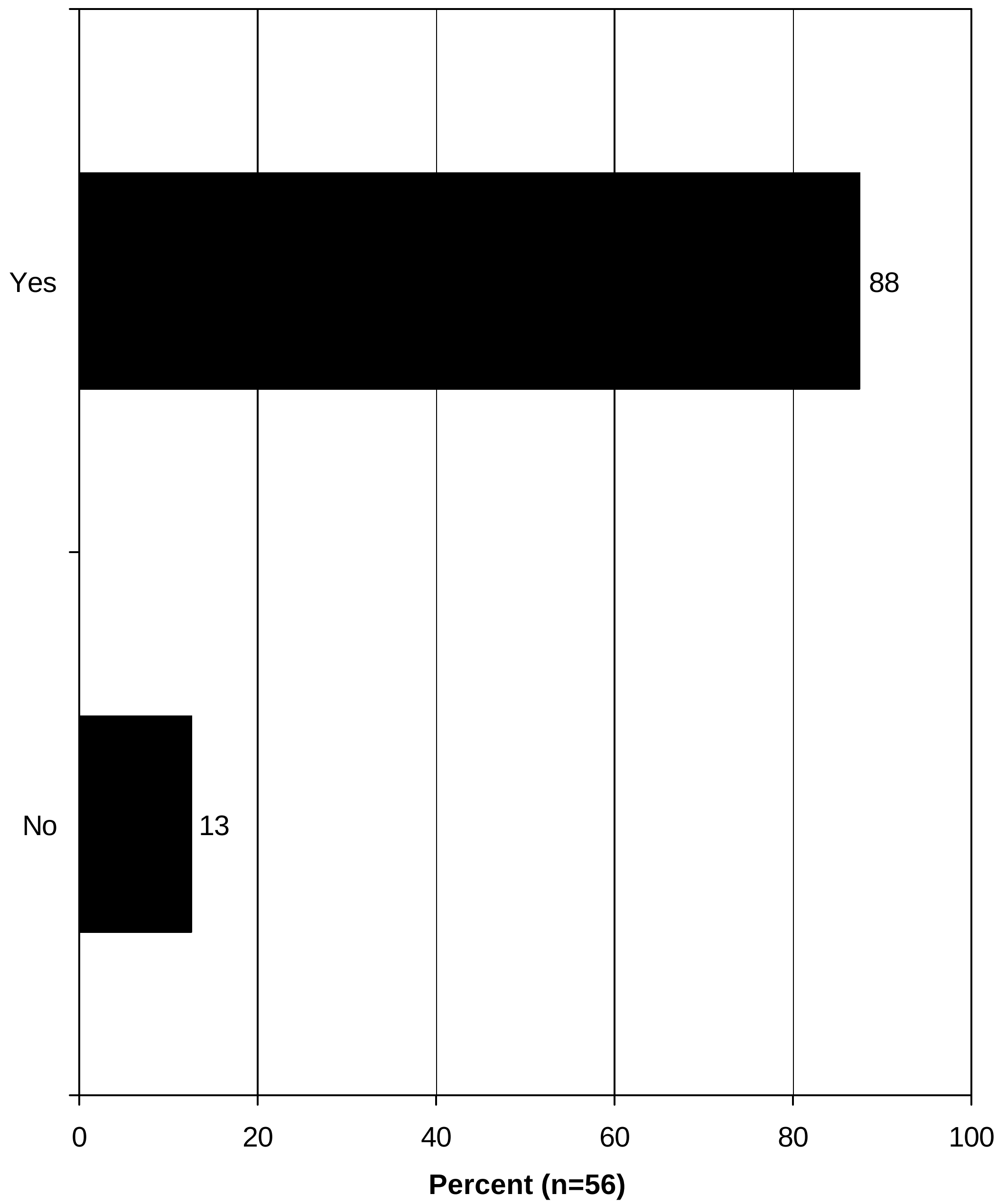
- An overwhelming majority of respondents (88%) are currently measuring nitrates/nitrites.

- The range of nitrates/nitrites measured is shown in the tabulation below:

Q40 and 71. What is the typical range of concentrations of the nitrates/nitrites you are currently measuring? (Asked of those who said they are currently measuring nitrates/nitrites.)

	Number of Respondents
< 1 µM	2
Sub µM-10 µM	1
Detection limit to 25 µM	1
0-5 µM	1
1-9 µM	5
0-15 µM	1
0-20 µM	1
2-25 µM	1
0-30 µM	3
15-30 µM	1
0-40 µM	1
0-100 µM	3
10-99 µM	1
0-120 µM	1
40-150 µM	1
10-250 µM	1
0-2,000 µM	1
0.002-0.8 mg/l	1
0.02-3.5 mg/l	1
< 1 mg/l	3
0-3 mg/l	1
0.007-5 mg/l	1
Less than 1-10 mg/l	1
Detection limit-10 mg/l	1
Below detection - 20 mg/l	1
0-10 mg/l	1
1-9 mg/l	1
1-15 mg/l	1
10-20 mg/l	1
10-99 mg/l	1
80-150 mg/l	1
1-1,000 mg/l	1
0-20,000 mg/l	1
0.004mdl	1
0.5 -10 ppm and 0.05-1ppm	1
Depends on ocean	1
Varies	1
Don't know	4

Q17. Are you currently measuring nitrates/nitrites?



PHOSPHATES

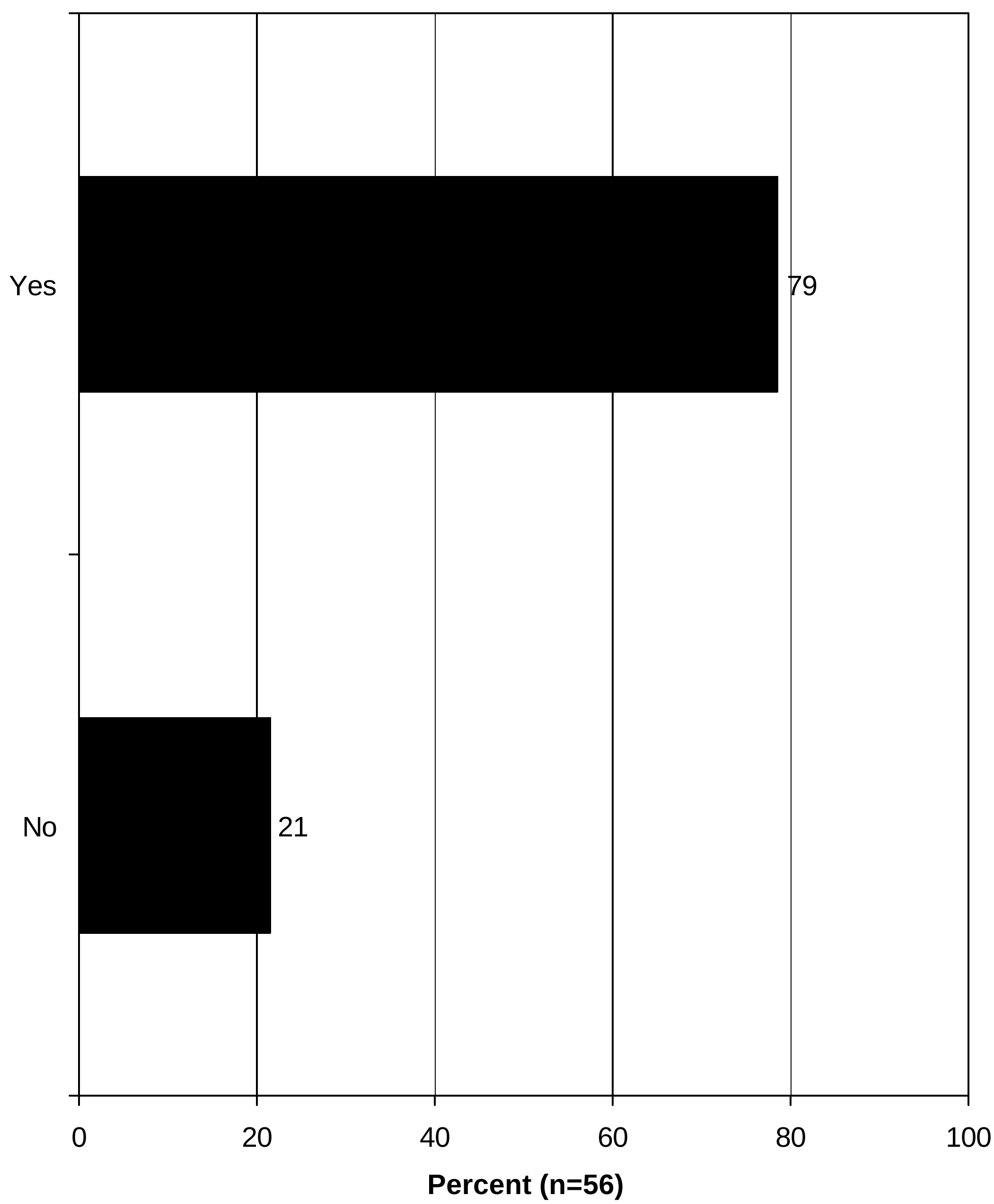
- A large majority of respondents (79%) are currently measuring phosphates.

- The range of phosphates measured is shown in the tabulation below:

Q42 and 73. What is the typical range of concentrations of the phosphates you are currently measuring? (Asked of those who said they are currently measuring phosphates.)

	Number of Respondents
< 1 µM	4
0-0.5 µM	1
Sub µM-1 µM	1
0-1.5 µM	1
0-2 µM	1
1-2 µM	1
0-3 µM	1
0-5 µM	3
Detection limit-5 µM	1
0-6 µM	1
0-10 µM	1
1-9 µM	4
0-20 µM	1
10-99 µM	1
0-200 µM	1
0.006-1 mg/l	1
0-1 mg/l	1
Below detection - 5 mg/l	1
Detection limit-20 mg/l	1
0.02-34 mg/l	1
Undetectable-500 mg/l	1
0.05-0.34 mg/l	1
0.003-0.3 mg/l	1
< 1 mg/l	2
0.01-4 mg/l	1
0-2 mg/l	1
6-70 mg/l	1
0-20,000 mg/l	1
1-20,000mg/l	1
0.1 mdl	1
Depends	1
Varies	1
Don't know	6

Q18. Are you currently measuring phosphates?



AMMONIUM

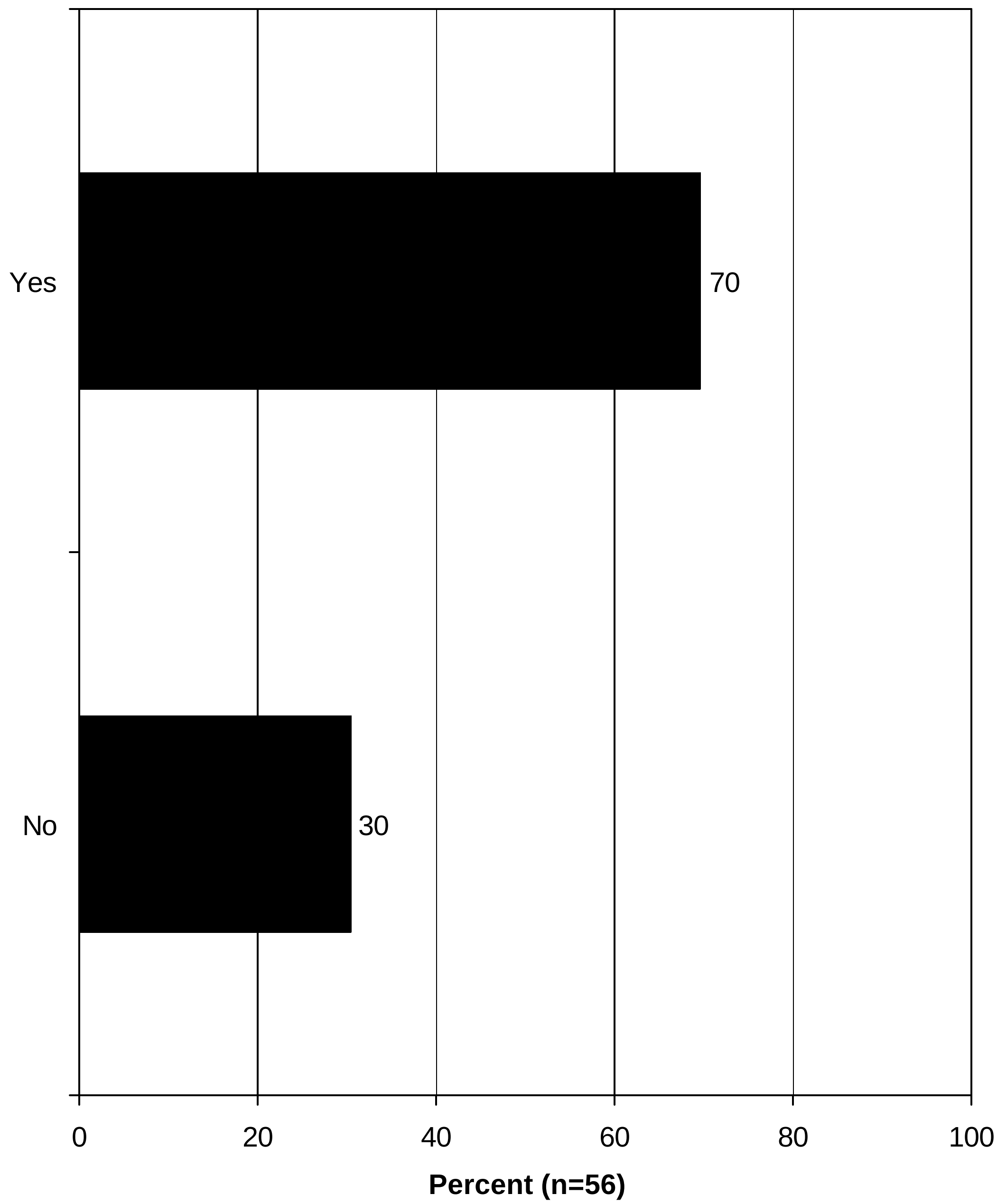
- A large majority of respondents (70%) are currently measuring ammonium.

- The range of ammonium measured is shown in the tabulation below:

Q44 and 75. What is the typical range of concentrations of the ammonium you are currently measuring? (Asked of those who said they are currently measuring ammonium.)

	Number of Respondents
< 1 µM	1
Detection limit to 10 µM	1
Sub µM-10 µM	1
0-2 µM	1
0-3 µM	1
0-4 µM	1
0-5 µM	1
0-10 µM	2
1-9 µM	6
0-12 µM	1
0-20 µM	2
0-100 µM	1
10-99 µM	1
0-300 µM	1
0-2000 µM	2
0.005-0.4 mg/l	1
0.08-0.9 mg/l	1
< 1 mg/l	1
Undetectable-1 mg/l	1
0.03-1 mg/l	1
0.1-2 mg/l	1
0-2 mg/l	2
5-100 mg/l	1
0-20,000 mg/l	1
1-10,000 mg/l	1
0.008 mdl	1
Depends	1
Don't know	5
Varies	1

Q19. Are you currently measuring ammonium?



SILICATE

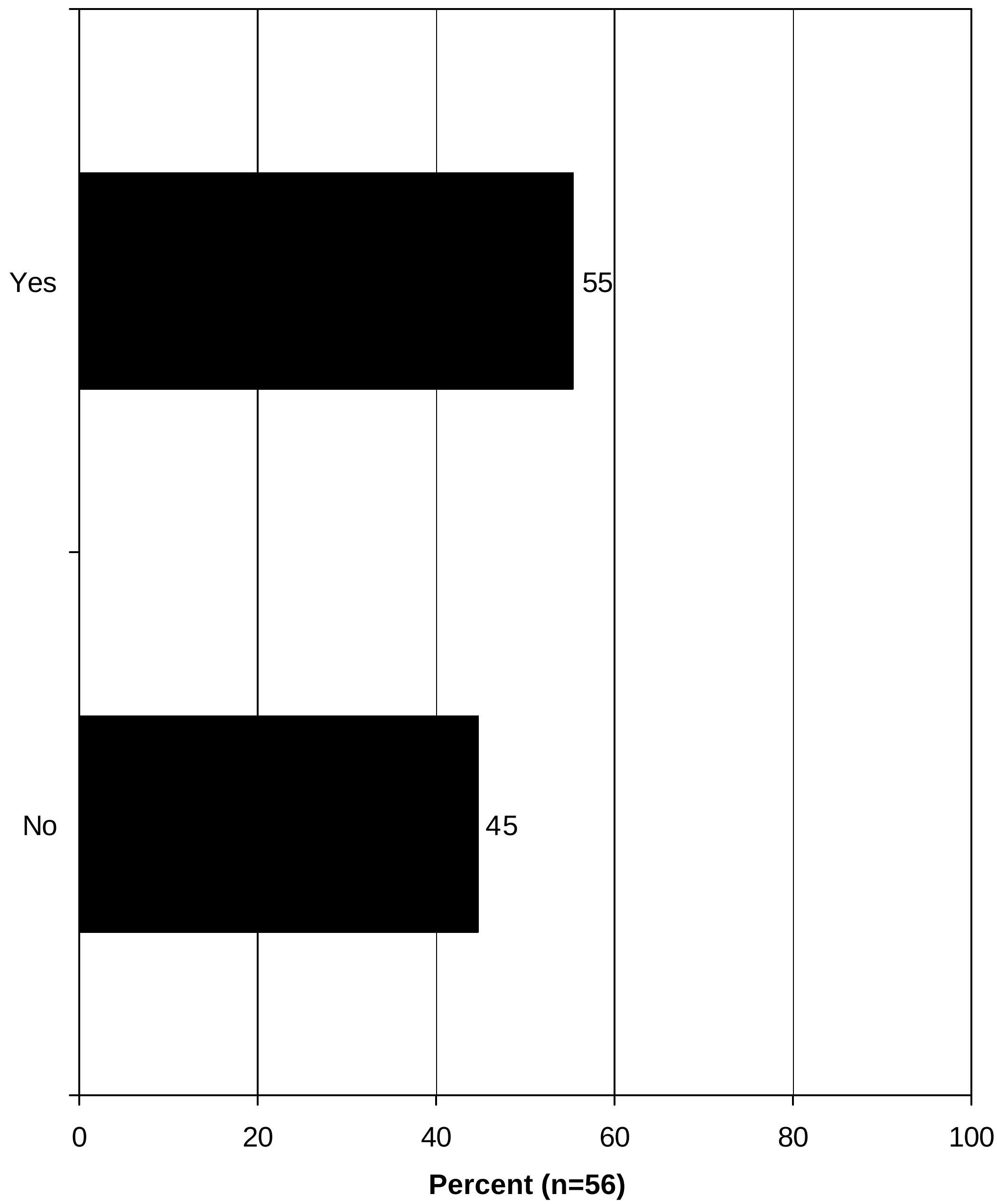
- A slight majority of respondents (55%) are currently measuring silicate.

- The range of silicate measured is shown in the tabulation below:

Q46 and 77. What is the typical range of concentrations of the silicate you are currently measuring? (Asked of those who said they are currently measuring silicate.)

	Number of Respondents
< 1 µM	1
Detection limit to 25 µM	1
Sub µM-50 µM	1
1-9 µM	2
0-25 µM	1
0-30 µM	1
0-50 µM	1
5-60 µM	1
40-85 µM	1
1-100 µM	1
10-99 µM	2
0-200 µM	1
10-200 µM	1
0-230 µM	1
0-1000 µM	1
20-200 µM	1
20-250 µM	1
0.1-5 mg/l	1
0.1-10 mg/l	1
1-5 mg/l	1
0-5,000 mg/l	1
100-10,000 mg/l	1
Depends	1
Varies	1
Don’t know	6

Q20. Are you currently measuring silicate?

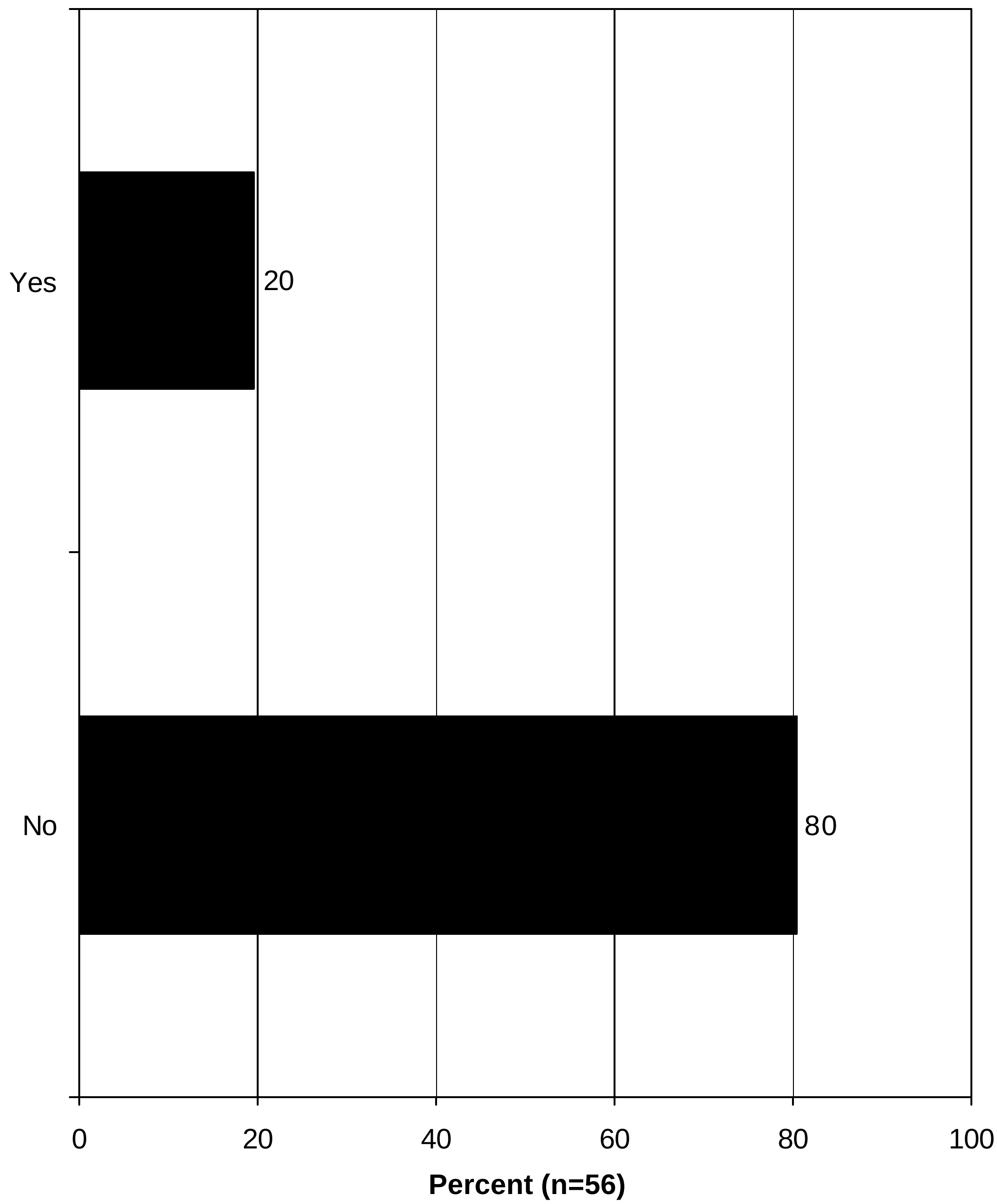


OTHER NUTRIENTS

- A fifth of respondents (20%) indicated that they are currently measuring other nutrients (other than nitrates/nitrites, phosphates, ammonium, and silicate). Other nutrients of interest and indications of the number of respondents who measure and who do not measure them are shown in the tabulation.

Nutrient of Interest	Number of Respondents Measuring the Nutrient	Number of Respondents Interested in but Not Measuring the Nutrient
Bromide	1	0
Calcium	2	0
Carbon	6	0
Chloride	2	0
Chromium	1	0
Copper	0	1
Iron	5	2
Mercury	0	1
Nitrogen	9	4
Other	2	0
Oxygen	1	0
Sulfides	1	0
Trace metals	2	0
Zinc	1	1

Q26. Are you currently measuring any other nutrients?

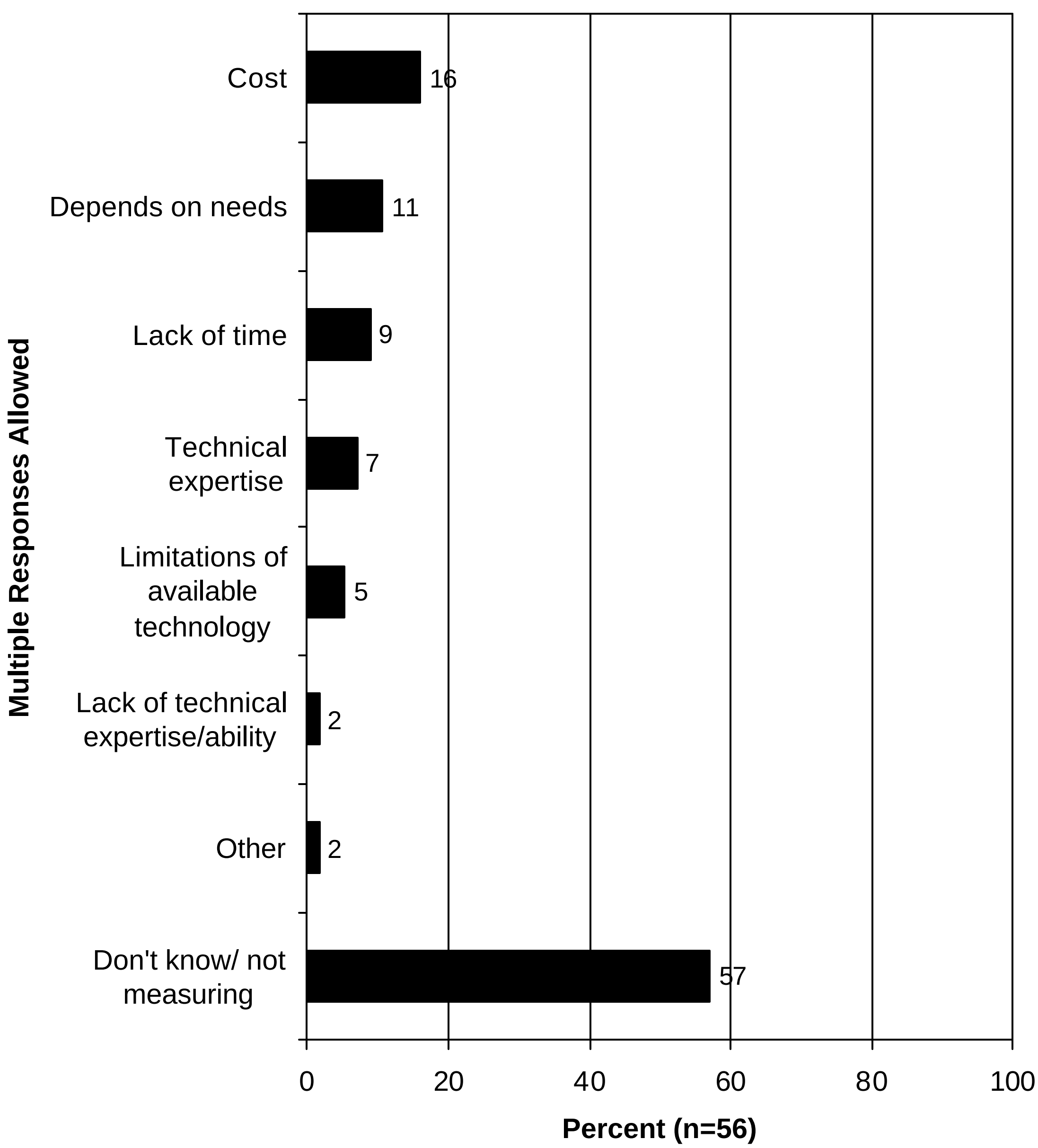


REASONS FOR NOT MEASURING PARTICULAR NUTRIENTS OR NOT USING IN-SITU SENSORS

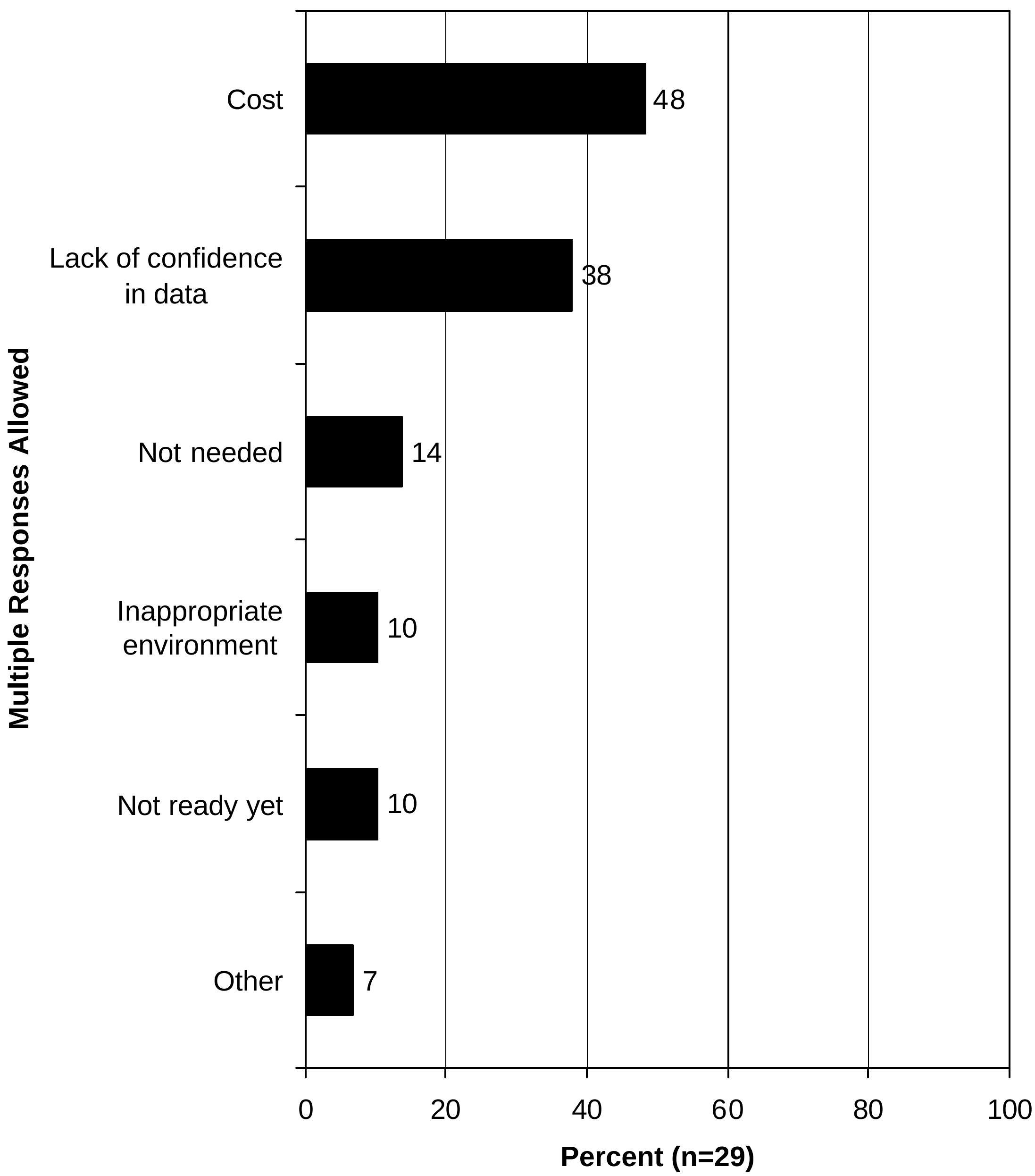
- Cost, lack of time, and technical expertise limitations are three important constraints to use of in-situ sensors, among those not currently measuring a nutrient of interest.

- Cost and lack of confidence in data are the top constraints to use of in-situ nutrient sensors, among those not using an in-situ nutrient sensor.
  - In a related question, when respondents were asked if they had plans to purchase new commercial sensors within the next 2 years, those who did not have plans most commonly cited lack of need and cost (this graph is shown in the section of the report titled, "Purchasing New Sensors").

Q37 and 38. If you have an interest in a nutrient/nutrients that you are not currently measuring, what are the reasons you are not currently measuring it/them?



Q137 and 138. Why don't you use an in-situ nutrient sensor? (Asked of those who do not currently use in-situ nutrient sensors.)



SPECIFIC PROCEDURES/ASPECTS OF MEASURING NUTRIENTS

- About half of the sample of coastal professionals (48%) currently use in-situ nutrient sensors, and these are typically commercial products.
    - Of those who currently use in-situ nutrient sensors, 70% use a commercial product alone, 4% use a custom-designed and custom-made sensor, and 26% use a combination of commercial and custom-made.

- The most common application for nutrient sensors is as a deployed sensor on a remote platform for continuous in-situ measurements.

- A majority of those who use in-situ nutrient sensors take measurements hourly (59%), by far the leading answer. In a related question, all respondents were asked how often they need to provide or obtain nutrient measurement data, and hourly was again the top answer.

- About a third of respondents (34%) are required to use specific approved analytical techniques and procedures, such as EPA-approved methods.
    - EPA methods were the most commonly used.

- Nearly a third of respondents (29%) said their sensor needs or requirements are non-standard; descriptions of their non-standard needs are shown.

- In-situ nutrient sensors are used by majorities of respondents for absolute concentrations (73%) as well as for relative changes (55%) in the nutrient(s) being measured.

- A majority of coastal professionals (68%) measure nutrients in µM (micromolars), while 40% measure nutrients in mg/l (milligrams per liter); these percents include the 11% who measure using both.

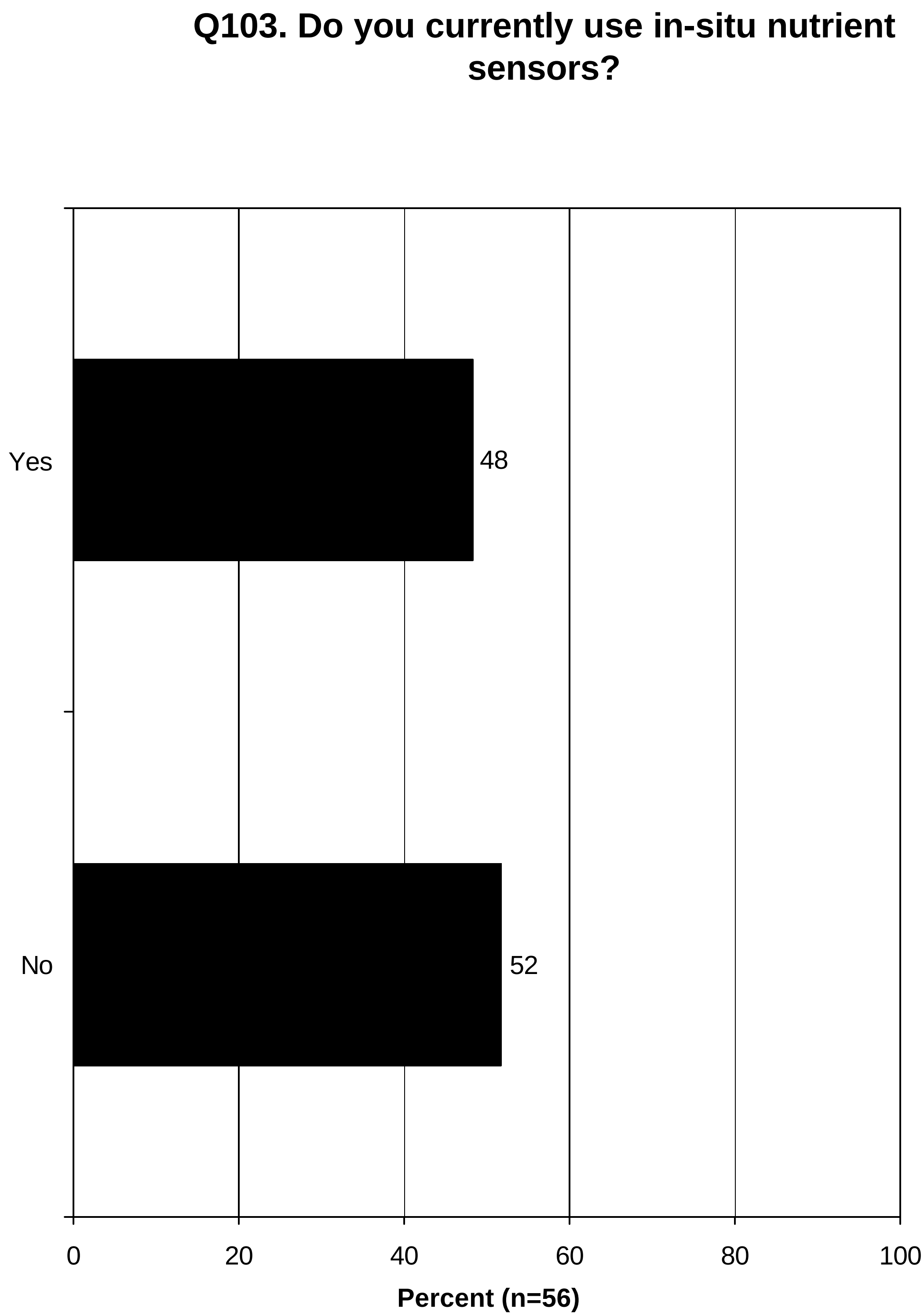
- Nearly a fifth of respondents (18%) indicated that there are detection limits for nutrients that they measure that are set by regulations or other needs of the data.

- An overwhelming majority of respondents conduct their own absolute calibrations (83%); descriptions of their calibration techniques are shown.

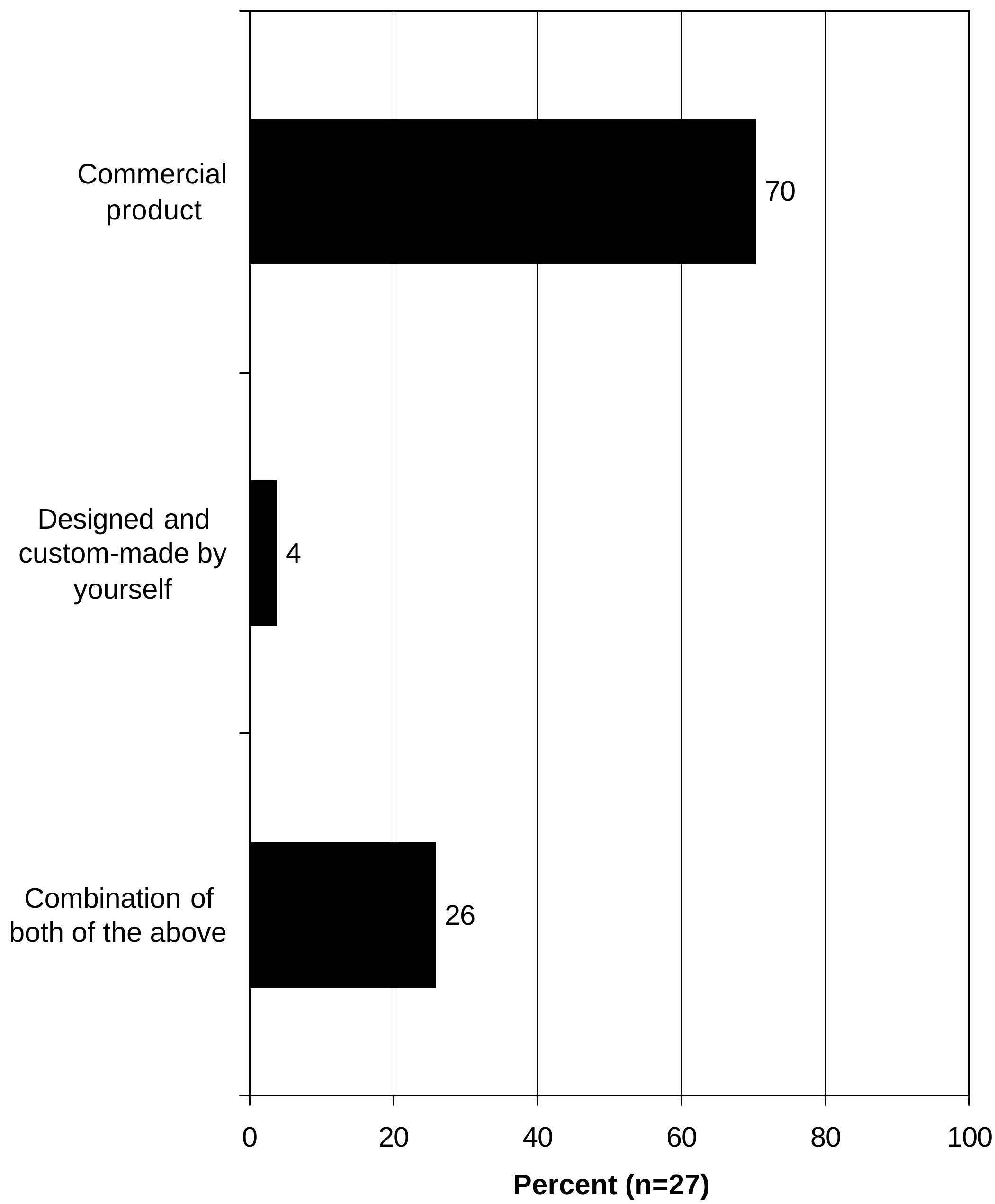
- An overwhelming majority of coastal professionals (81%) use in-house sample analyses to measure nutrients at least some of the time, with most of those using in-house sample analyses exclusively; 38% contract with a laboratory to conduct analyses at least some of the time, with about half of those using an outside lab exclusively.

- The performance characteristics of most importance are reliability, accuracy, precision, range/detection limits, and key operational parameters. Other performance characteristics considered important are shown in the tabulation that follows the ratings tabulation.

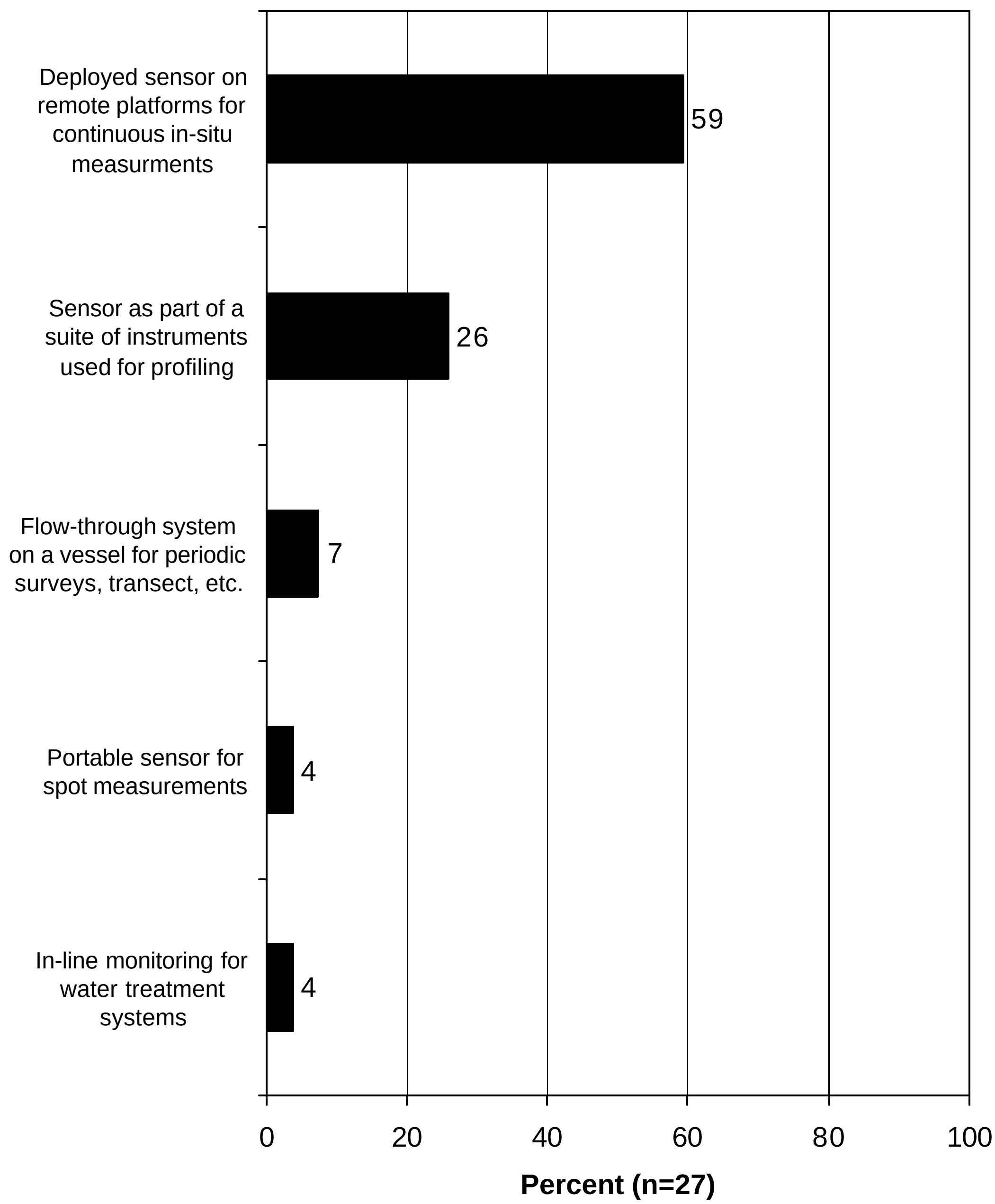
- The overwhelming majority of those who plan to purchase new commercial sensors within the next 2 years (85%) will have a trained person on staff to operate the new sensor.


Q103. Do you currently use in-situ nutrient sensors?
Yes
48
No
52
0
20
40
60
80
100
Percent (n=56)

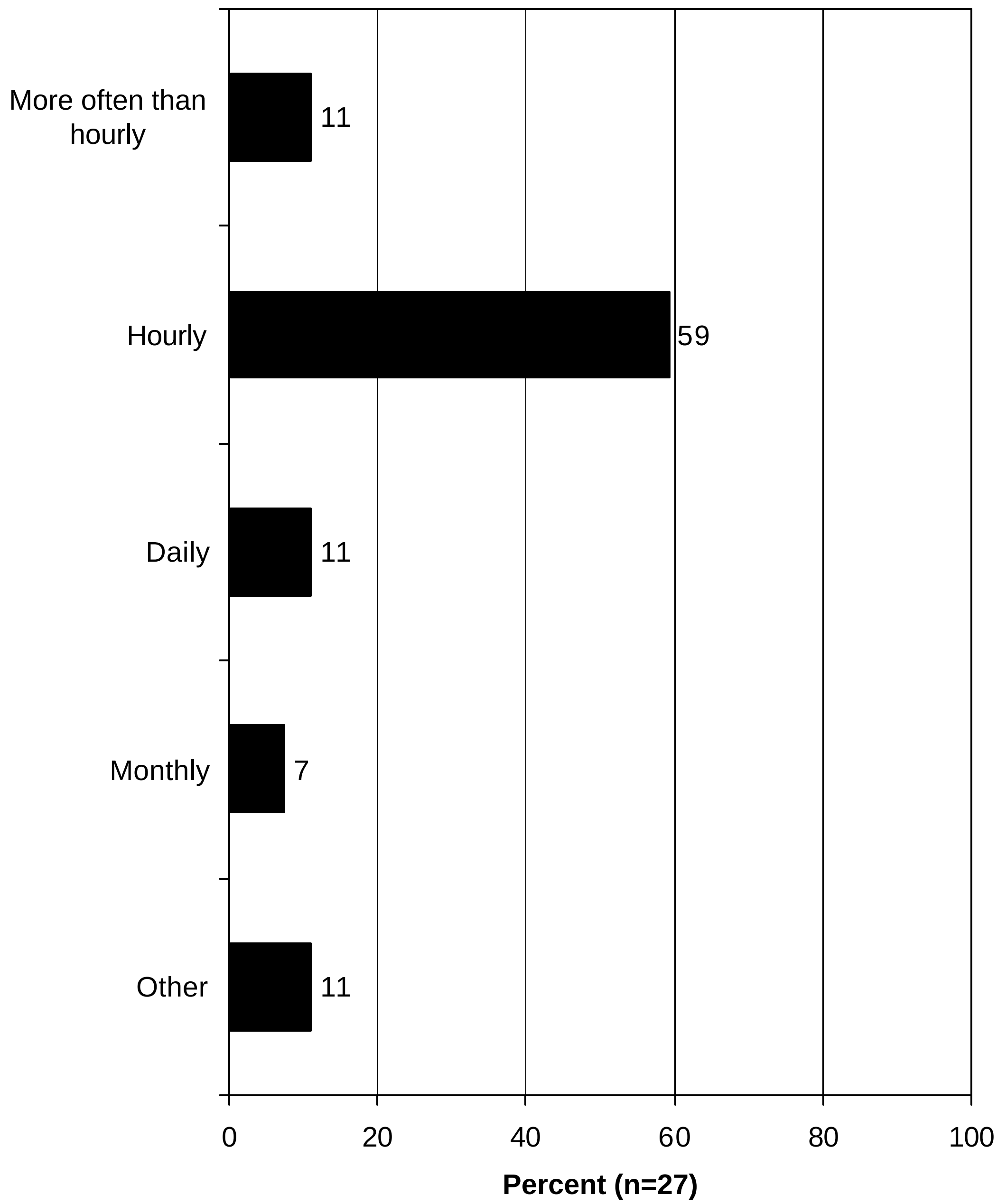
Q106. Which of the following best describes your current sensors? (Asked of those who currently use in-situ nutrient sensors.)



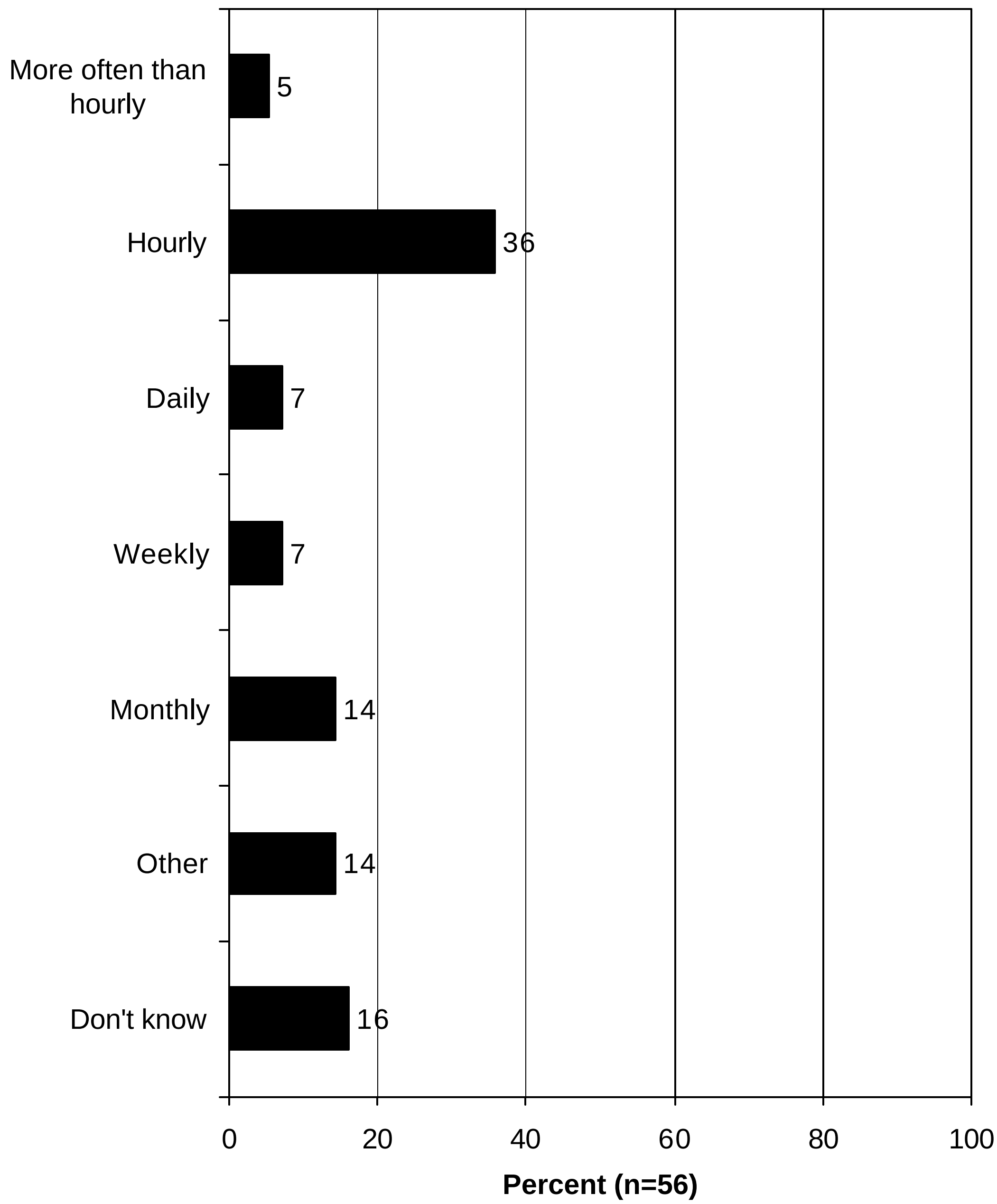
Q104 and 105. What is your most common application? (Asked of those who currently use in-situ nutrient sensors.)

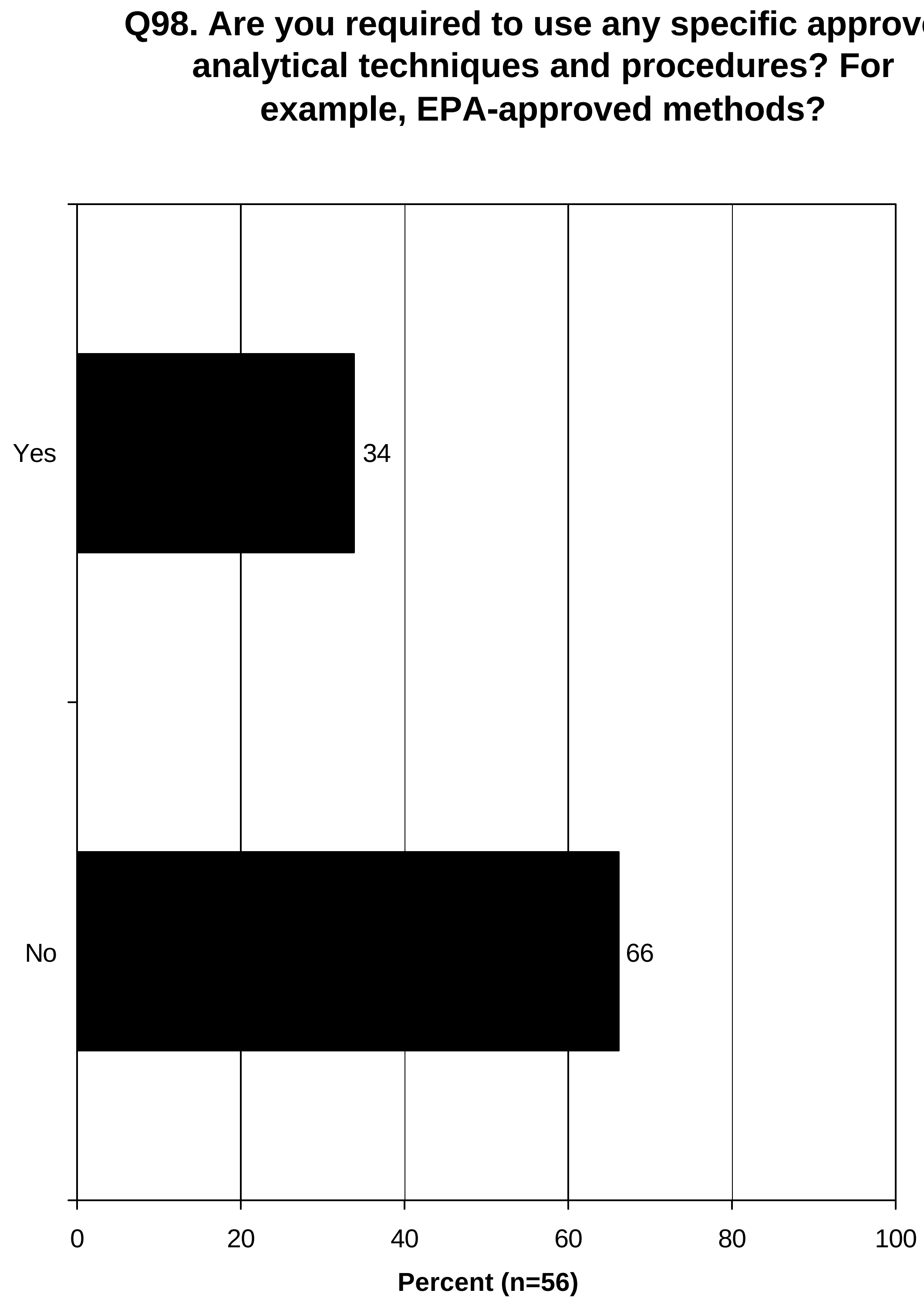


Q107. How often do you need to do in-situ nutrient measurements? (Asked of those who currently use in-situ nutrient sensors.)



Q139. How often do you need to provide and/or acquire nutrient measurement data?

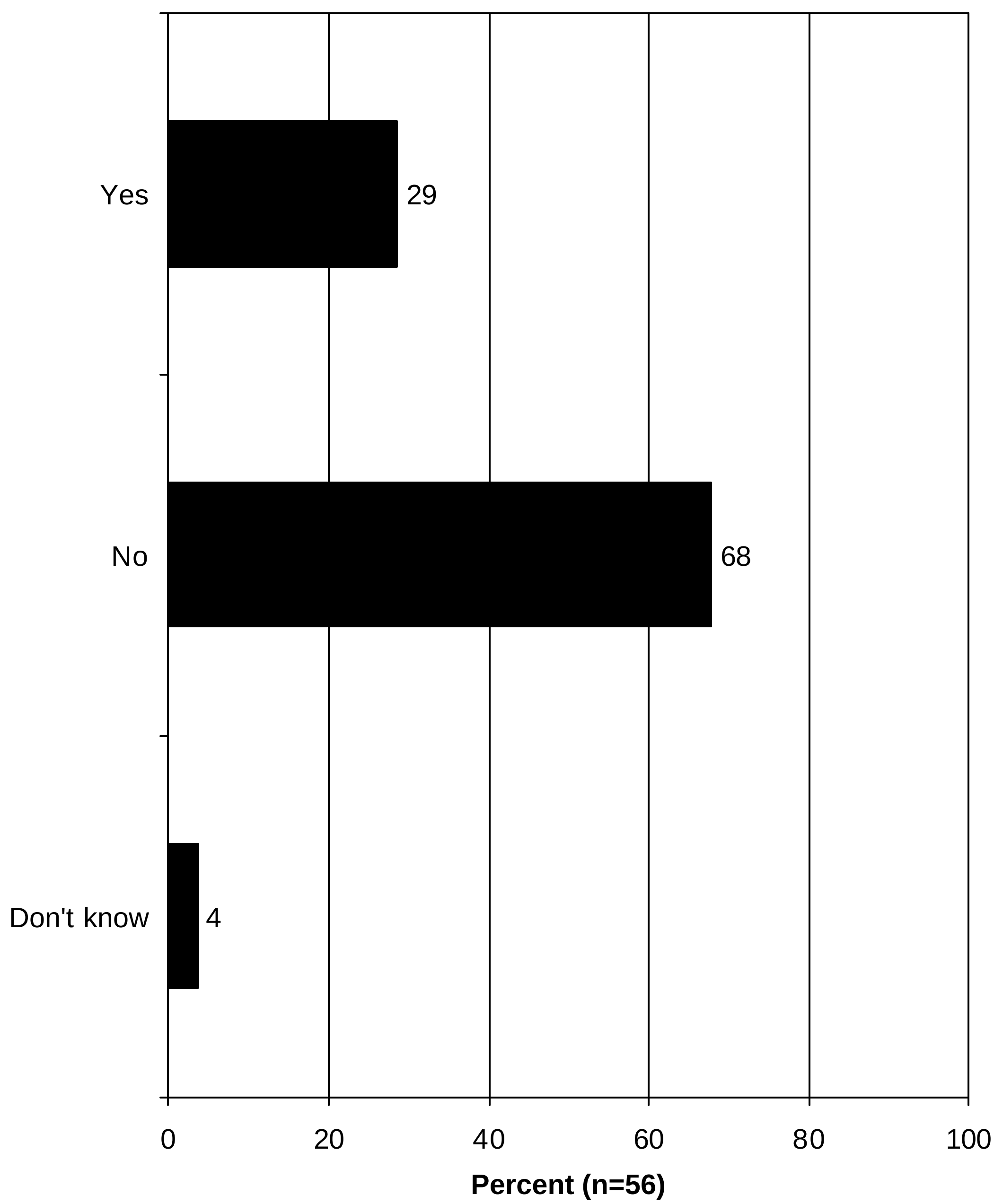



Q98. Are you required to use any specific approved analytical techniques and procedures? For example, EPA-approved methods?
Yes
34
No
66
0
20
40
60
80
100
Percent (n=56)

Q99. Analytical techniques and procedures used.

Analytical Technique	**Number of Respondents Who Use It**
American Society for Testing and Materials	1
Chain of evidence	1
Depends on project	1
EPA	8
EPA and Florida DEP	1
EPA, American Public Health Association, USGS	1
EPA, QA-QC, in-house	1
National Estuarine Reserve Nutrient guidelines	1
Standard academic procedures	1
USGS	1
USGS and EPA methods	1

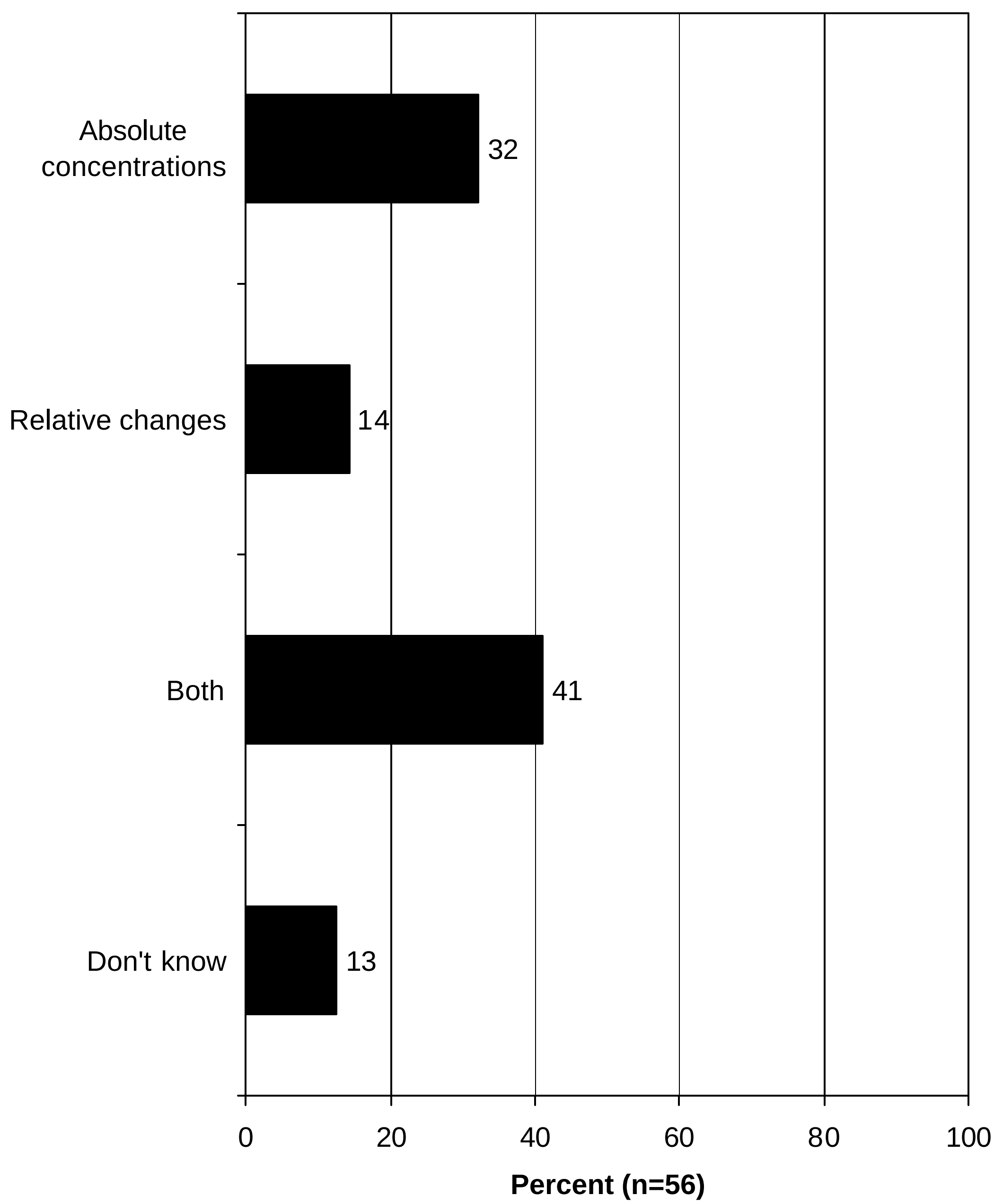
Q201. Are any of your sensor needs or requirements non-standard?



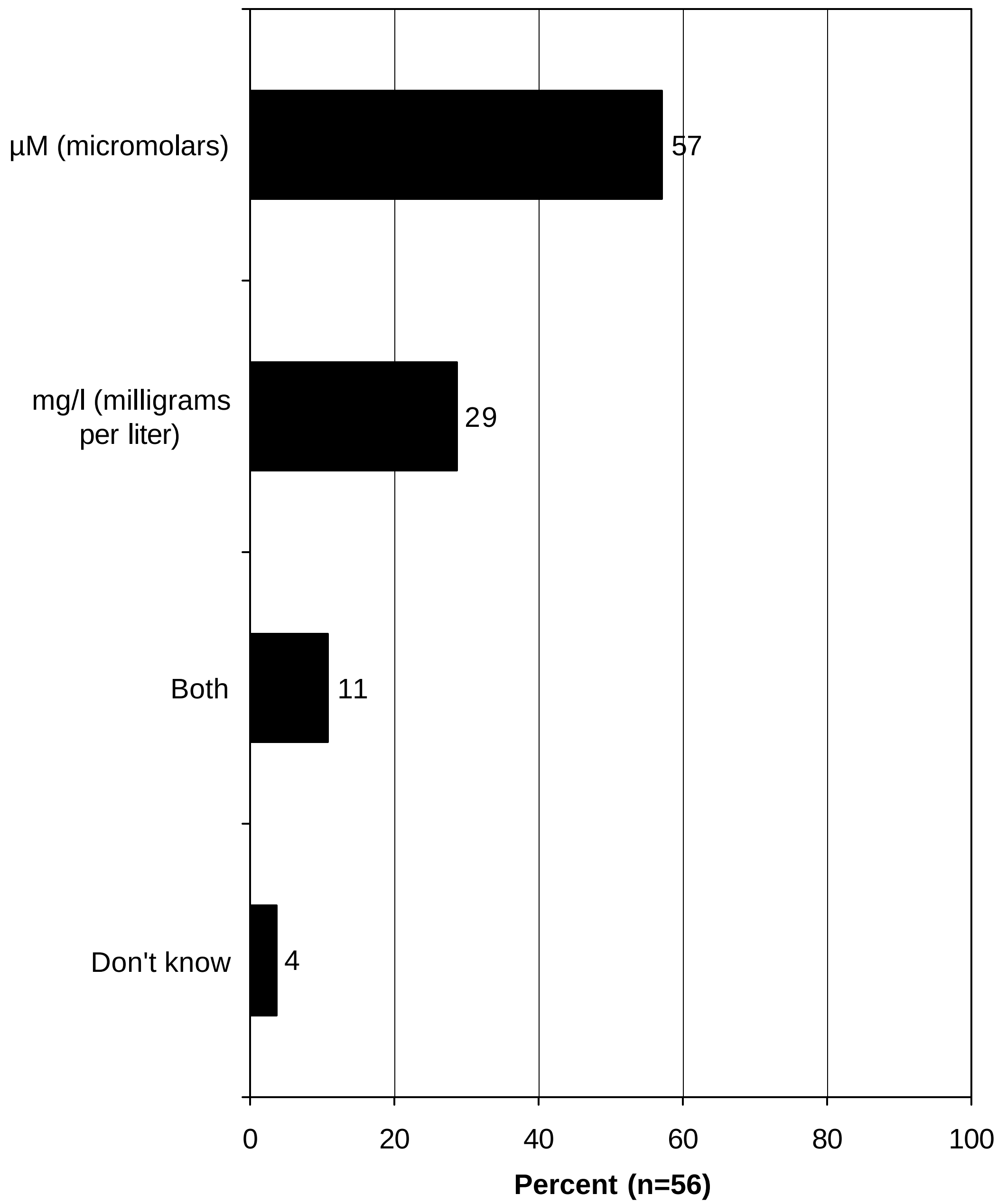
Q202. Please describe briefly the non-standard sensor needs or requirements. (Asked of those who said they had sensor needs and requirements that were non-standard.)

Ability to handle variable solidity; needs to be able to self-calibrate
Building a urea sensor, reprogram Envirotech instruments for more accuracy
Calcium work non-standard; being able to detect low phosphate levels
Collection of samples on a moving vessel
Deployment time but still trying to match up the physics
Detecting lower limits
Development of new parameters; experiment dependant
Estuarine deployment; cold weather deployment
Flexibility
Must be able to work in a variety of environments: freshwater to saltwater, clear to turbid water, and highly colored water
Non-nutrient chemicals
Past research required; some requirements do not exist in sensor types. Needs a real-time dissolved propane or sf6 analyzer.
The sensor has more channels than on the market, and depth range was extended as well
Very small sample sizes

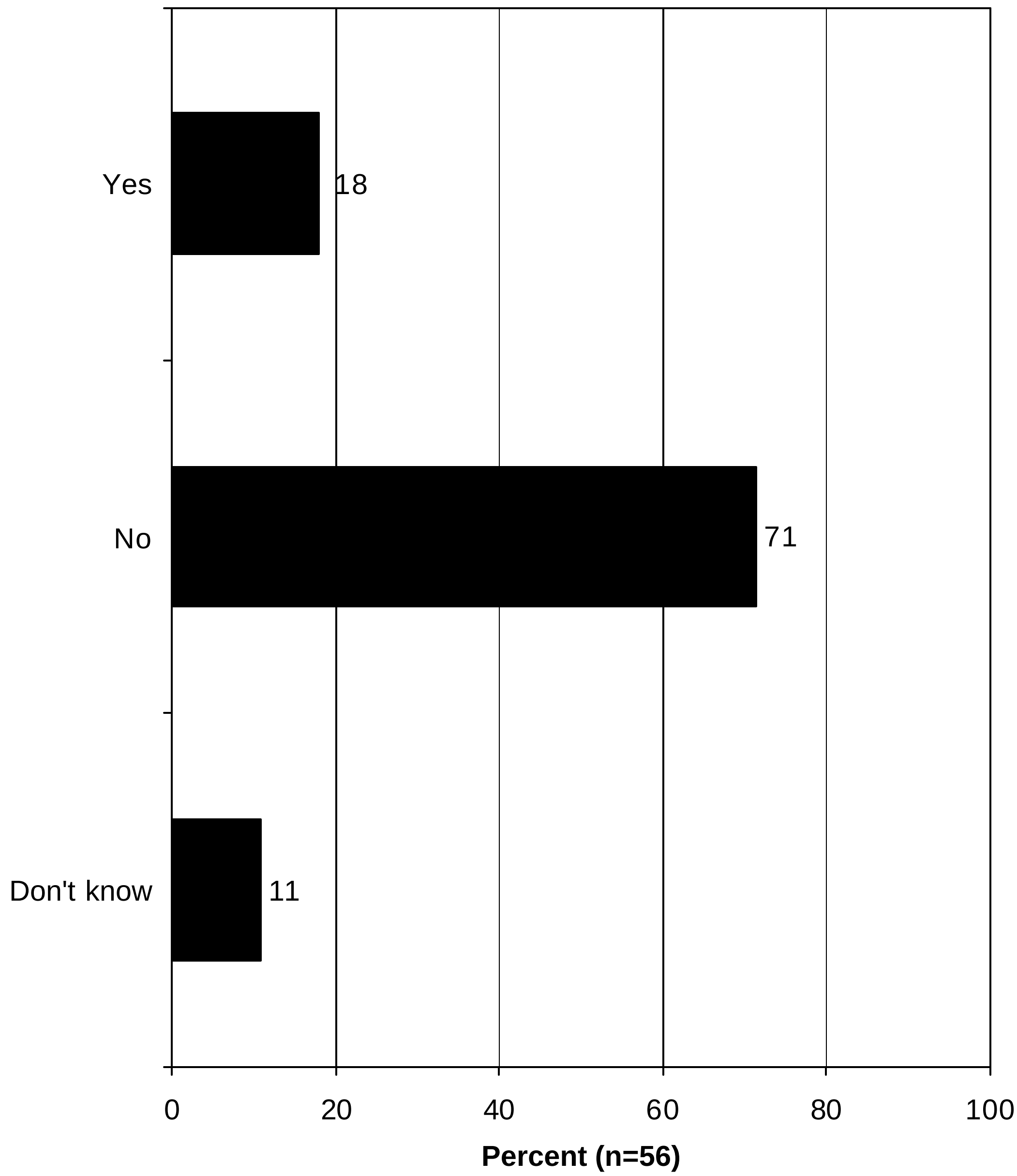
Q203. Do you use your in-situ nutrient sensor to determine absolute concentrations or relative changes?



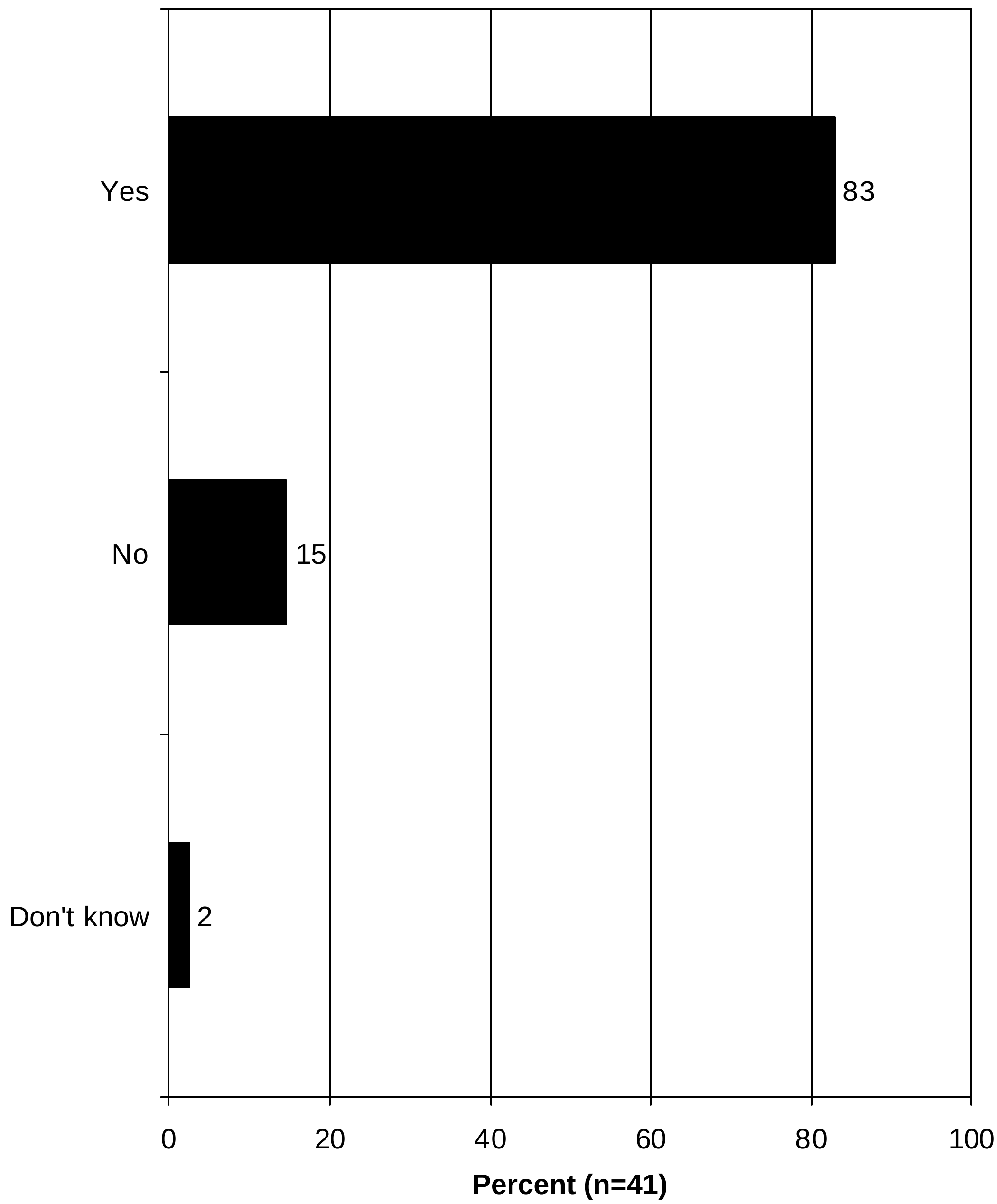
Q39. Do you measure nutrients in µM (micromolars) or mg/l (milligrams per liter)?



Q69. Are there any required detection limits and/or ranges, for instance by regulations, for the nutrient(s) you are currently measuring? (Asked of those who are currently measuring a nutrient/nutrients.)



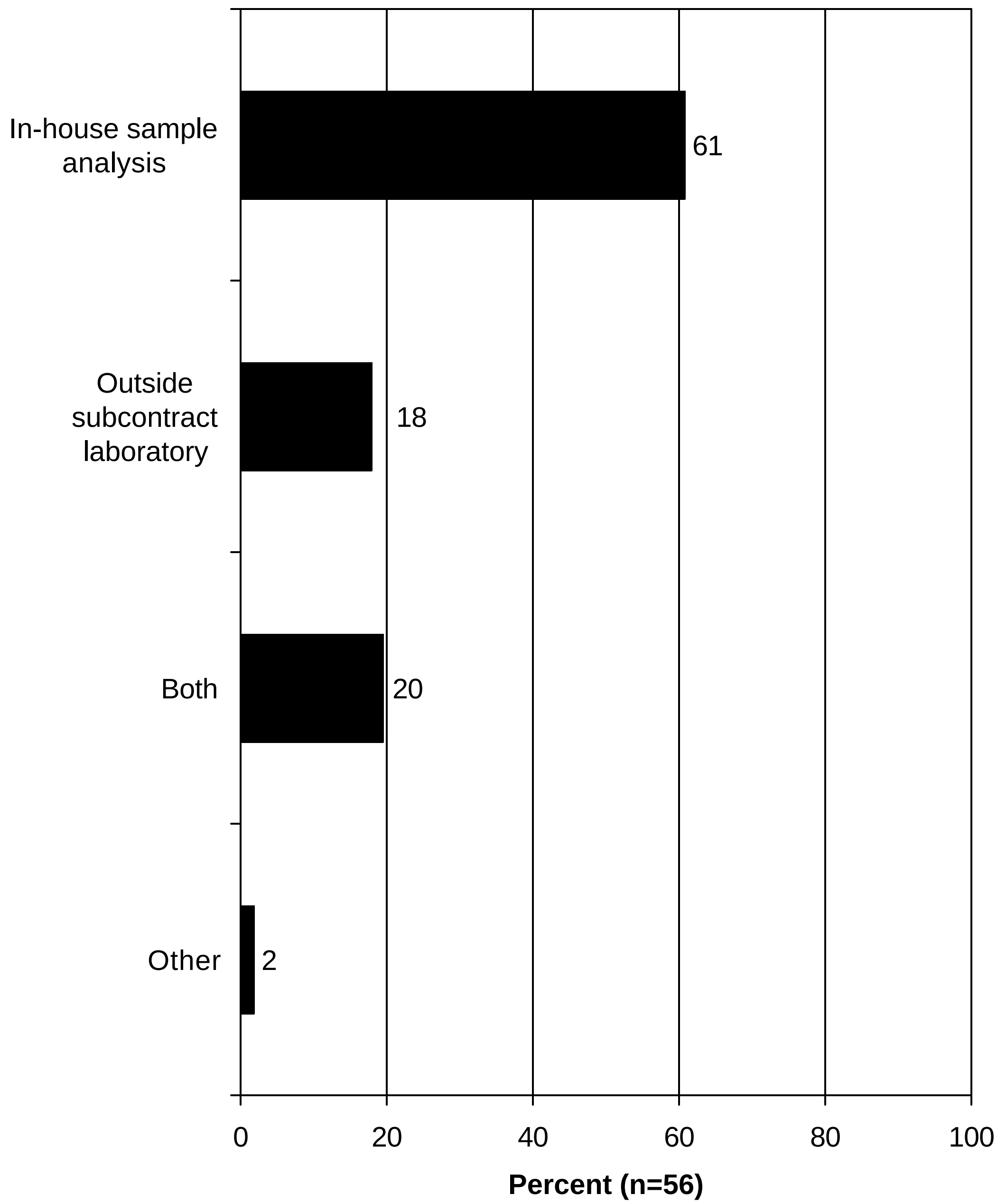
Q204. Do you conduct your own absolute calibrations? (Asked of those who said they use the in-situ nutrient sensor to determine absolute concentrations.)



Q205. If yes, what method do you use to calibrate? (Asked of those who said they use the in-situ nutrient sensor to determine absolute concentrations and that they conduct their own calibrations.)

Auto analyzer in lab to cross-calibrate
Automatic
Certified concentration standards
External standards
Gravimetric standards in lab vis-à-vis run as unknowns
In-house standards (answer given by 12 respondents)
In-lab standard and in-field standards
Laboratory-based analysis
Laboratory standard solution
Multipoint linear progression
Own laboratory standard; compare with other institutions
Photometric analysis or auto-analyzer
Post deployment calibration checks
Standard automated oceanographic techniques
Standard
Standard lab methods (answer given by 2 respondents)
Standard wastewater
Varies; chemistry

Q141. How do you currently measure nutrients?



Ratings of the Importance of the Following Performance Characteristics

Performance Characteristic (sorted by mean)	**Percent Rating Item the Highest in Importance (5)**	**Percent Rating the Item Low in Importance (1, 2, or 3)**	**Mean**
Q180. Reliability	81	4	4.77
Q177. Accuracy	72	11	4.56
Q178. Precision	57	8	4.49
Q176. Range/detection limits	59	9	4.48
Q175. Key operational parameters	64	22	4.36
Q191. Product support/ warranty/vendor reputation	51	17	4.34
Q193. Cost	38	30	4.06
Q181. Deployment life (e.g., biofouling resistance, power limitations, re-agent limitations)	33	26	4.04
Q182. Operating life (i.e., life expectancy of the instrument)	33	27	4.04
Q183. Calibration life	24	25	3.98
Q190. In-field maintenance	53	32	3.94
Q185. Ease of calibration	38	42	3.91
Q192. Quality of product handbook/documentation	32	34	3.87
Q184. Automatic calibration	23	35	3.69
Q179. Sampling interval/ frequency	21	53	3.51
Q188. Input/output interfaces	20	49	3.51
Q186. Real-time sensor data display and/or analysis	15	56	3.31
Q189. Packaging	19	60	3.29
Q187. Off-sensor telemetry	14	59	3.18
	Mean is: 39.32	*Mean is: 31.46*	*Mean is: 3.96*

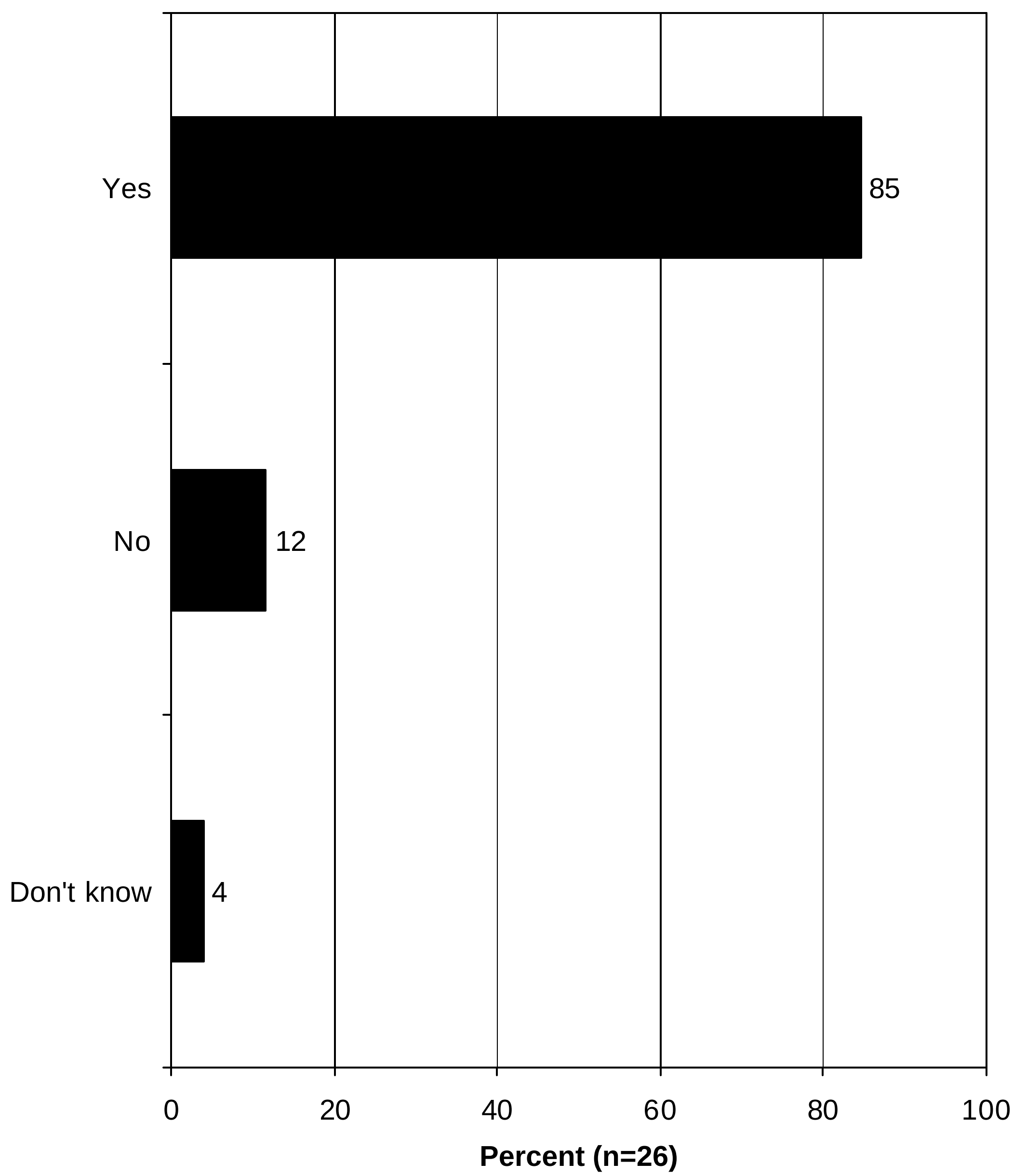
Scale is 1 to 5, with 5 being the highest importance.

Q195-200. Other Characteristics of Interest in Nutrient Sensors and Rating

Characteristic	**Rating by the Respondent for the Given Other Characteristic**
Ability for multiple analysis with one instrument	5
Biofouling and operations power	5
Communication power requirements	5
Compatibility with multiple instrument packages	4
Decreased toxicity	3
Ease of use	4
Fouling	5
In-field adaptability or remote adaptability	4
Installation and communication with other instruments	4
Interfacing	4
Interfacing with other instruments	3
Methodology used—measurement based techniques	5
Methods of minimizing fouling is a major issue	3
Parameters that can be measured; that it can do multiple things	4
Power consumption	4
Power supply	5
Skilled technicians	3
Waste disposal and production	5
Waste generation	3

Scale is 1 to 5, with 5 being the highest importance.

Q172. Would you have a trained person to operate the newly acquired commercial in-situ nutrient sensor? (Asked of those who plan on acquiring new commercial sensors within the next 2 years.)



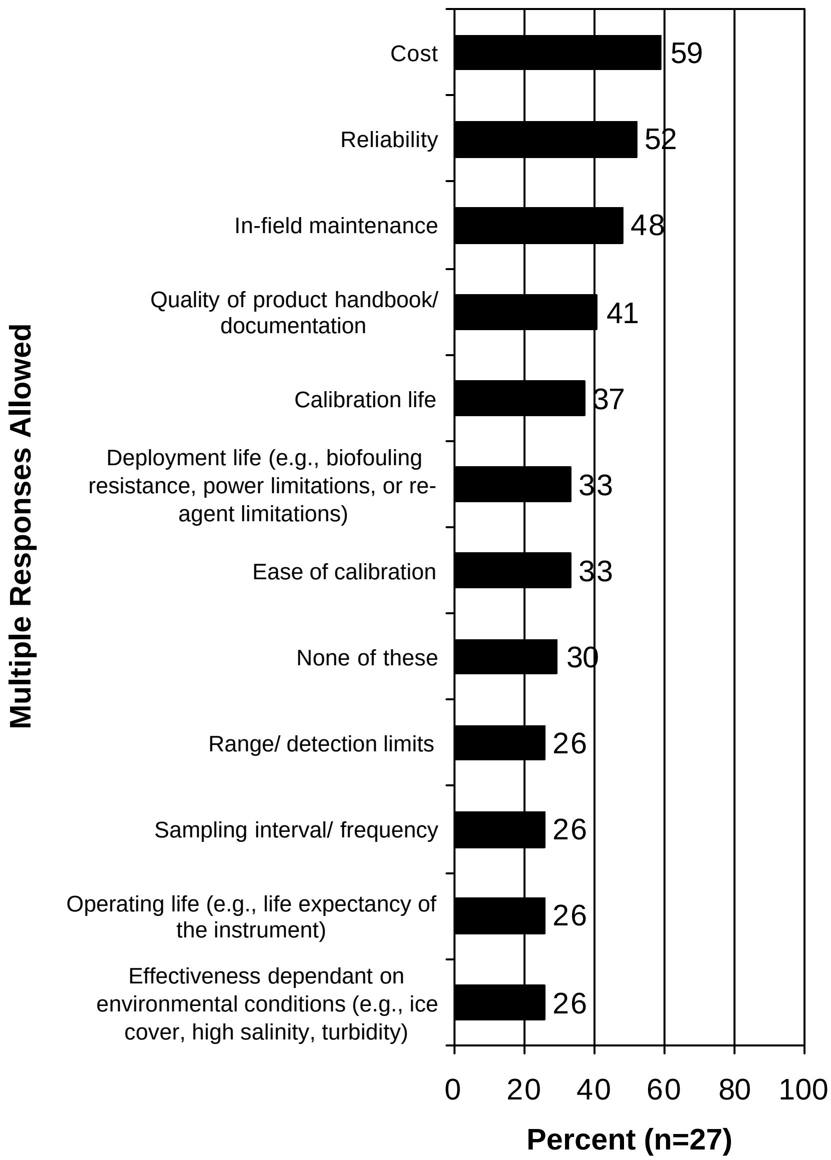
LIMITATIONS OF SENSORS

- Cost, reliability, and in-field maintenance are the top areas in which current in-situ nutrient sensors have limitations, do not meet expectations, or do not meet needs.

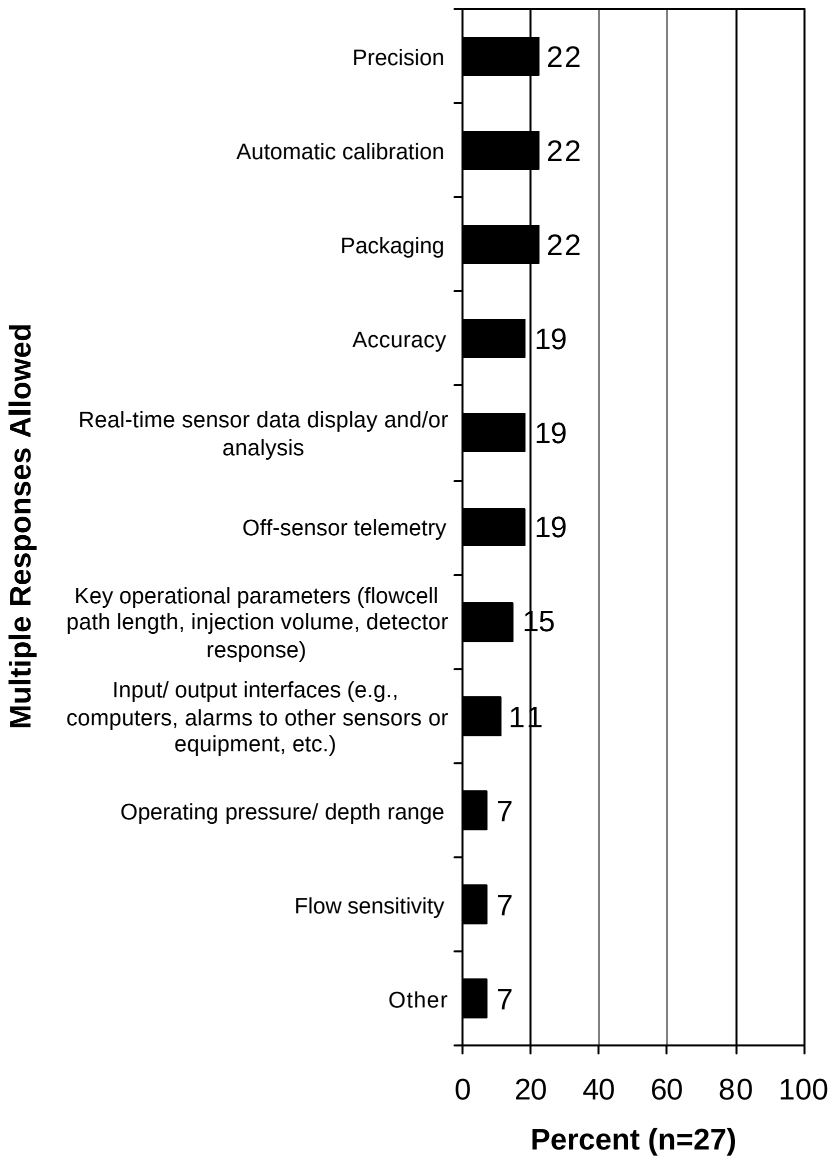
- Ease of calibration, reliability/durability/maintenance, analytical time, hardware, software/data management, and range/detection limits are the top areas in which in-house sample analyses have limitations, do not meet expectations, or do not meet needs—all of these responses had more than 20% giving the answer (of those who use in-house sample analyses as opposed to those who use an outside subcontract laboratory for analyses).

- Analytical time is the top limitation on contracted laboratory analyses.
  - 40% indicated that their contracted laboratory analyses had no significant limitations.

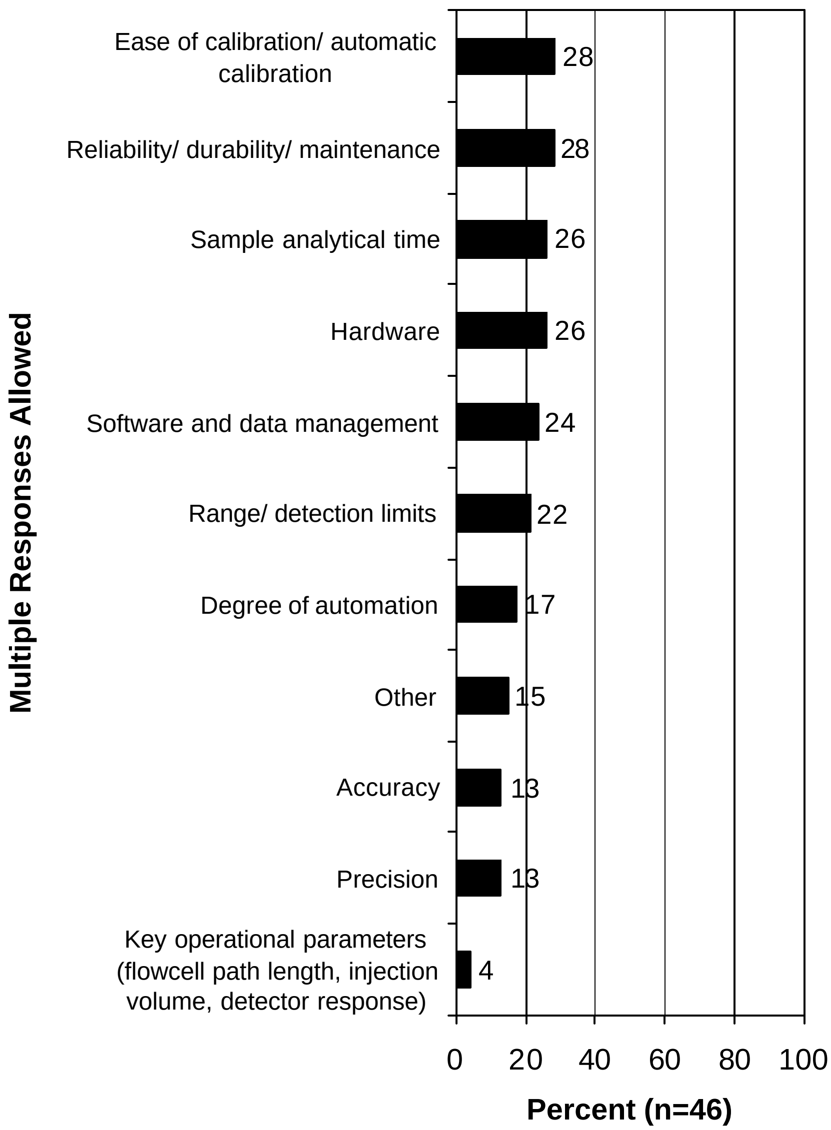
Q110 and 112. In which of the following areas does the in-situ nutrient sensor/system you are using have significant limitations, not live up to specifications or expectations, or not meet your needs? (Asked of those who currently use in-situ nutrient sensors.) (Part 1.)



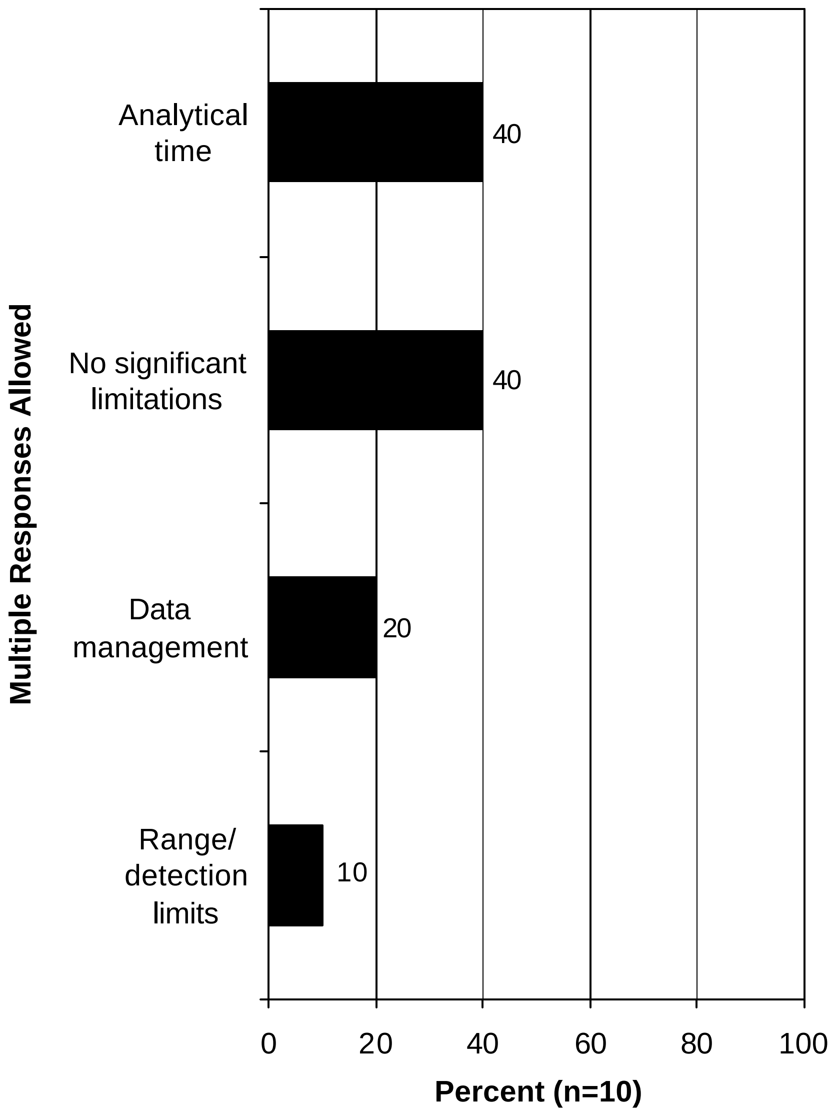
Q110 and 112. In which of the following areas does the in-situ nutrient sensor/system you are using have significant limitations, not live up to specifications or expectations, or not meet your needs? (Asked of those who currently use in-situ nutrient sensors.) (Part 2.)



Q144. In which of the following areas does the analytical system you are currently using have significant limitations, does not live up to specification or expectations, or does not meet your needs? (Asked of those who use an in-house sample analysis.)



Q158. When subcontracting the analysis, in which of the following areas does the analytical service have significant limitations, not live up to specifications or expectations or not meet your needs? (Asked of those who use exclusively an outside subcontract laboratory for analysis.)



- Issues with each of the performance characteristics of the sensor/sensor system are shown in the tabulations that follow.

Q114. What were the issues with key operational parameters of the sensor(s) that had significant limitations or did not live up to specifications or expectations?

Cannot measure every possible nitrate and phosphorus species
Detection techniques not available or extensive enough; development time of the chemistry
More things that you could measure
Not adequate nutrient sensors—level of detection not low enough

Q115. What were the issues with range/detection limits of the sensor(s) that had significant limitations or did not live up to specifications or expectations?

Detection limitations are lower, lower than they are right now
Estuarine applications—storm events = big increases—out of range (silicate and ammonium)
In more pristine environments, cannot get the detection limit low enough
Detection limit
Not as sensitive as it should be, especially at lower end of detection
Not low enough (specifically for nitrates)
Range inadequate at the low end

Q116. What were the issues with accuracy of the sensor(s) that had significant limitations or did not live up to specifications or expectations?

Biofouling and calibration issues
Calibration doesn't give you the same number back—precise but not accurate
Detections not low enough; reproducibility not there, better accuracy needed by a factor of 10
Lack of accuracy
When close to the detection limit, get a lot of variation; don't know how much variability with temperature change

Q117. What were the issues with precision of the sensor(s) that had significant limitations or did not live up to specifications or expectations?

Biofouling and calibration
Improvements in flow cell would improve precision—for most coastal environments, satisfactory technology exists to make it better
Lack of precision
Noise in the calibration—condition of surface not reliable (reduction step)
Not a number of significant figures, factor of at least 10 higher than present
Replication of standards

Q118. What were the issues with sampling interval/frequency of the sensor(s) that had significant limitations or did not live up to specifications or expectations?

Accuracy
Cannot sample frequently enough
Different chemistries for different nutrients; time consuming; cannot do all simultaneously
Hard-wired protocol—substitution of a standard = gapped time series, data analysis problems
Instrument dependant—cannot select any sampling rate that you desire, has to be multiples of 2, 4, etc.; frequency not rapid enough to match up with other instruments
Multi-channel more use = less frequency, cannot get 3 channels to work at once, need more frequency
Too slow

Q119. What were the issues with reliability of the sensor(s) that had significant limitations or did not live up to specifications or expectations?

Most sensors still in beta test mode
Accuracy
Biofouling; workmanship
Breakdowns
Don't work very well
High particle loads difficult
Instrument malfunctions
Lack of reliability
Strange standards—non-consistent
Success rate of deployed instruments is about 1 in 3—plumbing issues
Too many mechanical problems
Tough to get started with correct measurements
Very complicated, many moving parts, wet chemistry—pipettes very tedious and complicated, ultra-violet light bulb dims over time

Q120. What were the issues with deployment life of the sensor(s) that had significant limitations or did not live up to specifications or expectations?

Biofouling and drift
Biofouling and workmanship
Fouling in longer-term deployments; calibration drift
In a mooring configuration, concerns with fouling; battery life
Limited reagent bags
Only deploy for 2-3 weeks, would like longer
Power
Reliability for long-time records at issue; some deployments called for are 2-3 years, and no instruments available for that time-frame
Stability of reagents

Q121. What were the issues with operating life of the sensor(s) that had significant limitations or did not live up to specifications or expectations?

Battery
Battery life; power hungry
Biofouling
Life not long enough for the price
Longer deployment, corrosion issues, biofouling, electrolysis
Not enough battery power for cold temps
Parts malfunction, replacement

Q122. What were the issues with operating pressure/depth range of the sensor(s) that had significant limitations or did not live up to specifications or expectations?

Had to modify to get to a reasonable depth
Profiling systems need to be comparable for the normal CTD sensor takes

Q123. What were the issues with flow sensitivity of the sensor(s) that had significant limitations or did not live up to specifications or expectations?

Hard to deploy (big), defouling, barnacles—all interconnected
Some extreme (esp. low) flow situations make sensor not operable—needs to be more rugged

Q124. What were the issues with calibration life of the sensor(s) that had significant limitations or did not live up to specifications or expectations?

Calibration not stable
Don't hold calibrations long enough
Drift (2 respondents gave this answer)
Ease of or the ability to hold a calibration
If changes in environmental conditions, then calibration becomes less accurate
Significant amount of drift esp. in long durations, cut drift factor down by a factor of 10
Stability of on-board standards not adequate
Stability or reagents

Q125. What were the issues with automatic calibration of the sensor(s) that had significant limitations or did not live up to specifications or expectations?

Calibration loops in software are not automatic; laborious and tedious; no commercially prepared standards available
Changes in optical response over time
Doesn't exist
Ease and ability to hold a calibration
Needed to avoid major field costs
Run out of autocalibration solution

Q126. What were the issues with ease of calibration of the sensor(s) that had significant limitations or did not live up to specifications or expectations?

Base-line subtraction, putting a spike in so constantly needs calibration
Cumbersome
Laborious, not automatic, don't trust given calibration
Not easy to calibrate in hostile environment
Primary importance—needs to be done frequently
Set up for a single calibration is simple; laborious to set up multiple calibrations
Standardization process too labor intensive, time-consuming
Still requires the laboratory analysis
Time-consuming compared to automatic

Q127. What were the issues with real-time sensor data display and/or analysis of the sensor(s) that had significant limitations or did not live up to specifications or expectations?

Designed to be deployed autonomously, consequently all data on compact flashcard; download after the instrument removed; telemetry system capabilities not yet figured out
Interfaces not completed, not known
Telemetry and modems
The instrument sends back a signal that we have to process, which is time-consuming
Without it, very difficult

Q128. What were the issues with off-sensor telemetry of the sensor(s) that had significant limitations or did not live up to specifications or expectations?

Not a part of conventional use or practice
Not all instruments allow that
Not straightforward, protocols not good
Set up would entail additional modifications and cost

Q129. What were the issues with input/output interfaces of the sensor(s) that had significant limitations or did not live up to specifications or expectations?

Interfaces with instrumentation changes—wet chemistry = crude form of computer language, very tedious
Standardization would be helpful
Written in own command languages, not user-friendly

Q130. What were the issues with packaging of the sensor(s) that had significant limitations or did not live up to specifications or expectations?

In water—not room for all reagents in container
Large, heavy, awkward
Size
Too big
Too big, cases corrode, not in a pressure case that can withstand the depths, too heavy
Too bulky

Q131. What were the issues with in-field maintenance of the sensor(s) that had significant limitations or did not live up to specifications or expectations?

Battery replacement, probe cleaning
Breakdowns hard to diagnose
Breakdowns, replacement reagent bags
Cost of labor, hazards (weather)
Defouling, cleaning
Difficult to address repairs/adjustments
Doesn’t exist
Hostile environments—malfunctions hard to determine; removal from field causes time and data loss
Large amount of reagents to go in and out, much hauling
Not reliable for more than 2-3 weeks, so have replace—time constraints
Physical set-up of instrument, reagent reservoirs
Very little modularity in computers; too tedious; wet chemistry instruments—too much time and personnel to get ready
Wet chemistry process requires labor; clogging; etc.

Q132. What were the issues with quality of product handbook/documentation of the sensor(s) that had significant limitations or did not live up to specifications or expectations?

Configuration material should be made clearer
Needs more information
Not clearly written
Not detailed enough
Not enough helpful information
Not enough information, obvious corners cut
Not schematic for the instrument—poorly done
Not thorough
Not user-friendly; should be portable and informative enough to be taken into the field
Want to tinker with machine, no direction for how the machine works, why it works the way it works; programming seems obscure

Q133. What were the issues with cost of the sensor(s) that had significant limitations or did not live up to specifications or expectations?

Cost of labor for deployment
Expensive for not much reliability
Not suitable for research environment and staff—for cost
Too expensive (9 respondents gave this answer)
Too expensive, need to work for a long period of time (many weeks-months) to be cost-effective
Too expensive, parts expensive to replace, repairs expensive
Very expensive-market driven—cheaper products available
Very expensive

Q135. What were the effectiveness issues of the sensor(s) resulting from dependency on environmental conditions that had significant limitations or did not live up to specifications or expectations?

Arctic deployments difficult
Biofouling
High particle loads—Mississippi River, unique circumstance
Limits on temperature (in ice and under ice), reagents freeze or degrade (Gulf of Mexico), electronics have larger drift in extreme temperatures
Problems specific to environment—Antarctic
Ruggedness, rivers run violently
Silicate sensor; standard reagents don't stay in solution below 8 Celsius

➢ Issues with each of the performance characteristics of the analytical system(s) are shown in the tabulations that follow.

Q146. What were the issues with key operational parameters of the analytical system(s) that had significant limitations or did not live up to specifications or expectations?

Limits of detection more than anything else
Urea—chemistry not amenable to good level detection

Q147. What were the issues with range/detection limits of the analytical system(s) that had significant limitations or did not live up to specifications or expectations?

Couldn't reach required detection limits on the lower end of the spectrum
Not enough detection capability on lower end
Not low enough
Part of this is an operator problem; no one was willing to run it to the detection levels we wanted
Phosphate levels in lakes are below detection levels
Pushed range on both ends
Range not broad enough, especially on the lower end
Sensitivity not there for information needed
Technicon #2—can measure most things—new ones not made that have the same capability; noisy base-lines with new/commercial instrument
Very low concentration limits

Q148. What were the issues with accuracy of the analytical system(s) that had significant limitations or did not live up to specifications or expectations?

Drift and frequent recalibration; is it a true signal or does it need recalibration?
Not highly accurate, precision more important
Older systems more accurate—new systems lack of reproducibility, have noisier output
Replicability
Very low concentrations accuracy becomes more difficult

Q149. What were the issues with precision of the analytical system(s) that had significant limitations or did not live up to specifications or expectations?

Being able to tell the difference between 2 samples
If the instrument is precise, reproducible, reliable and sensitive--than the user has to make that standard accurate
Noisy output--older systems more accurate
Not high level of precision
Replicability

Q150. What were the issues with sample analytical time of the analytical system(s) that had significant limitations or did not live up to specifications or expectations?

If we could run faster, we would have more sample; there is a bottleneck at the analysis stage
Daily sample load limitations
Field collect and process—analysis takes too long
Heated chemistries too time consuming
It's labor intensive
Laborious
Length of time for wet chemical analysis is limiting
Many samples per hour are not necessarily accurate
Slow
Time is limited
Turn around time

Q151. What were the issues with degree of automation of the analytical system(s) that had significant limitations or did not live up to specifications or expectations?

Equipment not completely automated
Lack of personnel to constantly monitor—many pieces
Not automated enough—staff time
Same as with analytical time
Takes too much time
Time and personnel are limited

Q152. What were the issues with ease of calibration/automatic calibration of the analytical system(s) that had significant limitations or did not live up to specifications or expectations?

Auto-analyzer has trouble getting stable curves
Drift (2 respondents gave this answer)
Instrument stability
Multipoint calibration too cumbersome
No commercial standards; make your own—very time consuming—too much time calibrating
Related to hardware, if the auto-analyzer hasn't been used in awhile, takes a long time to set up
Reliable external standards
Technician effort
They take a lot of steps and, in turn, take a lot of time; and the frequency of calibration
Time/personnel limits
Too laborious, vendors' software should be simplified

Q153. What were the issues with software and data management of the analytical system(s) that had significant limitations or did not live up to specifications or expectations?

Age/outdated
Difficult automated output in preferred form
Needs software for direct data entry
No good software for metric data
Stinks! Write my own—I read my peaks on my own.
System crashes = reliability, "buggy"
System is not updated to best level of software
Time/personnel limits, not easily accessible to downloading into Excel
Too generic
User interface—ease of use

Q154. What were the issues with hardware of the analytical system(s) that had significant limitations or did not live up to specifications or expectations?

Age
Age = 30 years = Technicon—still works well, better than new products, but aging
Aging equipment and compatibility
Antiquated, volume of hazardous waste (cadmium)
Complexity
Contamination, multiple-channel analysis
Get hardware in field, it would help a lot
Old system—pumps still working, newer ones less-lasting, constant repair, electronic circuits can go with ships' currents
Parts/breakdowns, not reliable
Start-up time if it hasn't been running in awhile; lack of expertise of technicians
Time issues

Q155. What were the issues with reliability/durability/maintenance of the analytical system(s) that had significant limitations or did not live up to specifications or expectations?

Complexity, too many moving pieces
Frequent breakdowns
Hard to repair
Instrument stability
Maintenance intensity (reagent replenishment)
Not cost-effective
Older equipment starting to fail and parts hard to replace
Tedious instrument to keep running—lack of trained personnel for upkeep
Time/personnel limits—breakdowns waste time

- Finally, the tabulation below shows comments regarding current shortfalls/future desires in terms of in-situ nutrient analyzers (all respondents were asked; 30 responded).
  - 9 respondents specifically mentioned durability, long maintenance interval, or long deployment capability, and 7 respondents mentioned reliability.
  - 7 respondents wanted a smaller sensor.
  - 7 mentioned issues regarding the ease of use.

Q206. Based on your experience with in-situ nutrient analyzers, are there any shortfalls in current designs or additions you'd like to see in future designs?

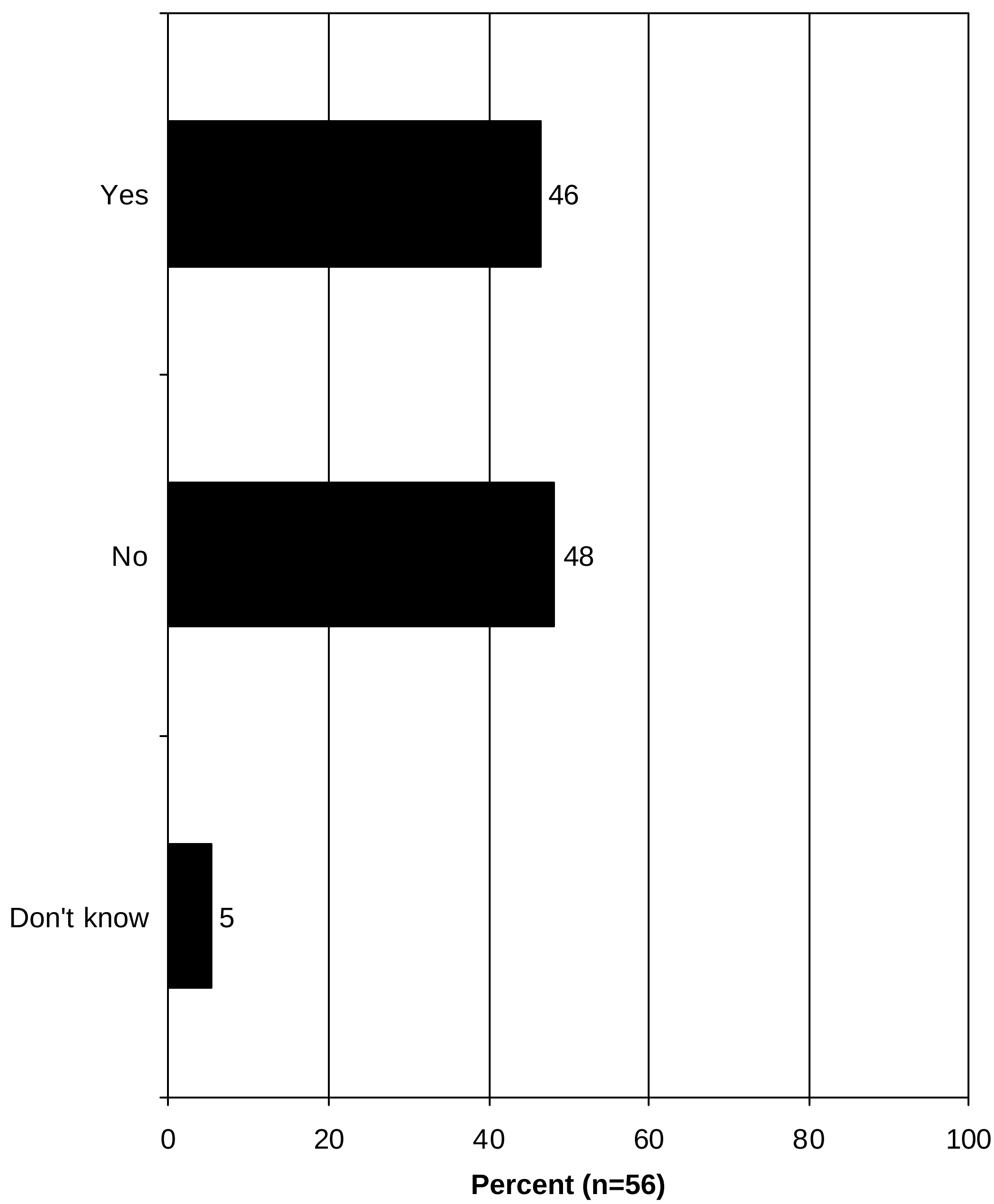
Blank out turbidity issue (1-400 ntu)
Cheaper, smaller, easier to use
Chemical storage and waste, sensor biofouling
Currently difficult to operate for our technicians
Deployment life a problem in estuarine environments
Dumb the fancy ones down; make the simple ones more robust
Ease of use
Ease of use, reliability, ease of calibration/maintenance
Expense and accuracy at low levels, reliability, difficulty in programming them to meet your needs—need a staff member dedicated to programming only
Improved reliability
Increased reliability and flexibility in mode of operations, less costly
Interface with other instruments needs improvement
Integrated anti-biofouling, size and power requirements, maintenance interval, cost
Long-term deployable instrument that can measure more
Made smaller, lower power requirements, pre-packaged reagents
Mainly level of detection, durability
Miniaturization and power consumption and stability
More affordable
More chemicals, longer operating life, higher reliability
Not very accurate
Optimizing aspects for ease of use
Precision—standard deviations too large, deployment time, data retrieval—more data analogs—retrieving from moorings etc., reagent life
Remote adaptability, reliability (chemistry manifold)
Robustness, higher frequency output
Smaller
Smaller, cheaper, faster
Stability, power, smaller, cheaper, faster, long-term autonomous operation
Total reactive nitrogen and phosphate measurements—including dissolved organic nutrients and particulate nutrients
Usability and reliability over time increased
Very limited in what we can measure and how many we can measure

PURCHASING NEW SENSORS

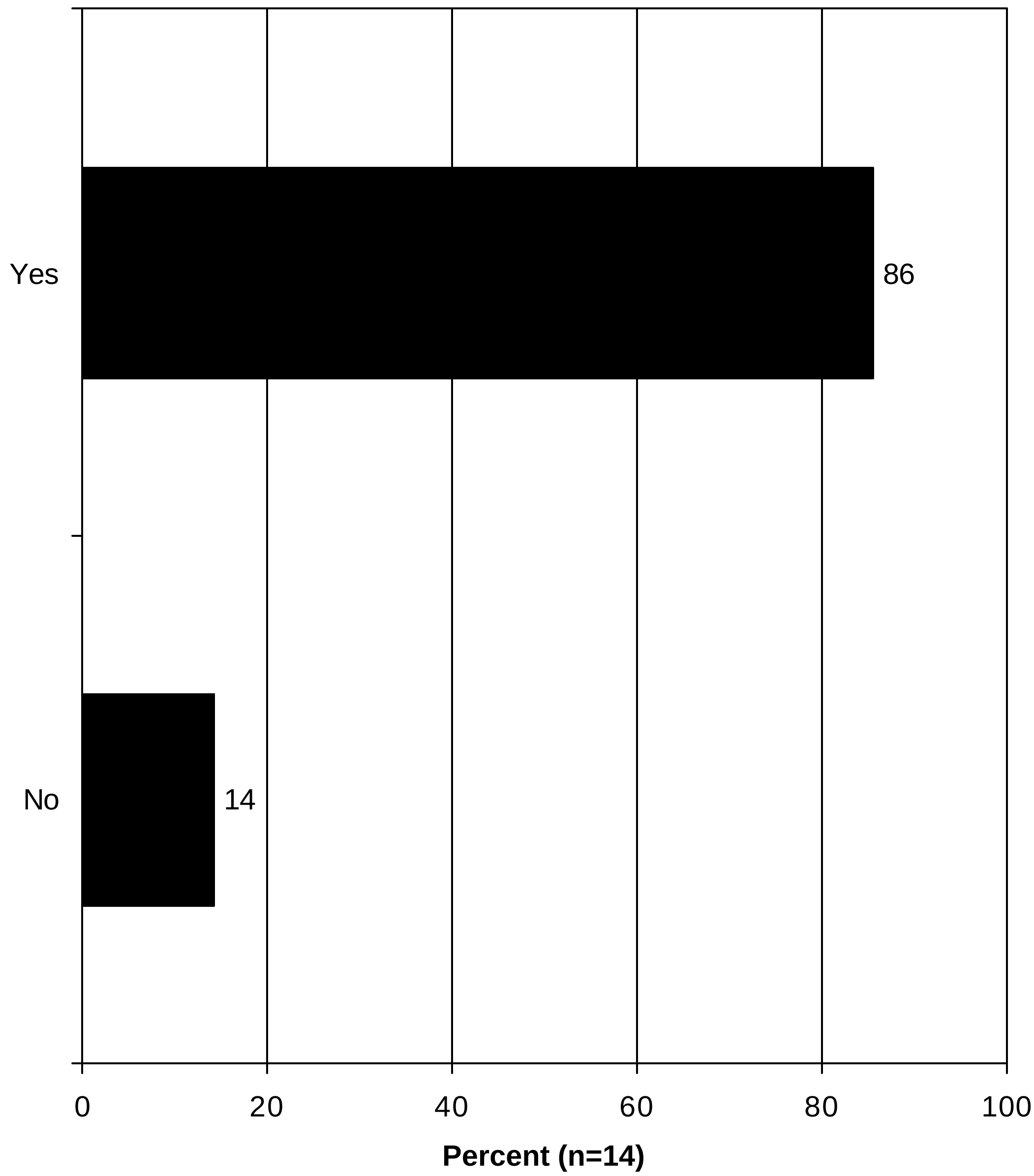
- A little less than half of respondents (46%) indicated plans to purchase new commercial sensors within the next 2 years.
  - The overwhelming majority of those who plan to purchase new commercial sensors within the next 2 years will have a trained person on staff to operate the new sensor (this graph was previously shown in the section of the report titled, "Specific Procedures/Aspects of Measuring Nutrients").
  - Of those who use in-situ sensors and who plan to purchase a new commercial sensor, the overwhelming majority indicated that they will consider a different type of sensor type than the one they are currently using.
  - Common reasons for planning to purchase new commercial sensors include an interest in new technology/new technology will address needs, facility/program expansion, and for replacement (other answers added a caveat regarding availability of funding).
  - Common constraints to purchases of new commercial sensors are lack of need and cost.
  - A tabulation shows responses regarding reasons respondents will consider using a different sensor type than the one currently being used.

- A final tabulation in this section of the report shows comments regarding what respondents (those who plan to acquire/purchase new equipment and will consider a different sensor type) require or would like to see in terms of customer support.
  - 16 of the 20 respondents mentioned the need for training of some kind, and 11 of them specifically said *on-site* training
  - 4 respondents specifically mentioned on-site set-up (these 4 also said on-site training).
  - 7 mentioned ongoing support (4 wanted telephone support, 1 wanted on-line support, 2 did not specify medium of support).
  - 3 mentioned a good manual.

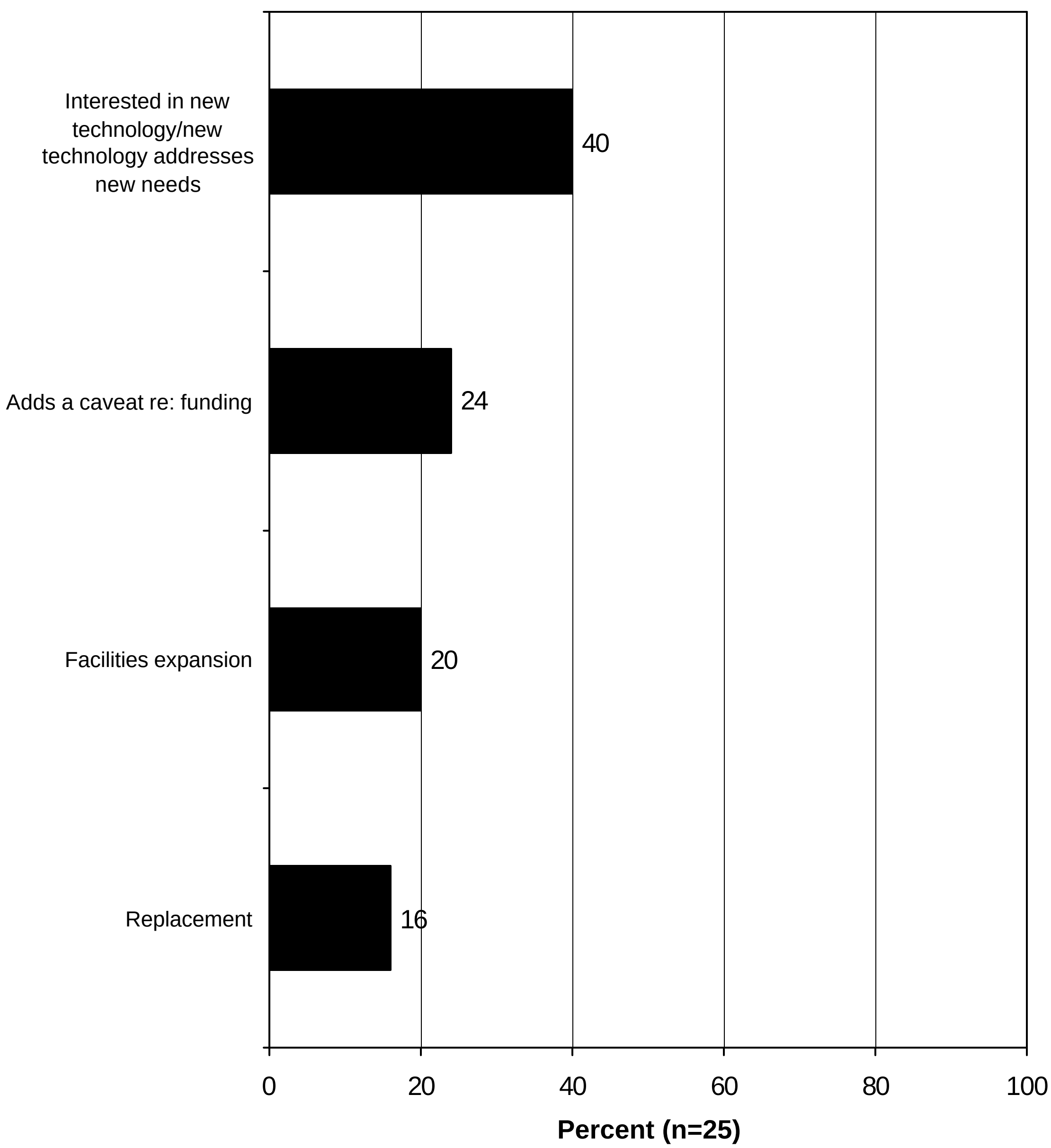
Q166. Do you plan on acquiring new commercial sensors within the next 2 years?



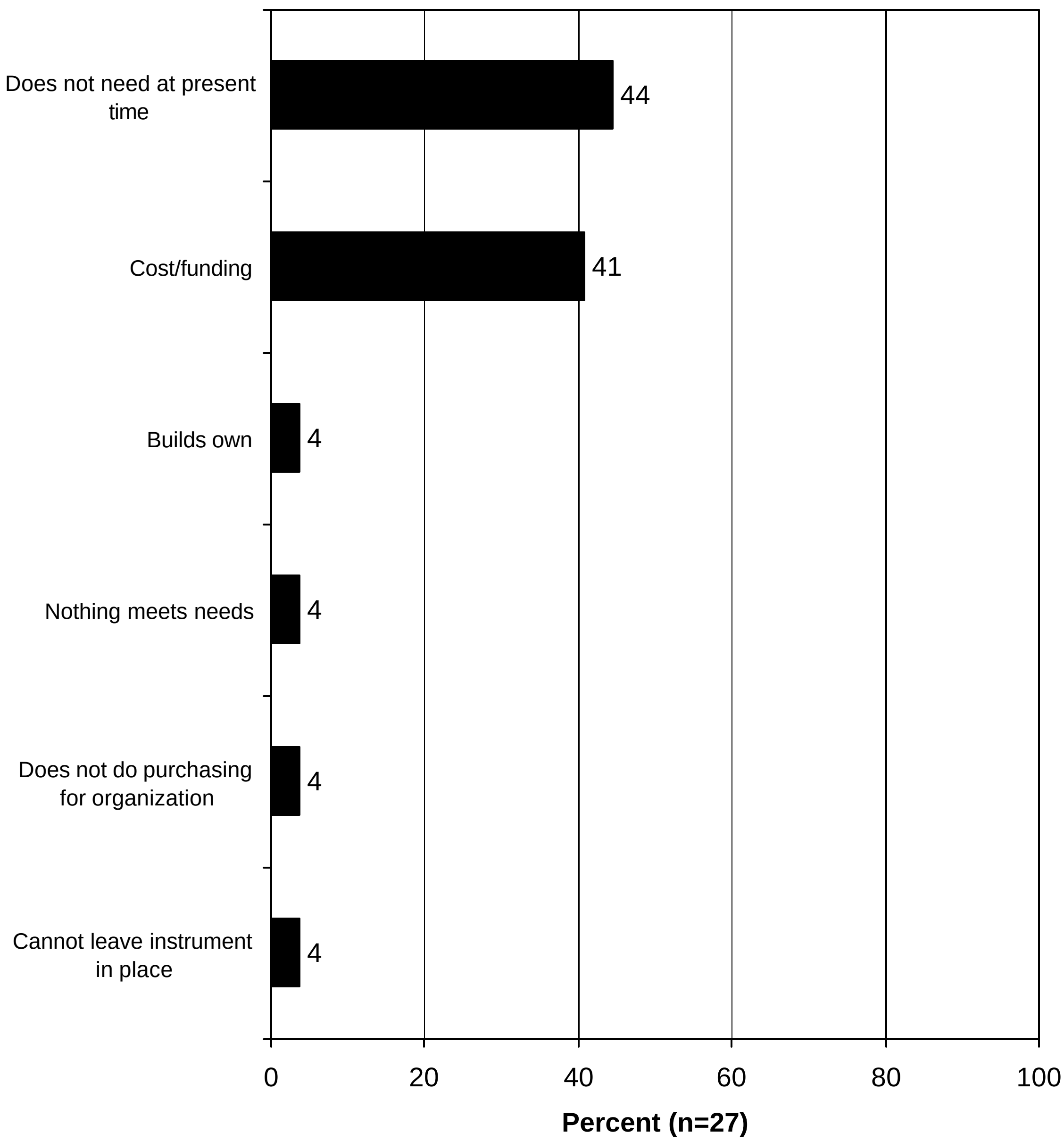
Q169. Will you consider a different sensor type than the one you are currently using to measure in-situ nutrients? (Asked of those who plan on acquiring new commercial sensors within the next 2 years.)



Q167. Please explain why you plan on acquiring new commercial sensors within the next 2 years. (Asked of those who plan on acquiring new commercial sensors within the next 2 years.)



Q168. Please explain why you do not plan on acquiring new commercial sensors within the next 2 years. (Asked of those who plan on acquiring new commercial sensors within the next 2 years.)



Q170. Please explain why you will consider a different sensor type than the one you are currently using to measure in-situ nutrients.

Compare ultra violet sensor to wet chemistry, if cost effective
Ease of operation/use
For the range of measurements, and if they are cheaper and easier to maintain
Improvements
Improvements in technology
More suitable to the project, has fewer problems
New and improved technology
New sensor technologies that overcome current problems with equipment
Optical sensors (ISIS) are less of a hassle and more robust
Reliability
Wants highest quality
Will consider modification on existing systems, wants to see what technology brings

Q173. What would you require or suggest in terms of training and customer support?

Each site should be considered a separate entity and addressed as such; prompt response time
Few days for on-site visit and set-up
Good manual, availability of tech support by phone
Good manual
Good manuals, good on-line support, representatives available to trouble-shoot
Hands-on time with a representative
Hands-on training experience
In-house
Multiple day introduction and regular follow-up
On-site training (3 respondents gave this answer)
Person needs to be skilled in analytical chemistry, skilled in lab in field labor
Qualified person come for on-site training and initial set-up
Response time is tight, and it is difficult to meet program needs, so on-call support is needed; need for a quick time-frame
Significant support—2 week course
Site visit to set up and demonstrate new equipment, suggested protocols for different ranges
Someone who really knows the instrument and all software to come on-site to train and be available by phone to resolve issues as they come up
That it be readily available; a one-day course would be helpful
Training course if complicated instrument
Training for chemical sensors—chemical, computer and engineering training by a company representative
Vendor should send technical support people to help with set-up and on-site training

CHARACTERISTICS OF SAMPLE

- The sample contained coastal professionals associated with the following organizations:

Organization	Number of Respondents
Atlantic Oceanographic and Meteorological Laboratory	1
Bard College—NY State Department of Environmental Conservation	1
Bedford Institute of Oceanography	1
Bermuda Biological Station for Research	1
Department of State (Texas) Health Services	1
Environmental Protection Agency	2
Food and Drug Administration	1
Georgia Department of Natural Resources	1
Greys Reef National Marine Sanctuary	1
Louisiana Universities Marine Consortium	1
Maryland Department of Natural Resources	1
Maryland Department of the Environment	1
Monterey Bay Aquarium Research Institute	1
National Marine Sanctuary Program	1
Natural Resources Research Institute—University of Minnesota	1
National Oceanic and Atmospheric Administration	1
North Carolina State University	1
Occoquan Watershed Monitoring Laboratory	1
Office of Navel Research	1
Ohio River Valley Water Sanitation Commission	1
Oregon State University	1
Rutgers University—IMCB	1
San Francisco State University-Romberg Tibouron Center	1
Sapelo Island (Georgia) National Estuarine Research Reserve	1
Skidaway Institute of Oceanography	3
South Florida Management District	1
South Florida Management District Team	1
South Florida Water Management District	1
Southern California Coastal Water Research Project	1
The Nitrate Elimination Co., Inc.	1
U.S. Fish and Wildlife Service	1
U.S. Geological Survey	3
U.S. Geological Survey—Wildlife Resources Division	1
University of Alaska	1
University of Delaware	1
University of Maine	1
University of Maryland	1
University of Maryland—Center for Environmental Science	3
University of Michigan	2

Organization	**Number of Respondents**
University of Rhode Island	1
University of Vermont	2
University of Washington	2
University of West Florida—Center for Environmental Diagnostics and Bioremediation	1
University of West Florida	1
Virginia Institute of Marine Science	1
WetLabs, Inc.	1

- The sample was 82% male.

Q209. Respondent's gender (not asked, but observed by interviewer).