

# Responsive Management



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

Conducted for the Alliance for Coastal Technologies  
by Responsive Management

2006

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

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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 August – September 2006. 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 (71%), while 18% listed their primary area of interest as resource management.
  
- 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 top aquatic environment of interest is estuarine, followed by coastal/near shore, rivers/lakes/freshwater wetland/groundwater, and open ocean.

- The nutrients most of interest/concern are nitrates/nitrites (93% said they are interested/concerned with these), phosphates (86%), ammonium (79%), and silicate (43%).
  - An overwhelming majority of respondents (88%) are currently measuring nitrates/nitrites.
  - A large majority of respondents (82%) are currently measuring phosphates.
  - A large majority of respondents (84%) are currently measuring ammonium.
  - A slight majority of respondents (55%) are currently measuring silicate.
  - A small yet substantial percentage of respondents (13%) indicated that they are currently measuring other nutrients (other than nitrates/nitrites, phosphates, ammonium, and silicate). Other nutrients of interest include chlorophyll, nitrogen, carbon, and urea.
  
- The large majority of respondents are measuring other parameters when measuring nutrients. Other parameters measured by the majority of respondents include temperature salinity, turbidity, and chlorophyll fluorometry.

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

- Cost and technical expertise limitations are important constraints among those not currently measuring a nutrient of interest.
  
- Cost and a lack of need for sensors 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 the lack of need.

#### SPECIFIC PROCEDURES/ASPECTS OF MEASURING NUTRIENTS

- A slight majority of respondents (54%) are required to use specific approved analytical techniques and procedures, such as EPA-approved methods.
  - EPA methods were the most commonly used.

- Most commonly, coastal professionals measure nutrients in  $\mu\text{M}$  (micromolars) (47%), while 38% measure nutrients in mg/l (milligrams per liter); these percents include the 11% who measure using both.
- A small percentage of respondents (11%) indicated that there are detection limits for nutrients that they measure that are set by regulations or other needs of the data
- Nearly a third of the sample of coastal professionals (29%) currently use in-situ nutrient sensors, with over half of those using commercial products.
  - A majority of those who use in-situ nutrient sensors take measurements hourly (69%), by far the leading answer.
- A majority of coastal professionals who do *not* currently use in-situ nutrient sensors (75%) use in-house sample analyses to measure nutrients at least some of the time, with most of those using in-house sample analyses exclusively; 28% contract with a laboratory to conduct analyses at least some of the time, with most of those using an outside lab exclusively.
  - Those who do *not* currently use in-situ nutrient sensors were asked how often they need to provide or obtain nutrient measurement data, and the top responses were weekly (23%) and monthly (23%), followed by hourly (13%).

#### ASPECTS OF IN-SITU NUTRIENT SENSOR USE AND SENSOR REQUIREMENTS

- Of those who currently use in-situ nutrient sensors, 56% use a commercial product alone, 6% use a custom-designed and custom-made sensor, and 38% use a combination of commercial and custom-made.
- About a quarter of respondents (27%) said their sensor needs or requirements are non-standard; descriptions of their non-standard needs are shown.
- The sensor performance characteristics of most importance are reliability, accuracy, precision, product support/warranty/vendor reputation, and range/detection limits.

- Most commonly, coastal professionals require a 3 to 4 year lifetime or length of efficient use for in-situ nutrient sensors (36% gave this response), followed by 5 years (27%).
- The most common application for nutrient sensors is as a deployed sensor on a remote platform for continuous in-situ measurements, such as buoys and cable systems.
- Of those who have or plan to integrate an in-situ nutrient sensor into a buoy or cable observation system, the overwhelming majority of respondents use the sensor for absolute concentrations (94%) with nearly half of those using the sensor to determine relative changes as well.
  - A large majority (87%) of those who have or plan to integrate an in-situ nutrient sensor into a buoy or cable observation system also conduct their own absolute calibrations; descriptions of their calibration techniques are shown.
- Protocol/interface details for using sensors on multiple systems are important to the large majority of those who have or plan to integrate an in-situ nutrient sensor into a buoy or cable observation system.

#### LIMITATIONS OF SENSORS

- Deployment life, reliability, and key operational parameters are the top areas in which current in-situ nutrient sensors have limitations, do not meet expectations, or do not meet needs.

#### LIMITATIONS OF IN-HOUSE AND CONTRACTED ANALYSES

- A slight majority of those who use in-house sample analyses indicated that the analysis system they are currently using does not have any significant limitations.
- Analytical time is the top limitation on contracted laboratory analyses.

## PURCHASING NEW SENSORS

- Slightly less than half of respondents (41%) indicated plans to purchase new commercial sensors within the next 2 years.
  - Common reasons for planning to purchase new commercial sensors include replacing old sensors, increasing the number of sensors used, and acquiring new technology.
  - The most common constraint to the purchase of new commercial sensors is a lack of need.
  - All (7) respondents who use in-situ sensors and who plan to purchase a new commercial sensor indicated that they will consider a different type of sensor type than the one they are currently using.
  - Common reasons for considering a different type of sensor than the one currently used include an interest in new or better technology and capabilities.
  - A majority of respondents (64%) indicated that if they were to purchase and use a new nutrient sensor, they would use a multi-channel system.
  
- The majority of those who plan to purchase new commercial sensors within the next 2 years (65%) will *need* personnel with previous training for sensor technology to operate the new sensor; 43% say they will need a science technician with a master's degree.
  - In a related question, those who plan on acquiring new commercial sensors within the next 2 years gave similar responses when asked what type of personnel they would most likely *have* to operate the new sensor.
  
- 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:
  - 9 of the 19 respondents mentioned the need for training of some kind, and 3 specifically said on-site, in-field, or hands-on training.
  - 4 respondents specifically mentioned customer support, and 1 mentioned technical assistance by telephone.
  - 7 mentioned ongoing support.
  - 3 mentioned a good manual or documentation.

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## **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 August – September 2006. Responsive Management obtained a total of 56 completed interviews.

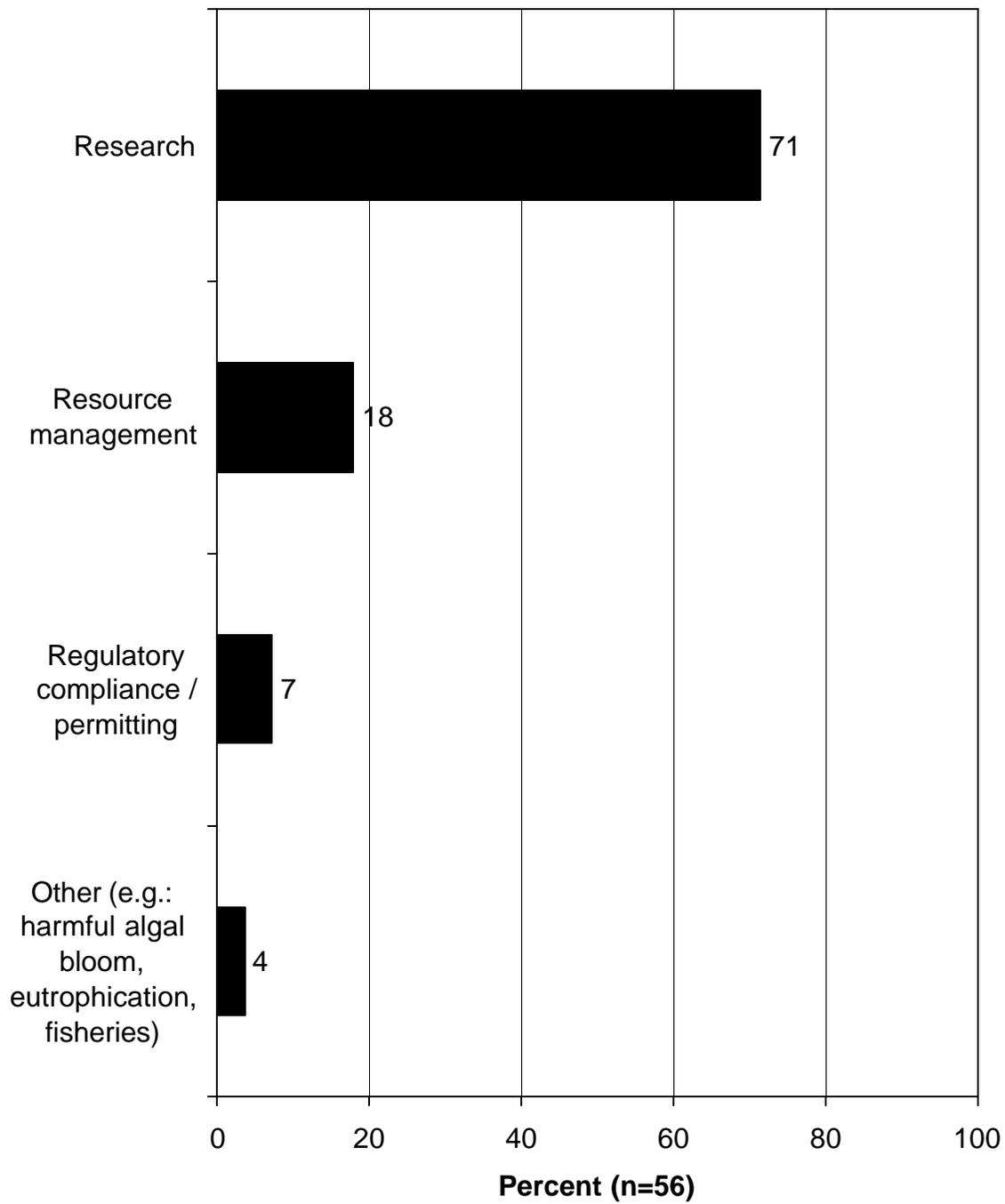
The software used for data collection was Questionnaire Programming Language 4.1 (QPL). The survey data were entered into the computer as each interview was being conducted, eliminating manual data entry after the completion of the survey and the concomitant data entry errors that may occur with manual 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.

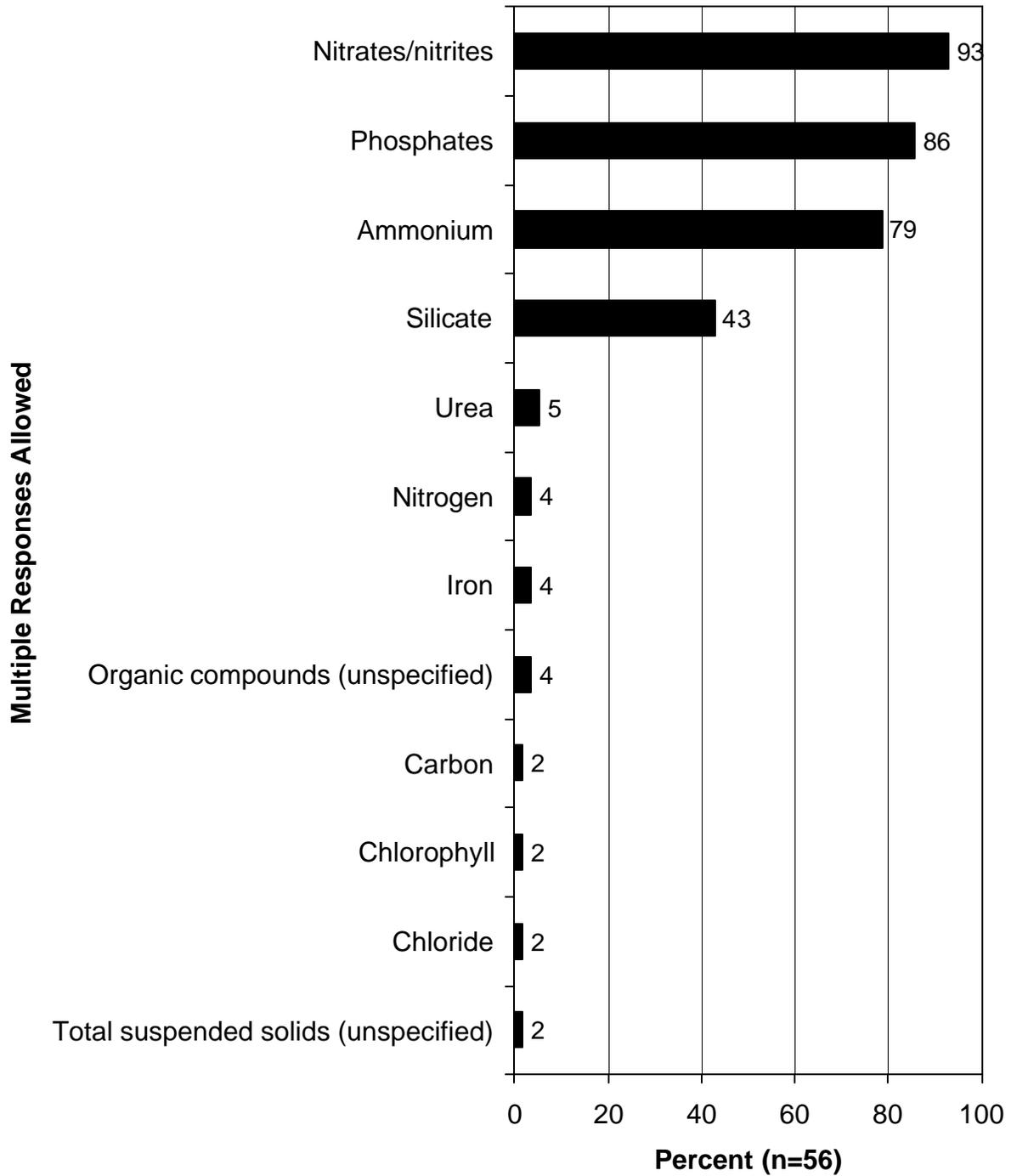
## **NUTRIENTS, PARAMETERS, AND AQUATIC ENVIRONMENTS OF INTEREST**

- Overwhelmingly, respondents listed their primary area of interest as research (71%), while 18% listed their primary area of interest as resource management. It is important to note, however, that the question asked for the *primary* area of interest and allowed only one response and does not account for those respondents who may have multiple areas of interest or application concern.
  
- 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 (93% said they are interested/concerned with these), phosphates (86%), ammonium (79%), and silicate (43%).
  
- The top aquatic environment of interest is estuarine, followed by coastal/near shore, rivers/lakes/freshwater wetland/groundwater, and open ocean.
  - They typical water temperature ranges for the aquatic environment of interest are shown.
  - They typical pressure ranges for the aquatic environment of interest are shown.
  
- The organizations of the respondents are listed in the section of this report titled, “Characteristics of Sample.”

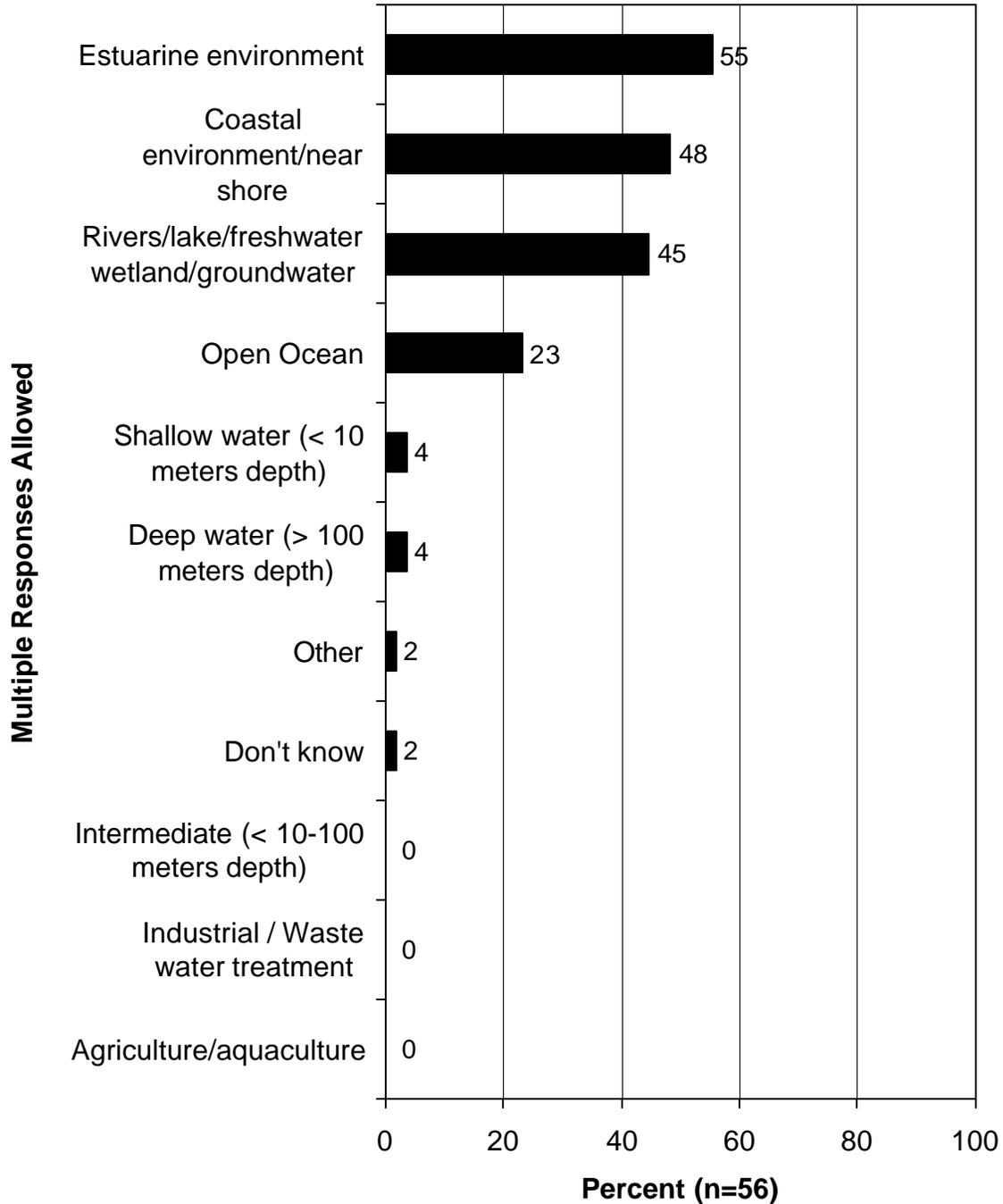
**Q7. Which of the following best describes your primary area of interest or application concern?**



**Q10, 12, and 14-18. Which of the following nutrients are of interest or concern for you?**



**Q106. Which of the following describes your primary investigation/monitoring aquatic environment?**



**Q108. What is the typical water temperature range for the primary investigation/monitoring aquatic environment you just mentioned?**

Typical Water Temperature	Number of Respondents
8-14 °C	1
10-14 °C	1
15 °C	1
10-17 °C	1
0-18 °C	1
15-18 °C	1
10-20 °C	1
15-20 °C	1
4-22 °C	1
9-22 °C	1
7-24 °C	1
8-24 °C	1
20-24 °C	1
0-25 °C	1
2-25 °C	1
5-25 °C	1
15-25 °C	1
16-25 °C	1
15-27 °C	1
5-28 °C	2
12-28 °C	1
20-28 °C	1
10-29 °C	1
0-30 °C	4
1-30 °C	1
2-30 °C	2
10-30 °C	1
15-30 °C	1
17-30 °C	1
20-30 °C	3
30 °C	1
0-32 °C	1
2-32 °C	1
18-32 °C	1
9-33 °C	1
15-33 °C	1
0-35 °C	2
4-35 °C	1
10-35 °C	2
15-35 °C	1
4-36 °C	1
1-40 °C	1

**Q109. What is the typical pressure range for the primary investigation/monitoring aquatic environment you just mentioned?**

<b>Typical Pressure Range</b>	<b>Number of Respondents</b>
1-1 PSI	1
0-3 PSI	1
1 PSI	2
2 PSI	1
10 PSI	1
0-100 PSI	1
100 PSI	2
760 PSI	1
767 PSI	1
740-780 PSI	1

**NITRATES/NITRITES**

- An overwhelming majority of respondents (88%) are currently measuring nitrates/nitrites.
- The range of nitrates/nitrites measured and detection limits are shown in the following tabulations:

**Q42 and 43. 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.)**

Typical Range	Number of Respondents
< 1 $\mu\text{M}$	2
1-10 $\mu\text{M}$	6
Below detection limits to 20 $\mu\text{M}$	1
0-30 $\mu\text{M}$	1
0-42 $\mu\text{M}$	1
10-100 $\mu\text{M}$	6
100 $\mu\text{M}$ or higher	2
0-2000 $\mu\text{M}$	1
0.02-0.5 mg/l	1
< 1 mg/l	3
0.001-1 mg/l	1
0.03-1 mg/l	1
0.01-1.2 mg/l	1
1-10 mg/l	6
0.01-20 mg/l	1
Below detection to 30 mg/l	1
0-30 mg/l	1
0.10-60 mg/l	1
10-100 mg/l	2
10-100,000 mg/l	1
0.001-20 micrograms per liter	1
0-5	1
Depends on the site	1
Don't know	6

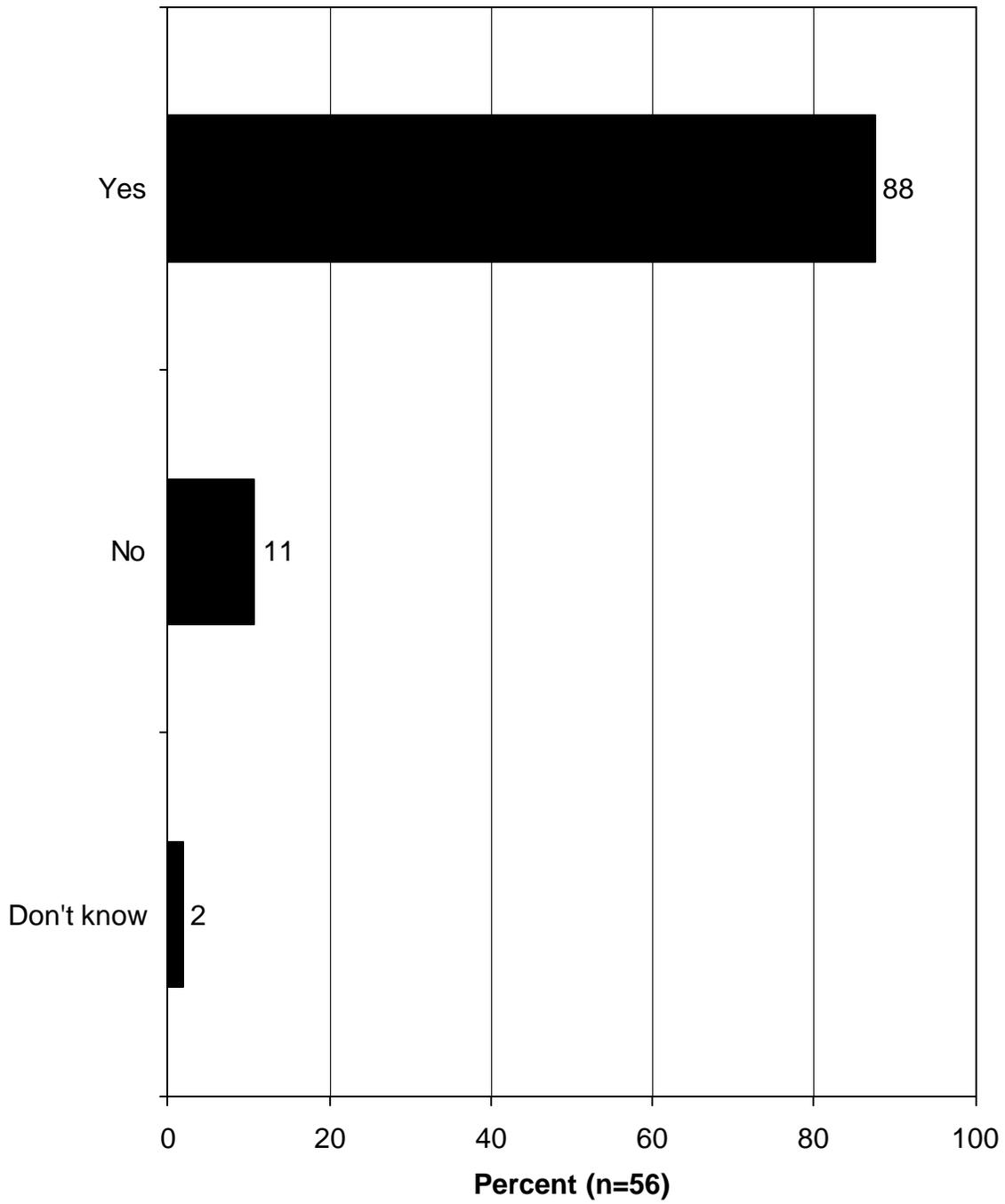
**Q73. What is the required range for the nitrates/nitrites you are currently measuring? (Asked of those who said there is a required range for the nitrates/nitrites being currently measured.)**

Required Range	Number of Respondents
0-5 $\mu\text{M}$	1

**Q72. What is the required detection limit for the nitrates/nitrites you are currently measuring? (Asked of those who said there is a required detection limit for the nitrates/nitrites being currently measured.)**

<b>Required Detection Limit</b>	<b>Number of Respondents</b>
03 $\mu$ M	1
10 mg/l	1
5 mg	1
2	1

### Q19. Are you currently measuring nitrates/nitrites?



## PHOSPHATES

- A large majority of respondents (82%) are currently measuring phosphates.
- The range of phosphates measured and detection limits are shown in the following tabulations:

**Q44 and 45. What is the typical range of concentrations of the phosphates you are currently measuring? (Asked of those who said they are currently measuring phosphates.)**

Typical Range	Number of Respondents
< 1 $\mu\text{M}$	6
Below detection to 1 $\mu\text{M}$	1
0.3-1.5 $\mu\text{M}$	1
0-5 $\mu\text{M}$	1
1-10 $\mu\text{M}$	10
0-20 $\mu\text{M}$	1
10-100 $\mu\text{M}$	1
0.05-0.2 mg/l	1
0.05-0.3 mg/l	1
< 1 mg/l	4
0.02-3 mg/l	1
0-5 mg/l	1
0.001-5 mg/l	1
0-6 mg/l	1
0-6 or 7 mg/l	1
1-10 mg/l	6
0.001-20 micrograms per liter	1
Depends on the site	1
Don't know	6

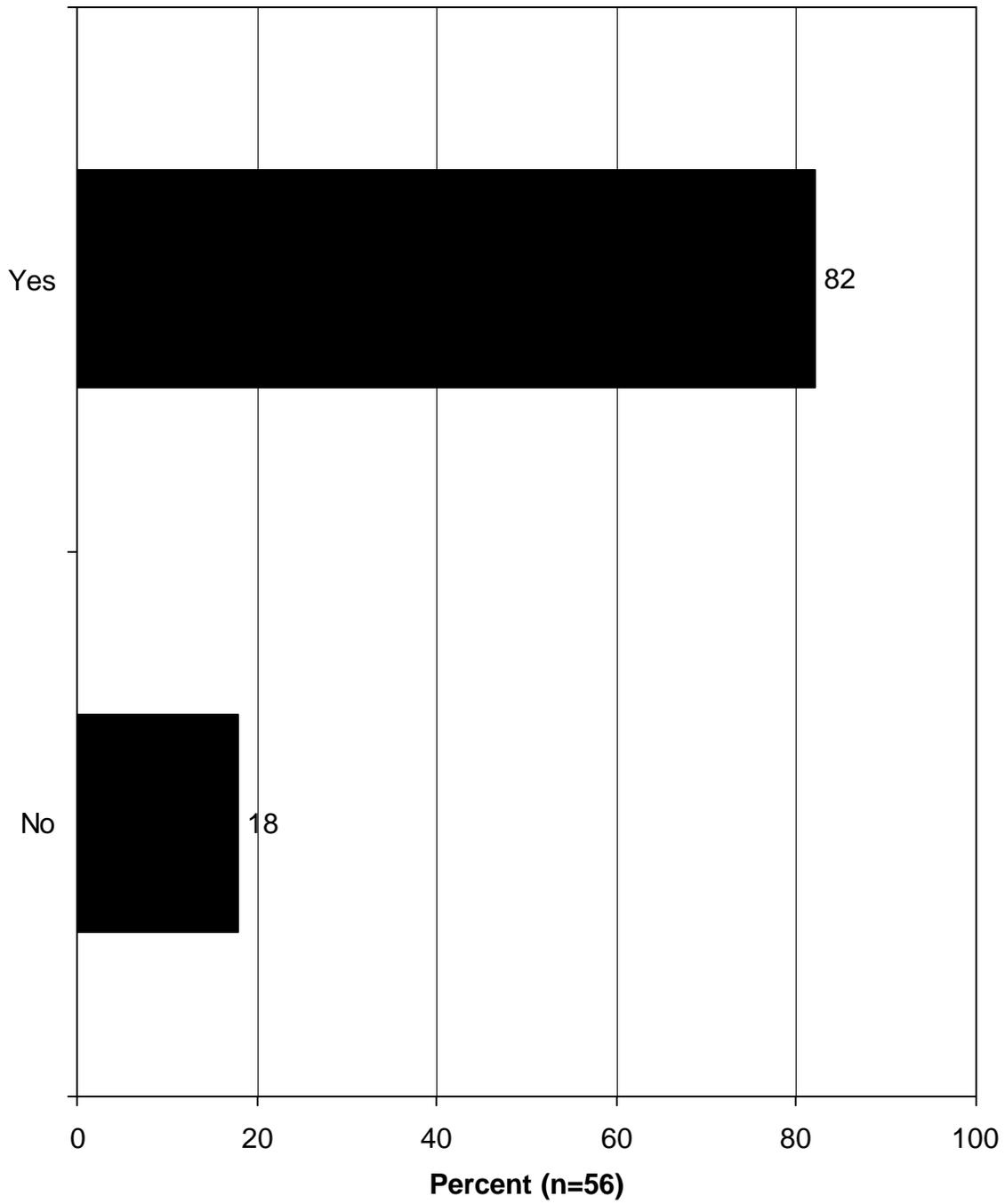
**Q75. What is the required range for the phosphates you are currently measuring? (Asked of those who said there is a required range for the phosphates being currently measured.)**

Required Range	Number of Respondents
50	1
0-1 $\mu\text{M}$	1

**Q74. What is the required detection limit for the phosphates you are currently measuring? (Asked of those who said there is a required detection limit for the phosphates being currently measured.)**

Required Detection Limit	Number of Respondents
1 $\mu\text{M}$	1

### Q20. Are you currently measuring phosphates?



**AMMONIUM**

- A large majority of respondents (84%) are currently measuring ammonium.
- The range of ammonium measured and detection limits are shown in the following tabulations:

**Q46 and 47. What is the typical range of concentrations of the ammonium you are currently measuring? (Asked of those who said they are currently measuring ammonium.)**

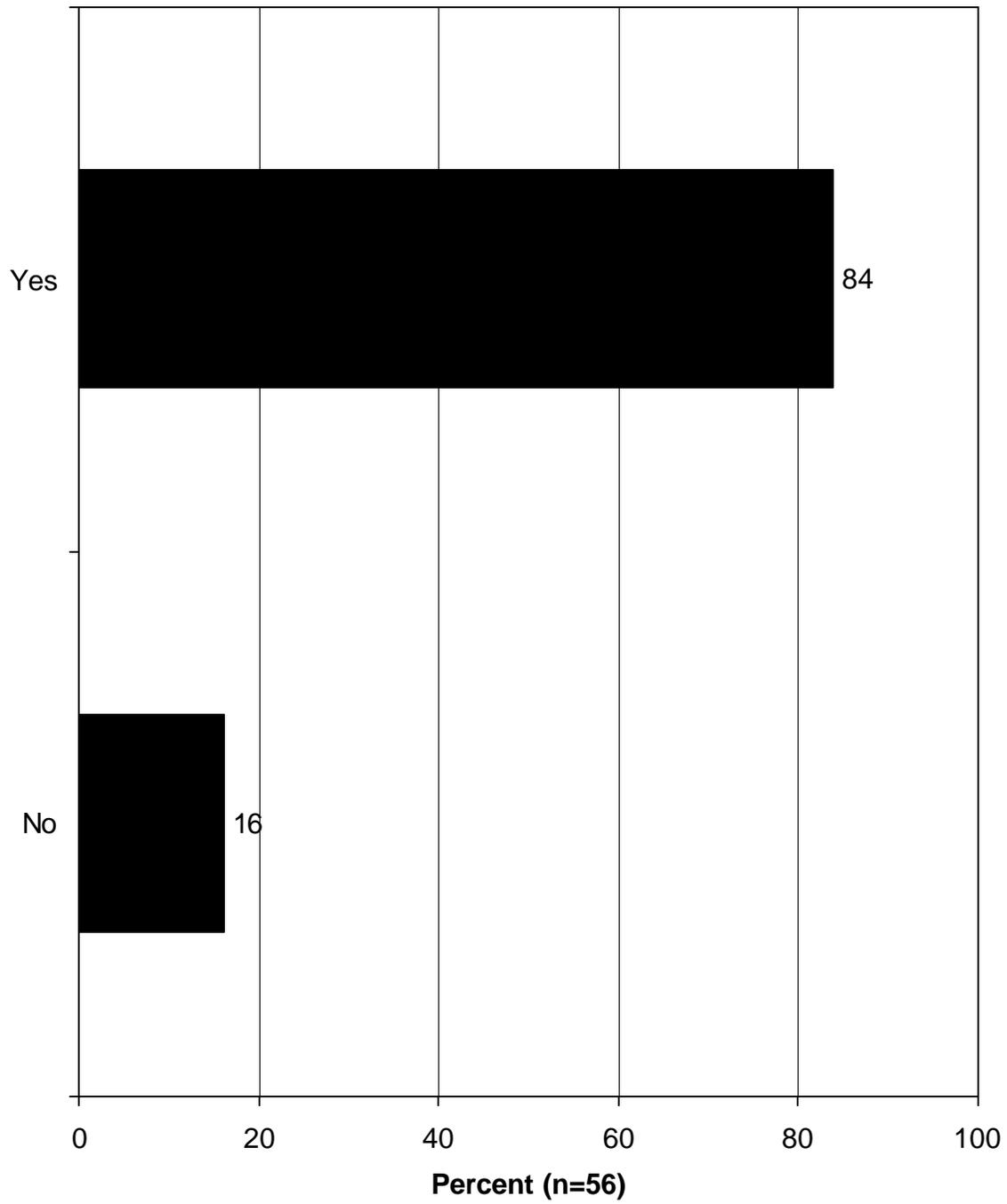
Typical Range	Number of Respondents
0.05-0.2 $\mu$ M	1
< 1 $\mu$ M	3
0-1 $\mu$ M	1
1-10 $\mu$ M	9
0-20 $\mu$ M	2
0-25 $\mu$ M	1
0.5-25 $\mu$ M	1
Detection to 40 $\mu$ M	1
10-100 $\mu$ M	1
0.01-0.2 mg/l	1
< 1 mg/l	4
0.01-1 mg/l	1
0.01-1.5 mg/l	1
0-2 mg/l	1
0.03-5 mg/l	1
0-6 mg/l	1
1-10 mg/l	4
30 mg/l	1
10-100,000 mg/l	1
0.001 - 20 micrograms per liter	1
0-2	1
Don't know	8

**Q77. What is the required range for the ammonium you are currently measuring? (Asked of those who said there is a required range for the phosphates being currently measured.)**

Required Range	Number of Respondents
0-10 $\mu$ M	1

**Q76. What is the required detection limit for the ammonium you are currently measuring? (Asked of those who said there is a required detection limit for the phosphates being currently measured.)**

<b>Required Detection Limit</b>	<b>Number of Respondents</b>
5 $\mu$ M	1
2 mg/l	1

**Q21. Are you currently measuring ammonium?**

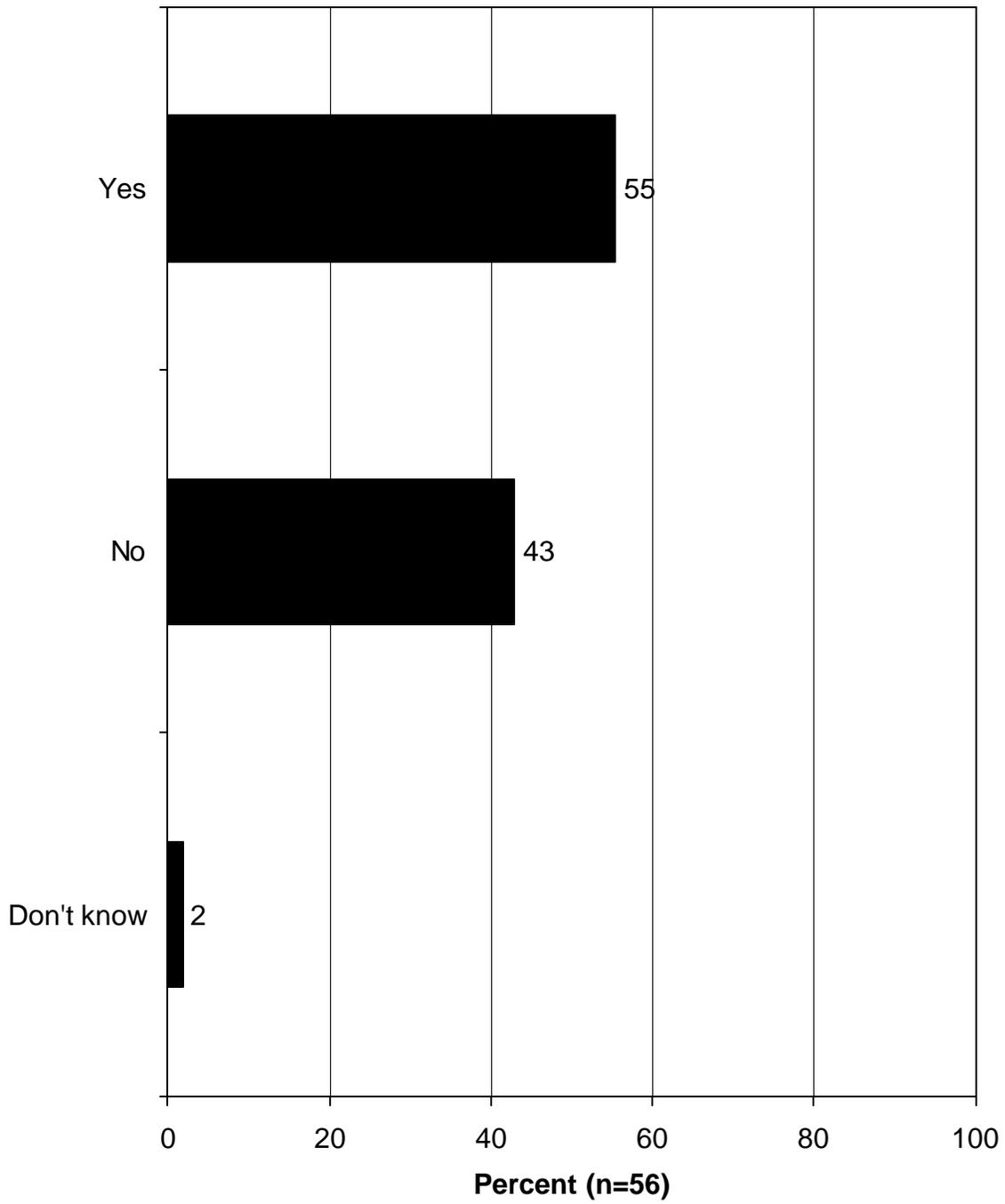
**SILICATE**

- A slight majority of respondents (55%) are currently measuring silicate.
  
- The range of silicate measured are shown in the tabulation below:

**Q48 and 49. What is the typical range of concentrations of the silicate you are currently measuring? (Asked of those who said they are currently measuring silicate.)**

Typical Range	Number of Respondents
< 1 $\mu\text{M}$	2
1-10 $\mu\text{M}$	4
5-20 $\mu\text{M}$	1
0-40 $\mu\text{M}$	1
10-100 $\mu\text{M}$	4
2-150 $\mu\text{M}$	1
0-1000 $\mu\text{M}$	1
< 1 mg/l	3
0-5 mg/l	1
0.5-7 mg/l	1
0-30 mg/l	1
10-100 mg/l	1
0.1-5 micrograms	1
Depends on the site	1
Don't know	8

### Q22. Are you currently measuring silicate?



## OTHER NUTRIENTS

- A small yet substantial percentage of respondents (13%) 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.
- The ranges for the other nutrients measured are shown below.
  - The range and detection limit for one of the other nutrients measured, the only one for which this data was applicable, is also shown.

Nutrient of Interest	Number of Respondents Measuring the Nutrient	Number of Respondents Interested in but Not Measuring the Nutrient
Carbon	3	0
Chloride	1	0
Chlorophyll	4	0
Iron	2	2
Nitrogen	4	1
Organic compounds (unspecified)	2	0
Total suspended solids (unspecified)	1	0
Urea	3	0

**Q50 and 51. What is the typical range of concentrations of the other nutrient you are currently measuring? (Asked of those who said they are currently measuring other nutrients.)**

Nutrient Measured	Typical Range	Number of Respondents
Carbon	Don't know	1
Chlorophyll	1-10 mg/l	1
Dissolved organic nutrients	Up to 25-30 $\mu$ M	1
Nitrogen	1-10 $\mu$ M	1
Organic nitrogen	1-30 $\mu$ M or 40 $\mu$ M	1
Phosphorus, iron, chloride	0.001-1	
Total organic nutrients	1-10 mg/l	1
Total suspended solids	100 mg/l or higher	1
Urea	0-.5 mg/l	1
Urea	Depends on the site	1
Urea	1-10 $\mu$ M	1

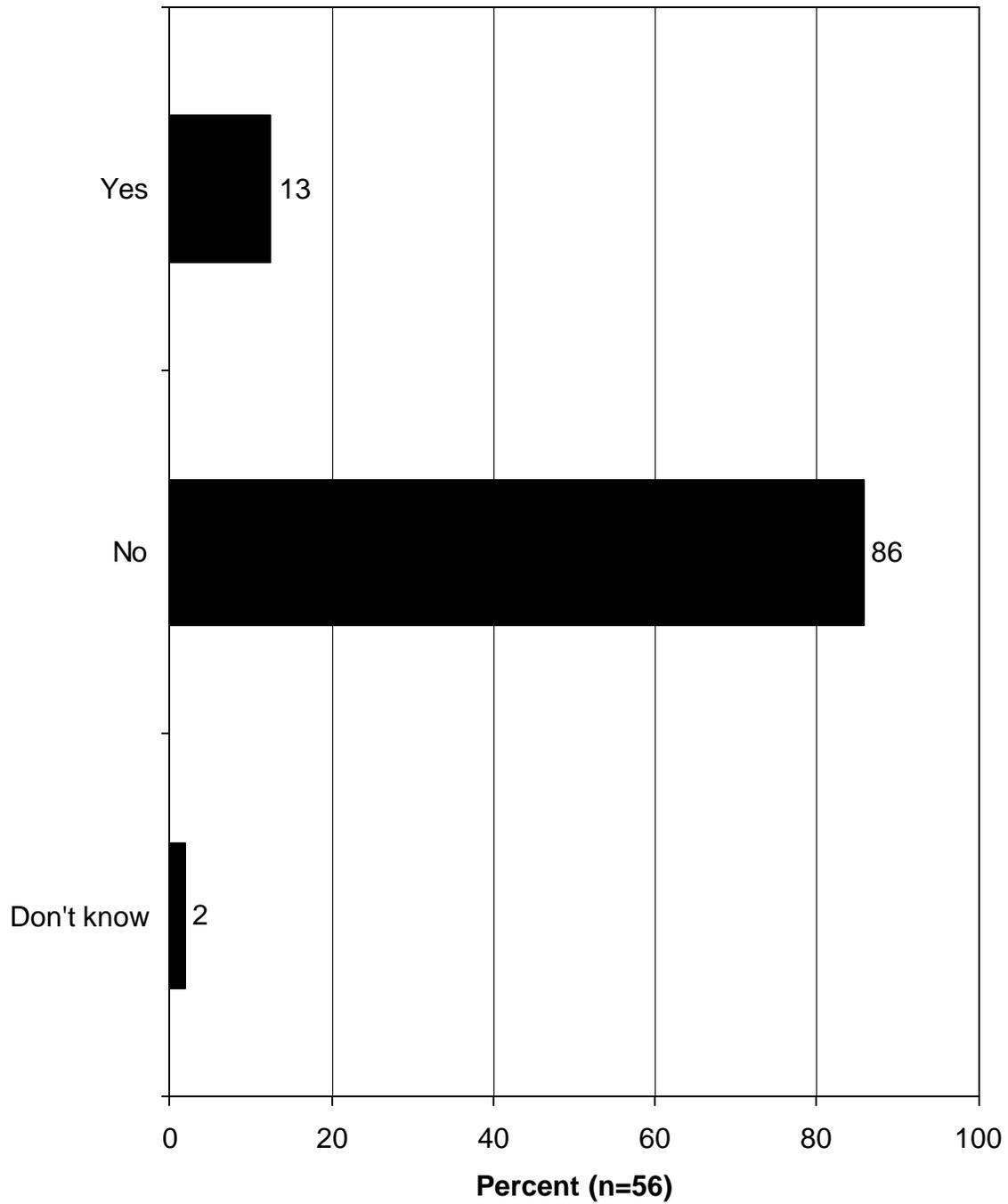
**Q81. What is the required range for the first other nutrient you are currently measuring?**

Nutrient Measured	Required Range	Number of Respondents
Total organic nutrients	0-2 mg/l	1

**Q80. What is the required detection limit for the first other nutrient you are currently measuring?**

<b>Nutrient Measured</b>	<b>Required Detection Limit</b>	<b>Number of Respondents</b>
Total organic nutrients	3 mg/l	1

**Q28. Are you currently measuring any other nutrients?**

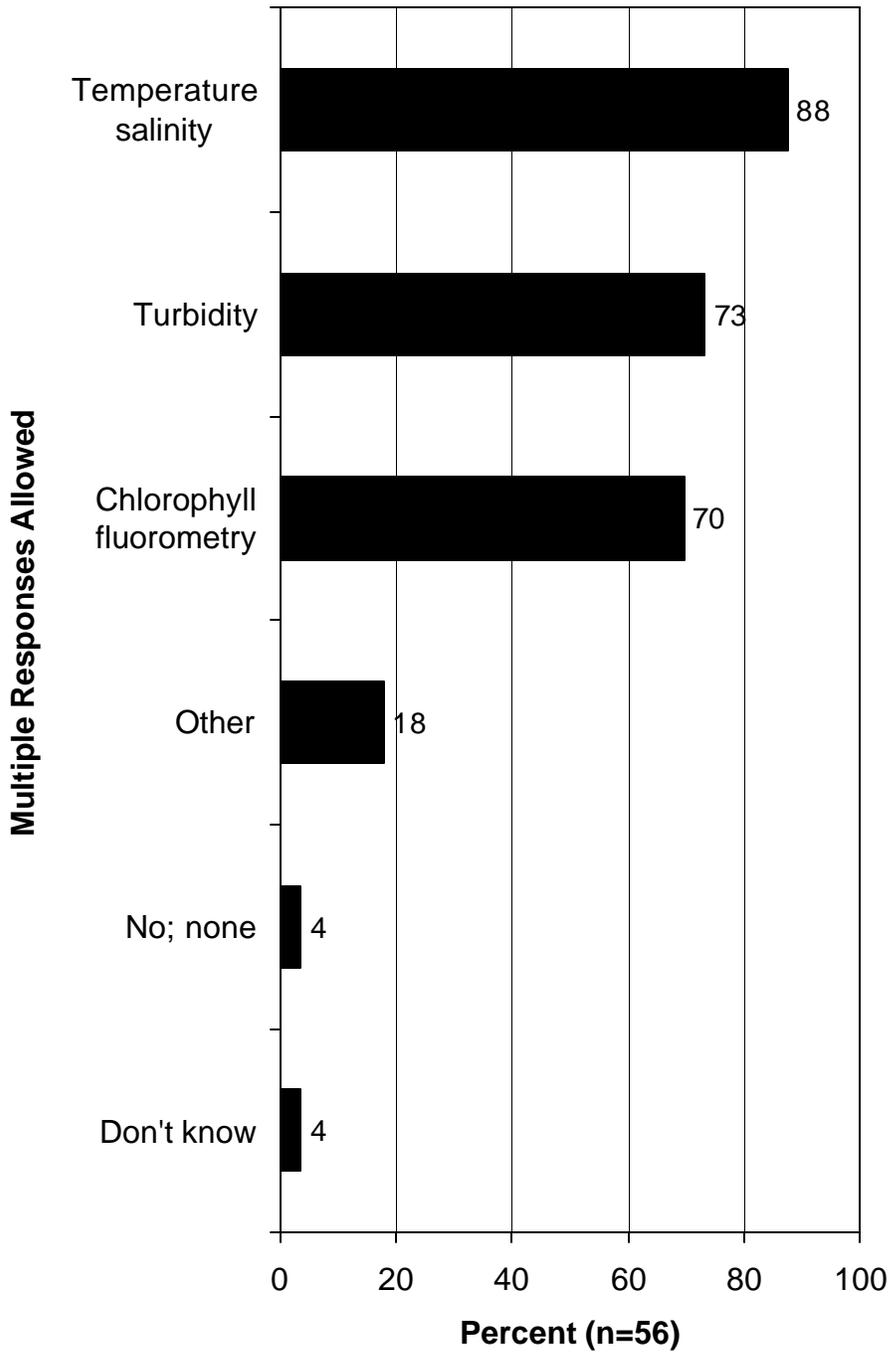


**PARAMETERS**

- The large majority of respondents are measuring other parameters when measuring nutrients.
- 88% measure temperature salinity.
  - 73% measure turbidity.
  - 70% measure chlorophyll fluorometry.
  - Other parameters measured and the number of respondents who measure them are shown in the tabulation.

<b>Parameter Measured</b>	<b>Number of Respondents Measuring the Parameter</b>
Alkalinity	1
Carbon dioxide	1
Chloride	1
Conductants	1
Dissolved oxygen	5
Oxygen	2
Ph	3

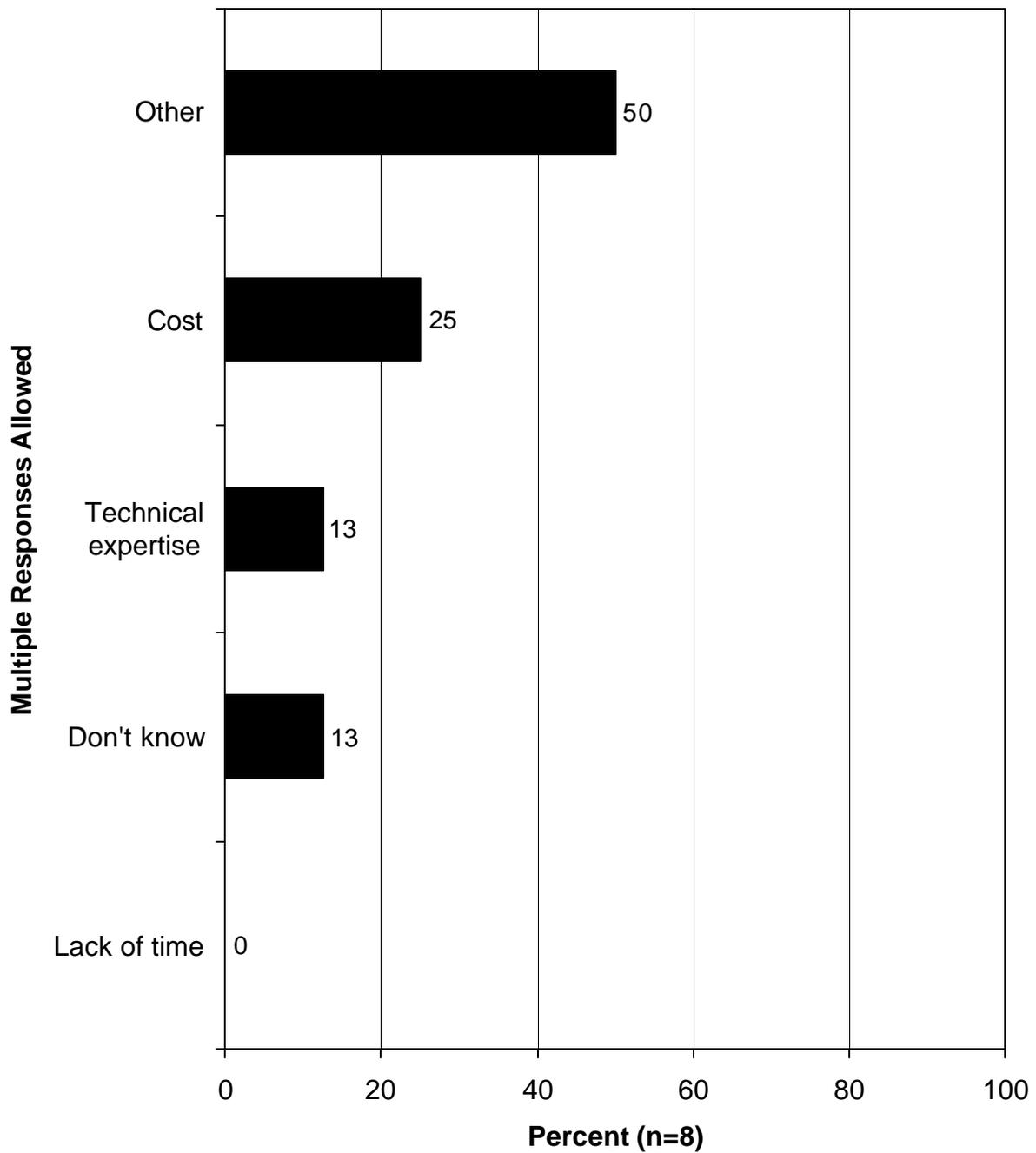
**Q103. Do you measure any other parameters at the same time as measuring nutrients, such as temperature salinity, turbidity, or chlorophyll fluorometry?**



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

- Cost and technical expertise limitations are important constraints among those not currently measuring a nutrient of interest; however, five of eight respondents gave other reasons for not measuring a nutrient of interest. These other responses are shown.
  
- Cost and a lack of need for sensors are the top constraints to use of in-situ nutrient sensors, among those not using an in-situ nutrient sensor.
  - Of those who indicated that cost was a reason they do not use an in-situ nutrient sensor, an overwhelming majority indicated that material costs were a specific expense considered when calculating the total cost for acquiring and 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 the lack of need (this graph is shown in the section of the report titled, “Purchasing New Sensors”).

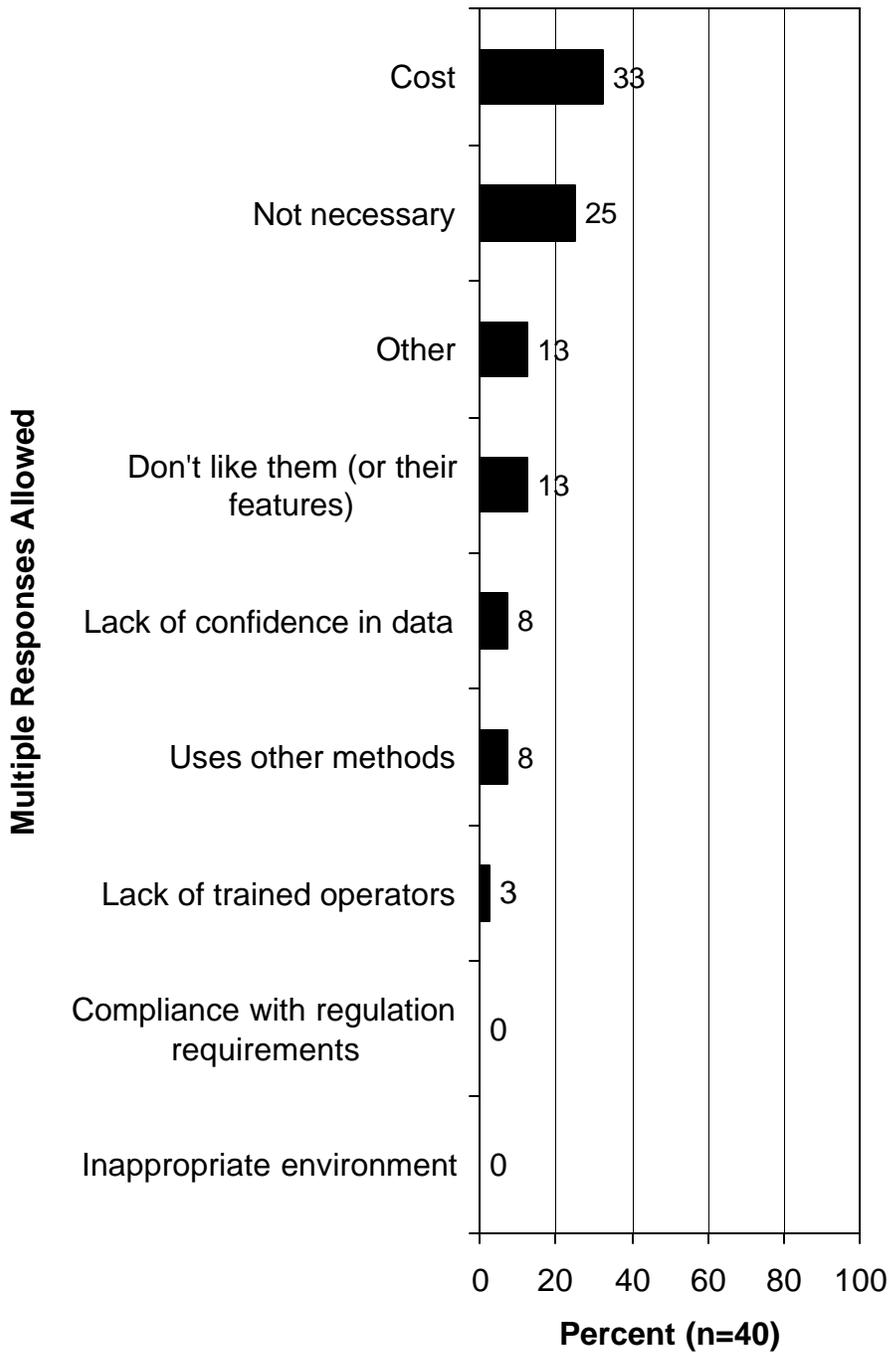
**Q39. You indicated that you have an interest in a nutrient that you are not currently measuring. What are the reasons you are not currently measuring that nutrient?**



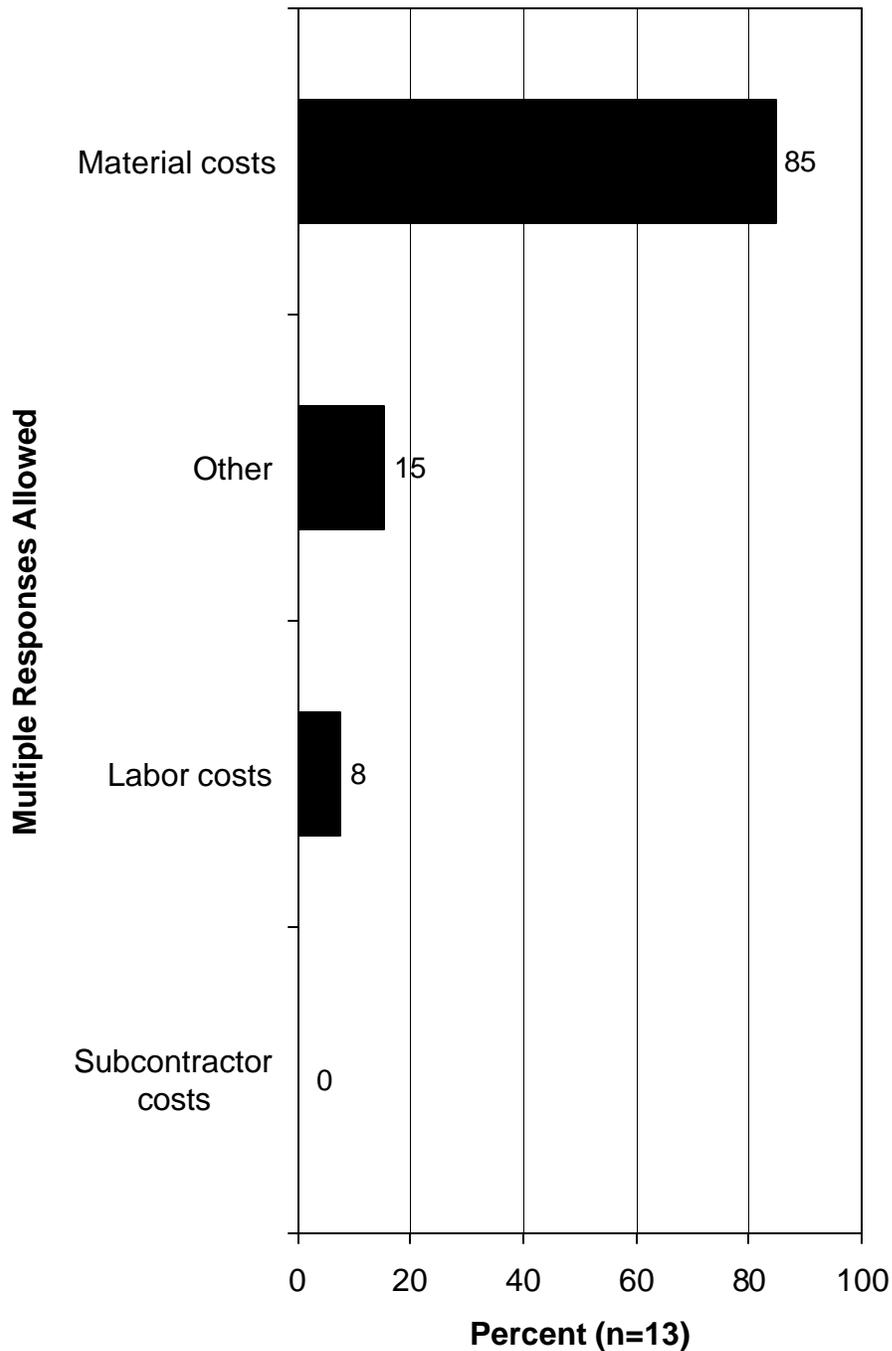
**Q40. Other Reason for Not Currently Measuring Nutrient of Interest**

<b>Reason for Not Measuring Nutrient of Interest</b>	<b>Number of Respondents</b>
A little overwhelming to bring back so many samples	1
Do not want to measure any others	1
Don't need to right now	1
Focusing on ammonium	1
Looking for something that can be deployed and give real time readings	1

**Q147. Why don't you use an in-situ nutrient sensor? (Asked of those who do not currently use an in-situ nutrient sensor.)**



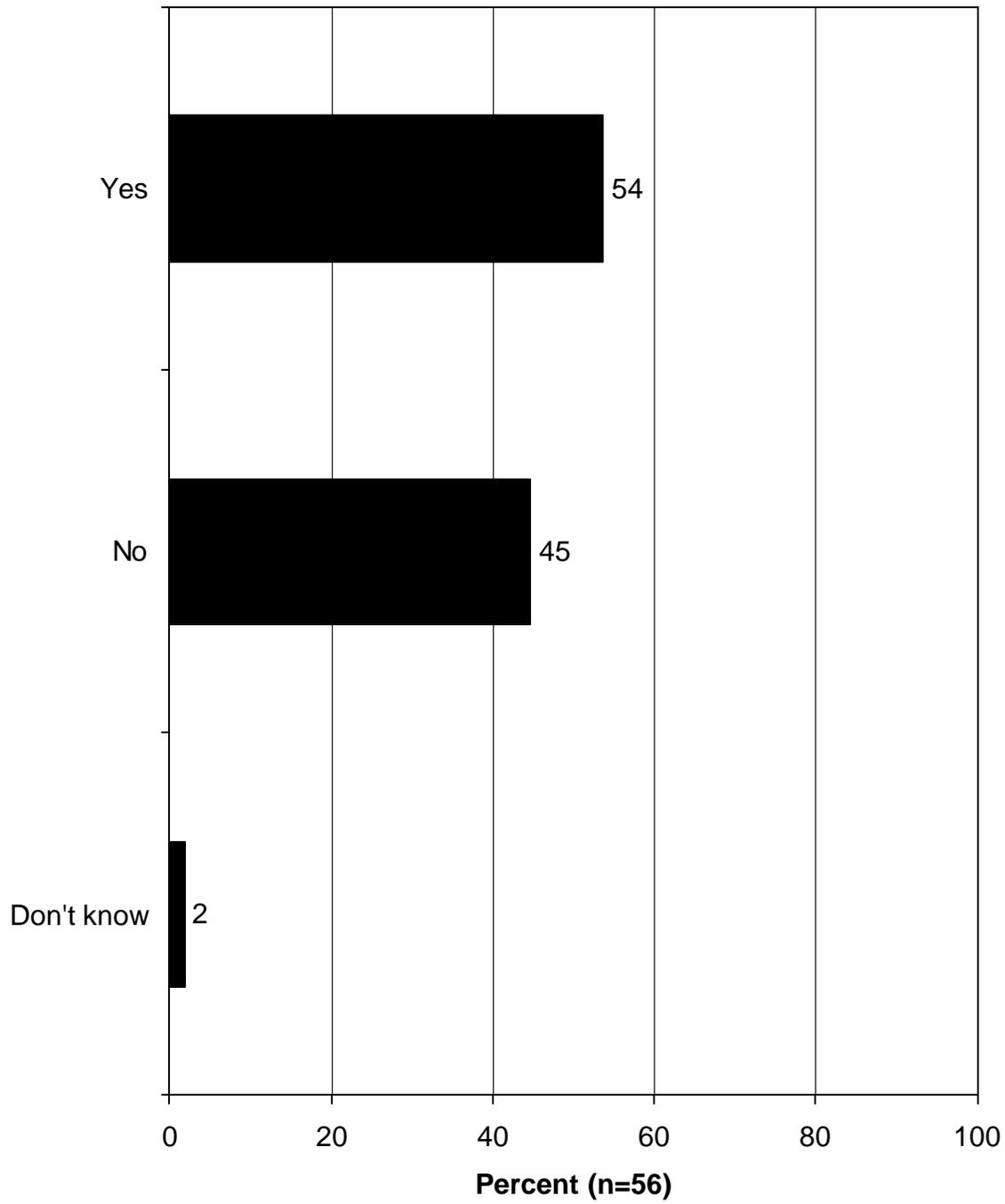
**Q150. Please tell me specifically what costs you considered when calculating the total cost for acquiring and using an in-situ nutrient sensor.(Asked of those who indicated cost is a reason they do not currently use an in-situ nutrient sensor.)**



## SPECIFIC PROCEDURES/ASPECTS OF MEASURING NUTRIENTS

- A slight majority of respondents (54%) are required to use specific approved analytical techniques and procedures, such as EPA-approved methods.
  - EPA methods were the most commonly used.
  
- Most commonly, coastal professionals measure nutrients in  $\mu\text{M}$  (micromolars) (47%), while 38% measure nutrients in mg/l (milligrams per liter); these percents include the 11% who measure using both.
  
- A small percentage of respondents (11%) indicated that there are detection limits for nutrients that they measure that are set by regulations or other needs of the data (the required detection limits for each nutrient measured are shown in tabulations in the section of the report titled, “Nutrients, Parameters, and Aquatic Environments of Interest”).
  
- Nearly a third of the sample of coastal professionals (29%) currently use in-situ nutrient sensors, with over half of those using commercial products (these graphs are shown in the section of the report titled, “Aspects of In-Situ Nutrient Sensor Use and Sensor Requirements”).
  - A majority of those who use in-situ nutrient sensors take measurements hourly (69%), by far the leading answer.
  
- A majority of coastal professionals who do *not* currently use in-situ nutrient sensors (75%) use in-house sample analyses to measure nutrients at least some of the time, with most of those using in-house sample analyses exclusively; 28% contract with a laboratory to conduct analyses at least some of the time, with most of those using an outside lab exclusively.
  - Those who do *not* currently use in-situ nutrient sensors were asked how often they need to provide or obtain nutrient measurement data, and the top responses were weekly (23%) and monthly (23%), followed by hourly (13%).

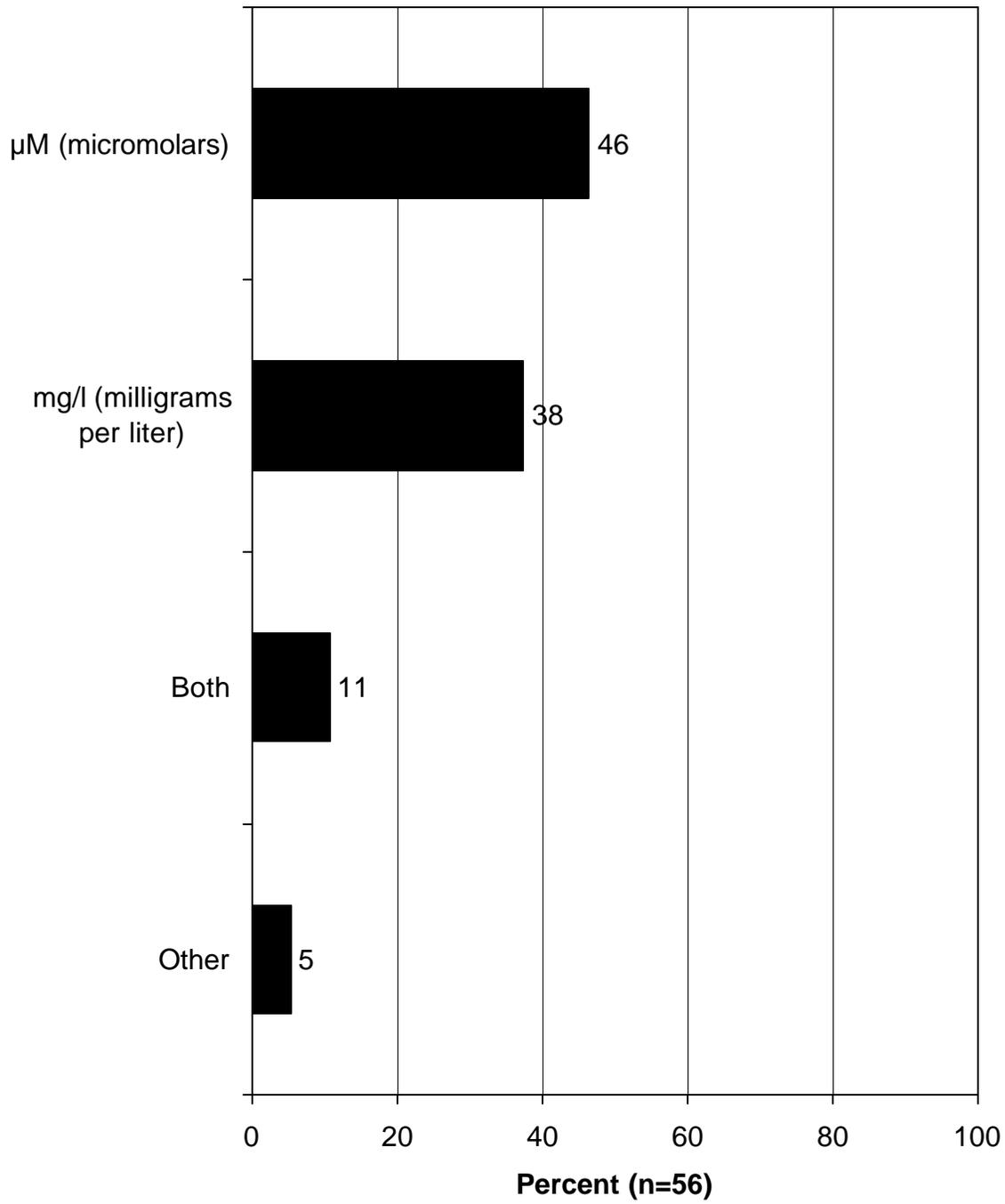
**Q100. Are you required to use any specific approved analytical techniques and procedures?  
For example, EPA-approved methods.**



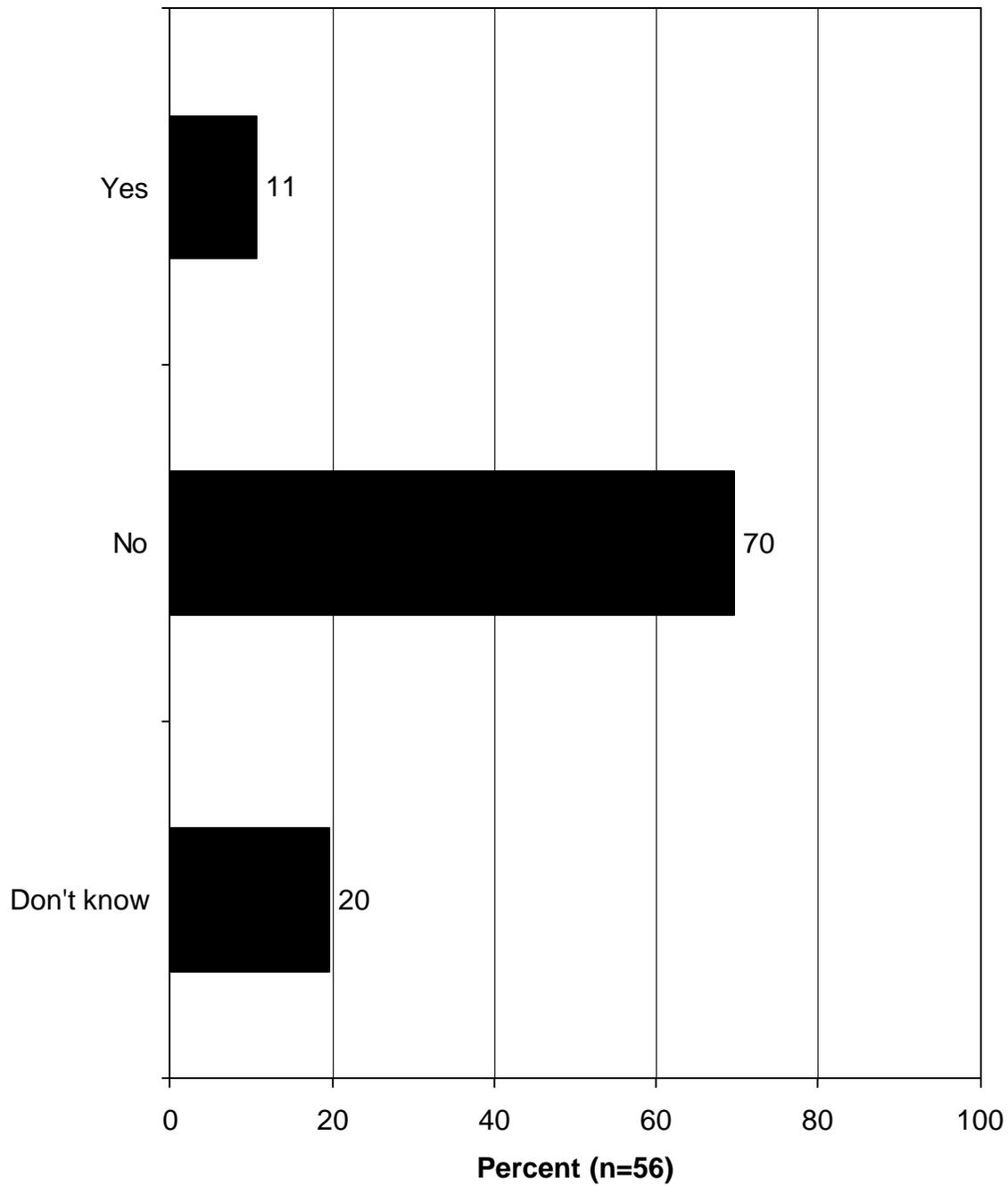
**Q101. Analytical techniques and procedures used.**

<b>Analytical Technique</b>	<b>Number of Respondents Who Use It</b>
EPA	28
NOAA standards	1
USGS	1

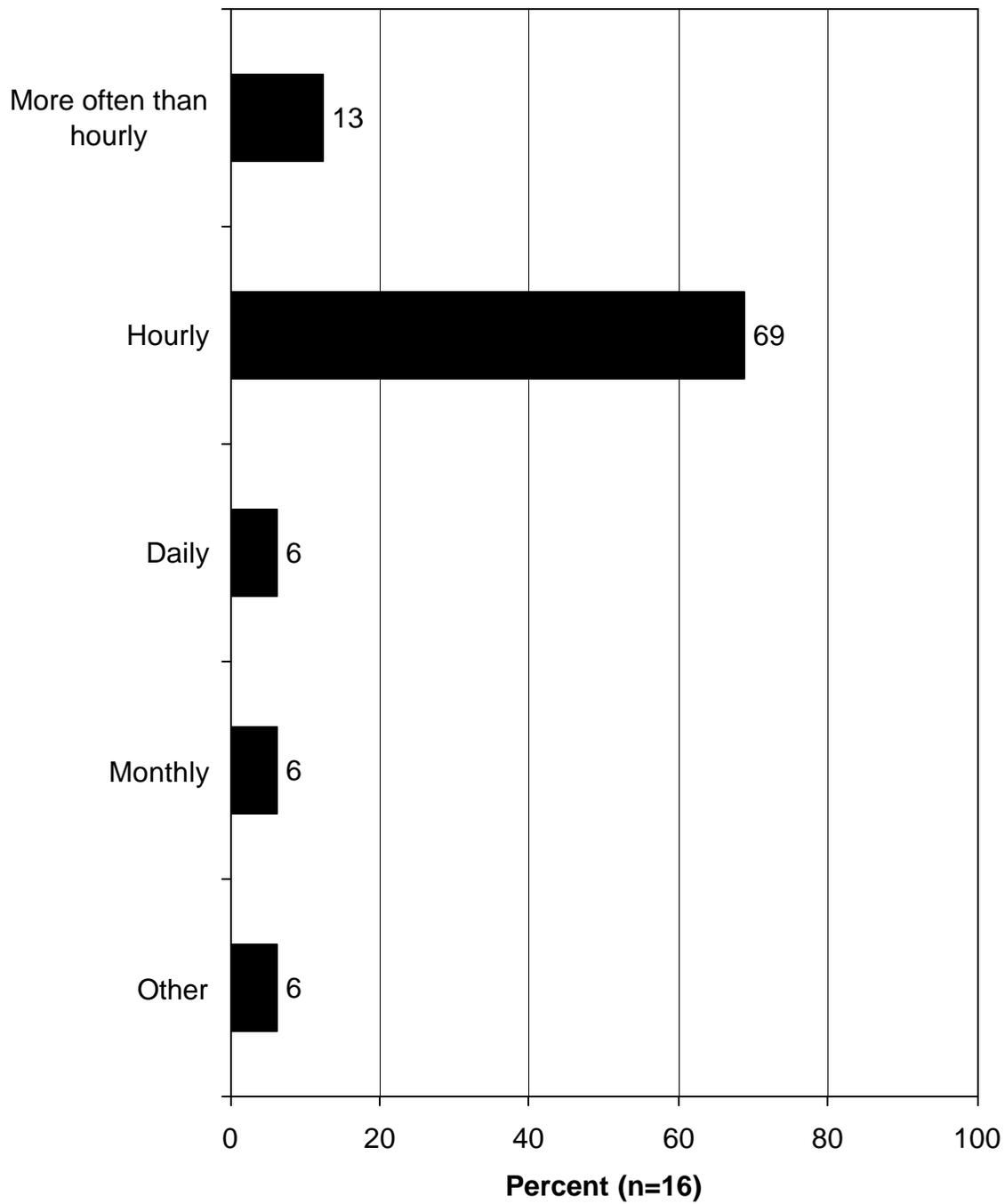
**Q41. Do you measure nutrients in  $\mu\text{M}$  (micromolars) or mg/l (milligrams per liter)?**



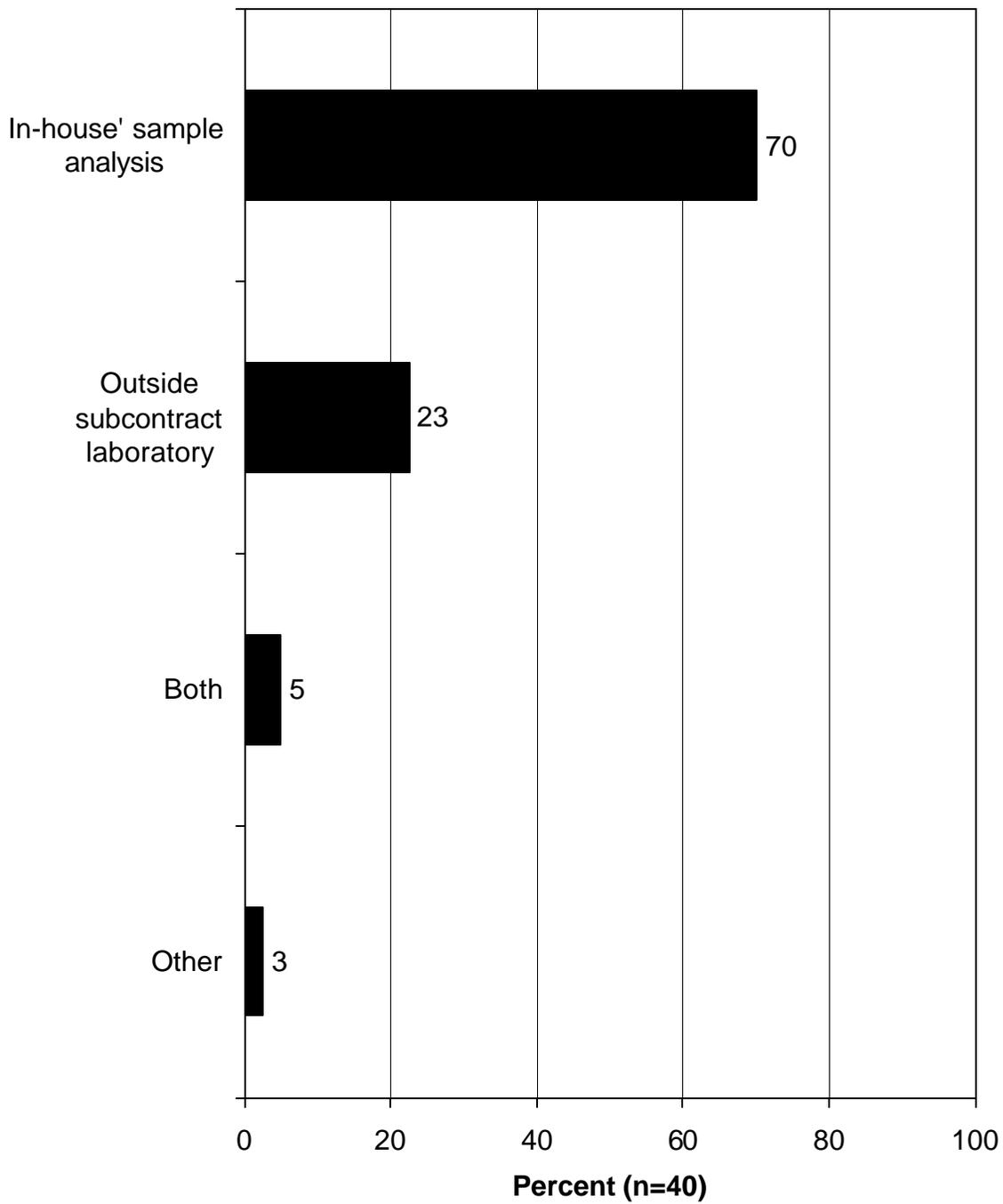
**Q71. Are there any required detection limits and/or ranges, for instance by regulations, for the nutrient(s) you are currently measuring? (Asked of those who are currently measuring a nutrient/nutrients.)**



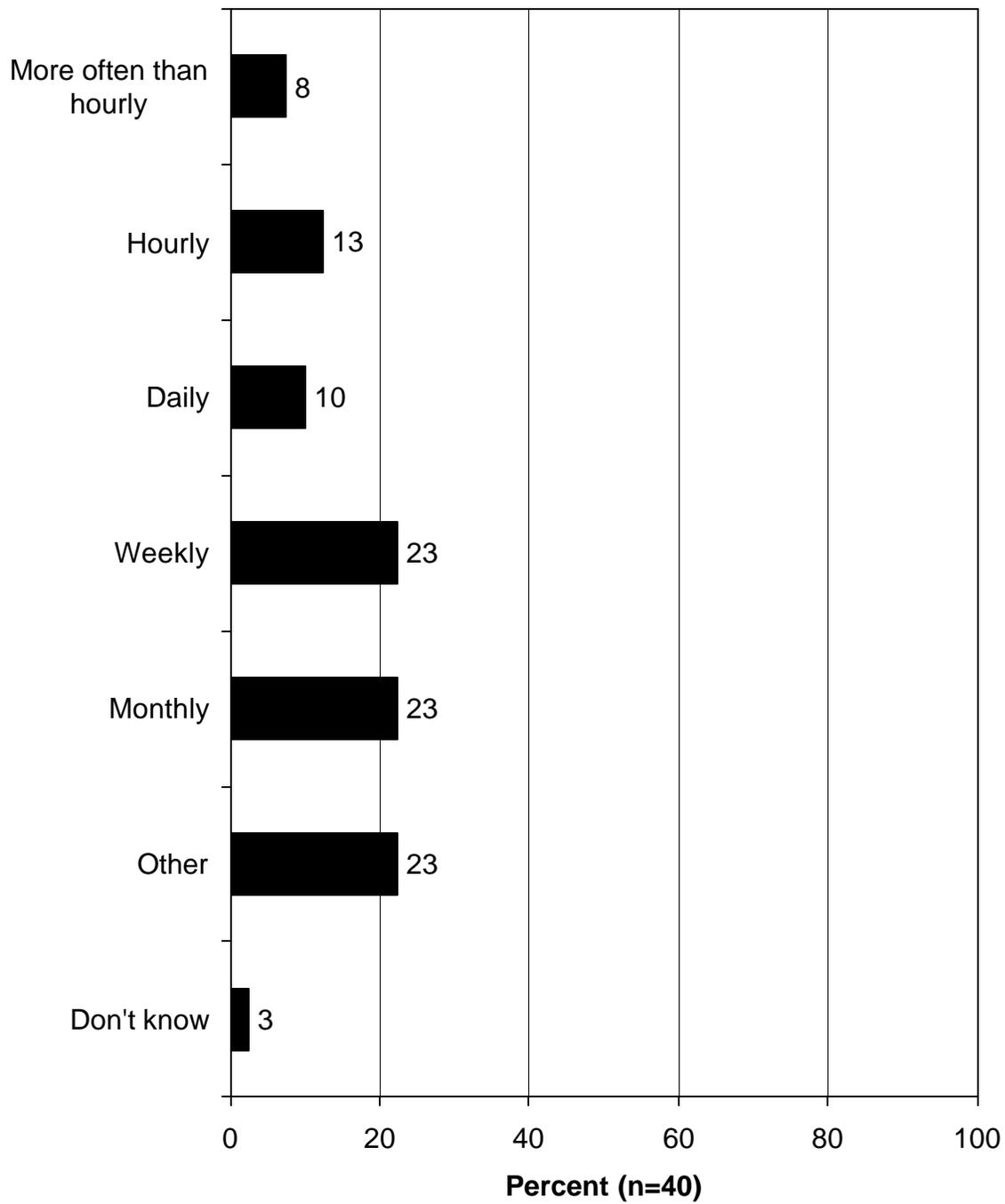
**Q115. How often do you need to do in-situ nutrient measurements? (Asked of those who currently use in-situ nutrient sensors.)**



**Q154. How do you currently measure nutrients?  
(Asked of those who do not currently use an in-situ  
nutrient sensor.)**



**Q152. How often do you need to provide and/or acquire nutrient measurements data? (Asked of those who do not currently use an in-situ nutrient sensor.)**



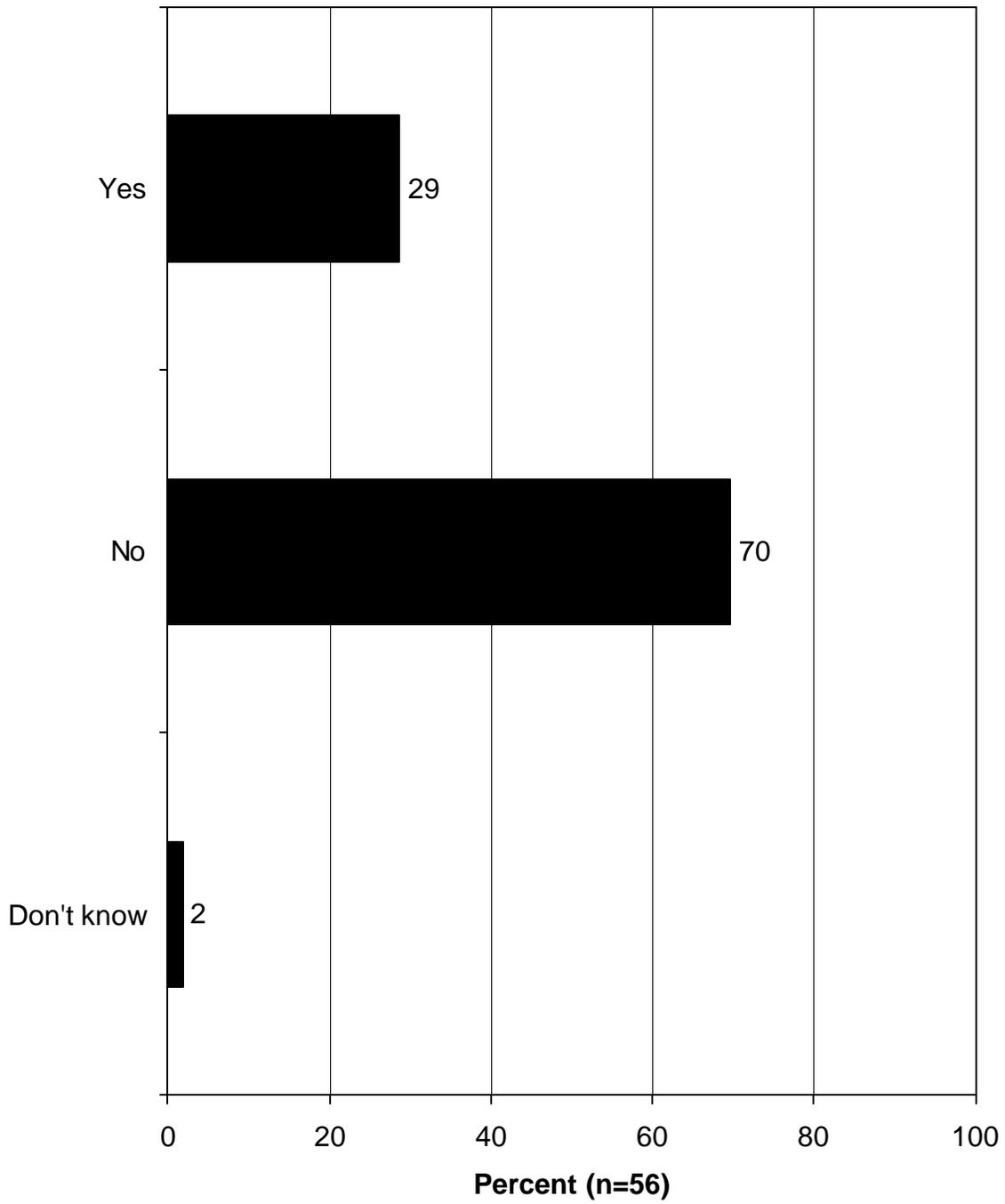
## **ASPECTS OF IN-SITU NUTRIENT SENSOR USE AND SENSOR REQUIREMENTS**

- Nearly a third of the sample of coastal professionals (29%) currently use in-situ nutrient sensors.
  - For this survey, half of respondents (28 “follow-up” respondents) had participated in the initial in-situ nutrient sensor study conducted approximately 1 year ago and half (28 “new” respondents) had not. Follow-up respondents who currently use in-situ nutrient sensors outnumber new respondents who currently use in-situ nutrient sensors 3 to 1. Use of in-situ nutrient sensors remained relatively stable with 43% of follow-up respondents currently using the sensors compared to 48% in 2005; the slight drop in usage among follow-up respondents was not statistically significant.
- Of those who currently use in-situ nutrient sensors, 56% use a commercial product alone, 6% use a custom-designed and custom-made sensor, and 38% use a combination of commercial and custom-made.
- A majority of those who use in-situ nutrient sensors take measurements hourly (69%), by far the leading answer (this graph is shown in the section of the report titled, “Specific Procedures/Aspects of Measuring Nutrients”).
- About a quarter of respondents (27%) said their sensor needs or requirements are non-standard; descriptions of their non-standard needs are shown.
- The sensor performance characteristics of most importance are reliability, accuracy, precision, product support/warranty/vendor reputation, and range/detection limits. Other performance characteristics considered important are shown in the tabulation that follows the ratings tabulation.
- Most commonly, coastal professionals require a 3 to 4 year lifetime or length of efficient use for in-situ nutrient sensors (36% gave this response), followed by 5 years (27%).

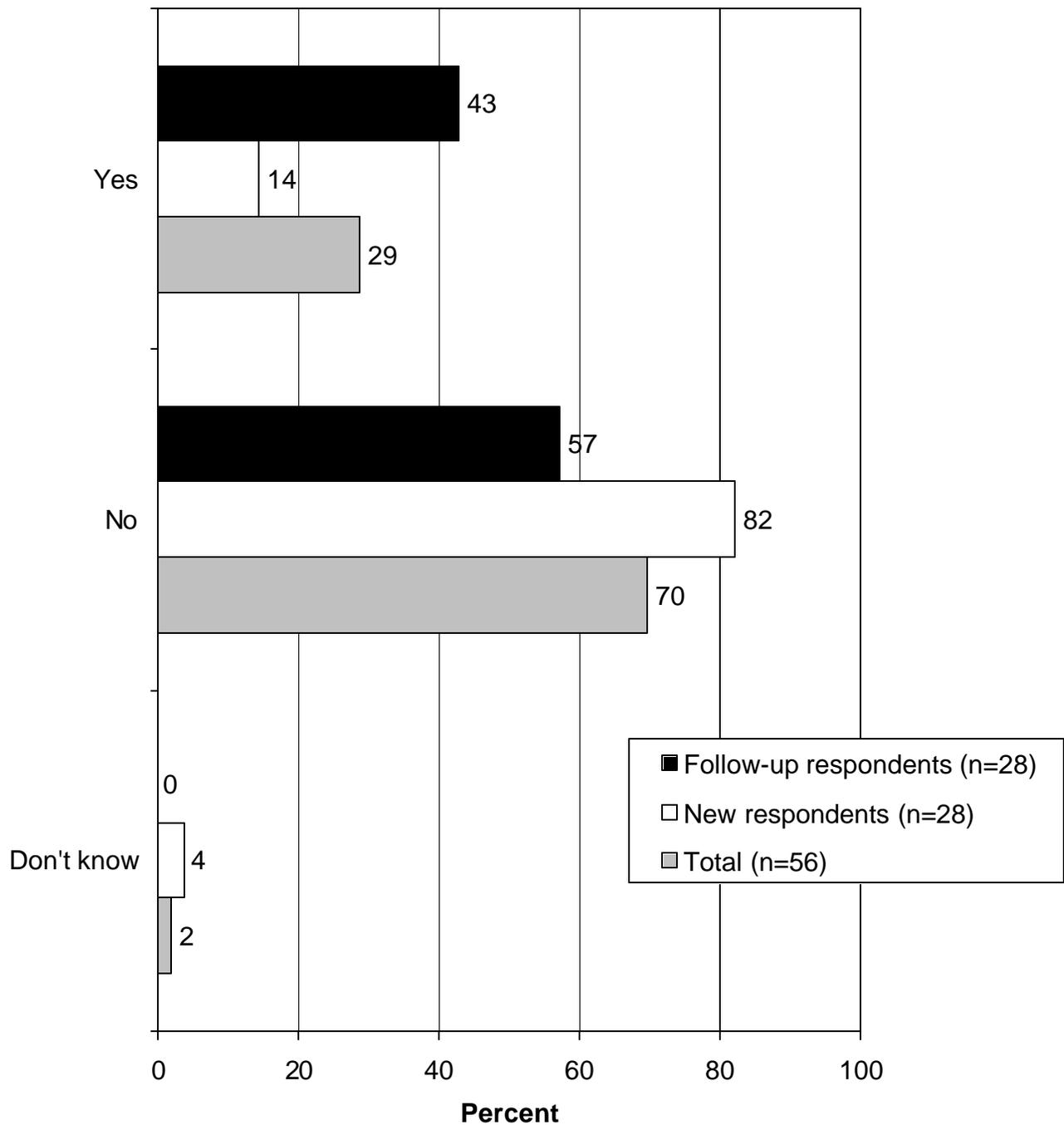
- The most common application for nutrient sensors is as a deployed sensor on a remote platform for continuous in-situ measurements, such as buoys and cable systems.
  - Although the most common application for nutrient sensors among those who use sensors is as a deployed sensor on a remote platform, in a related question a slight majority of *all* respondents (57%) indicated that they have not and do not plan to integrate an in-situ nutrient sensor into a buoy or cable observation system; nonetheless, 43% have done so or plan to do so.
  
- The frequency at which those who use a deployed sensor on a remote platform for continuous in-situ measurements add, remove, replace, or service the sensors is shown.
  - In a related question, those who currently use in-situ nutrient sensors and/or plan on acquiring new commercial sensors within the next 2 years expect to add, remove, replace, or service the sensor weekly (38% gave this response) or monthly (25%) when it has been deployed on an observation platform.
  
- Of those who have or plan to integrate an in-situ nutrient sensor into a buoy or cable observation system, the overwhelming majority of respondents use the sensor for absolute concentrations (94%) with nearly half of those using the sensor to determine relative changes as well.
  - A large majority (87%) of those who have or plan to integrate an in-situ nutrient sensor into a buoy or cable observation system also conduct their own absolute calibrations; descriptions of their calibration techniques are shown.
  
- Protocol/interface details for using sensors on multiple systems are important to the large majority of those who have or plan to integrate an in-situ nutrient sensor into a buoy or cable observation system.
  
- A majority of respondents (64%) indicated that if they were to purchase and use a new nutrient sensor, they would use a multi-channel system (this graph is shown in the section of the report titled, “Purchasing New Sensors”).

- The majority of those who plan to purchase new commercial sensors within the next 2 years (65%) will *need* personnel with previous training for sensor technology to operate the new sensor; 43% say they will need a science technician with a master's degree.
  - In a related question, those who plan on acquiring new commercial sensors within the next 2 years gave similar responses when asked what type of personnel they would most likely *have* to operate the new sensor.
  - These graphs are shown in the section of the report titled, "Purchasing New Sensors."

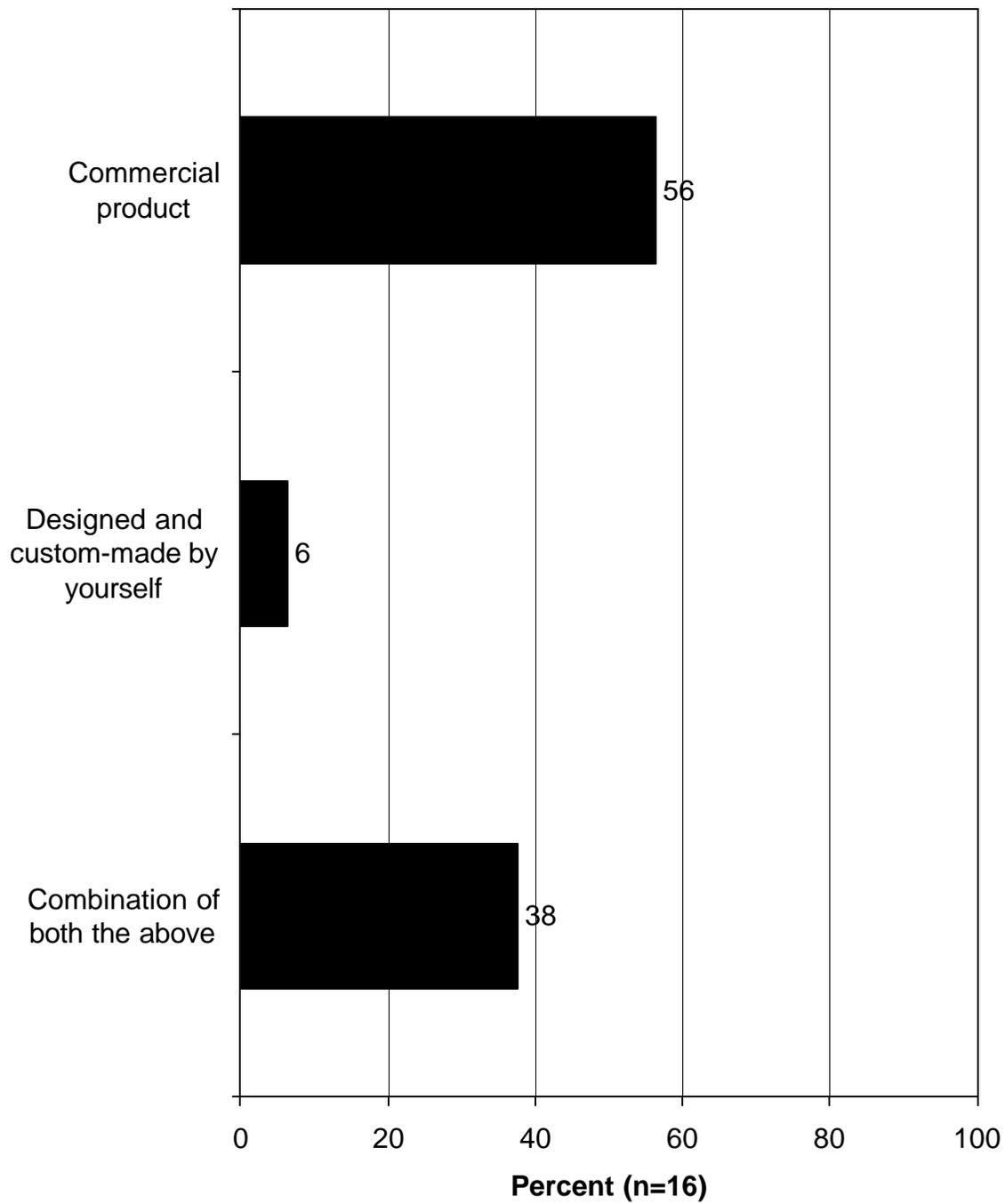
### Q110. Do you currently use in-situ nutrient sensors?



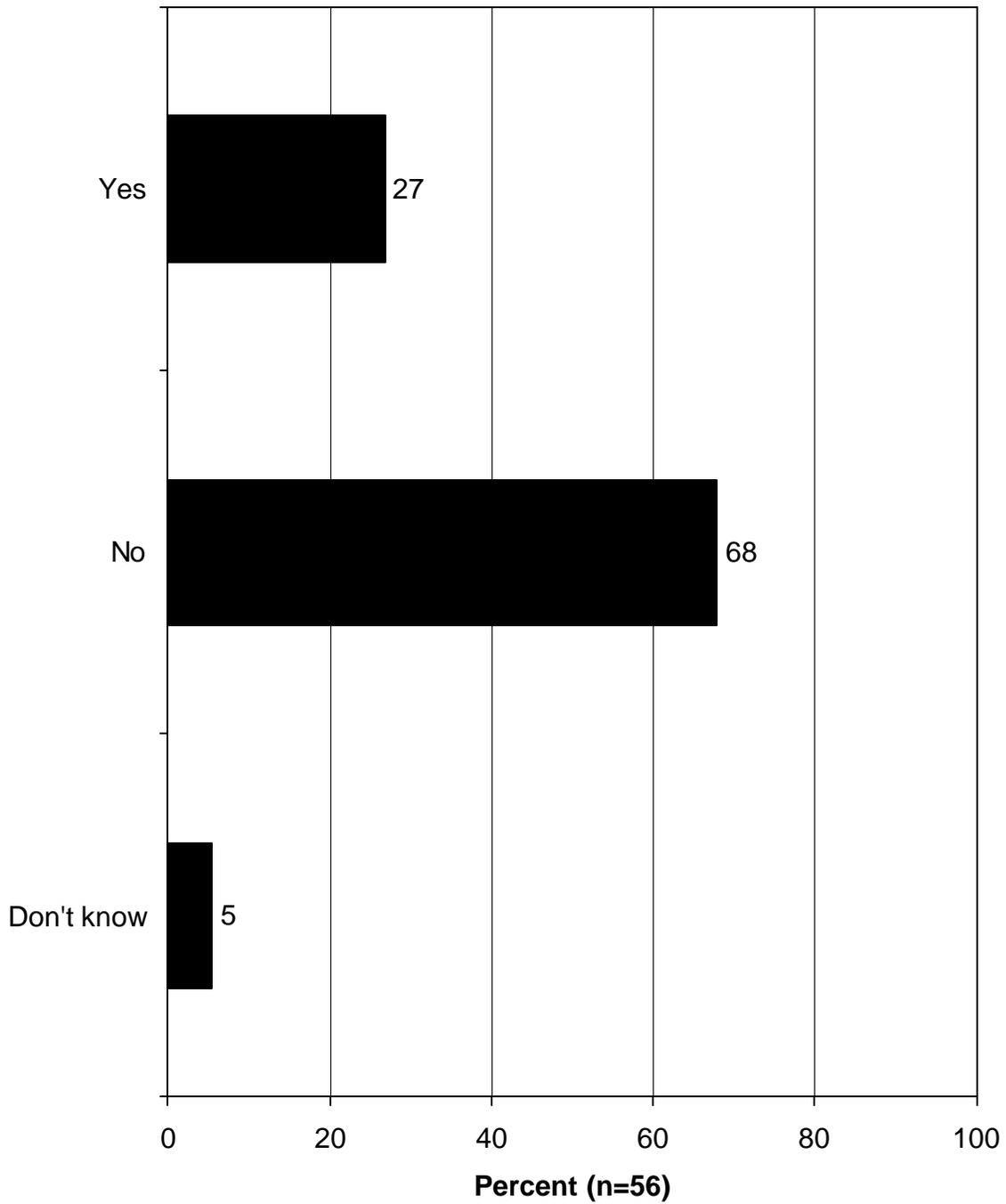
### Q110. Do you currently use in-situ nutrient sensors?



**Q114. Which of the following best describes your current sensors? (Asked of those who currently use in-situ nutrient sensors.)**



**Q218. Are any of your sensor needs or requirements non-standard or custom?**



**Q219. 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 of an instrument to measure in different salinities
Adjusted the stock chemistry
Almost everything is customized
Almost everything is non-standard
Detection limits aren't good enough
Extra protection for different circumstances
Ground water sampling
Have floating sensors to measure the top of water
Low detection limit
Measures below and longer than standard limits
Most needs are non-standard
Multi-channel
Operating on a ship
Response time
Urea system is custom

**Q192-210, 212-213. Ratings of the Importance of the Following Performance Characteristics**

<b>Performance Characteristic (sorted by mean)</b>	<b>Percent Rating Item the Highest in Importance (5)</b>	<b>Percent Rating the Item Low in Importance (1, 2, or 3)</b>	<b>Mean</b>
Q197. Reliability	80	2	4.79
Q194. Accuracy	71	11	4.61
Q195. Precision	61	5	4.55
Q213. Other (See other characteristics named in the following tabulation.)	55	0	4.55
Q208. Product support/ warranty/vendor reputation	62	7	4.53
Q193. Range/detection limits	57	14	4.43
Q200. Calibration life	45	20	4.16
Q192. Key Operational Parameters	47	24	4.13
Q209. Quality of product handbook/documentation	33	22	4.09
Q202. Ease of calibration	38	29	4.05
Q199. Operating life (e.g., life expectancy of the instrument)	39	34	4.02
Q207. In-field maintenance	32	29	3.96
Q198. Deployment life (e.g., biofouling resistance, power limitations, or re-agent limitations)	36	34	3.91
Q210. Cost	27	41	3.82
Q205. Input/output interfaces	22	37	3.72
Q201. Automatic calibration	25	43	3.66
Q206. Packaging	21	55	3.46
Q196. Sampling interval/frequency	9	61	3.38
Q203. Real-time sensor data display and/or analysis	21	57	3.36
Q204. Off-sensor telemetry	12	62	3.19

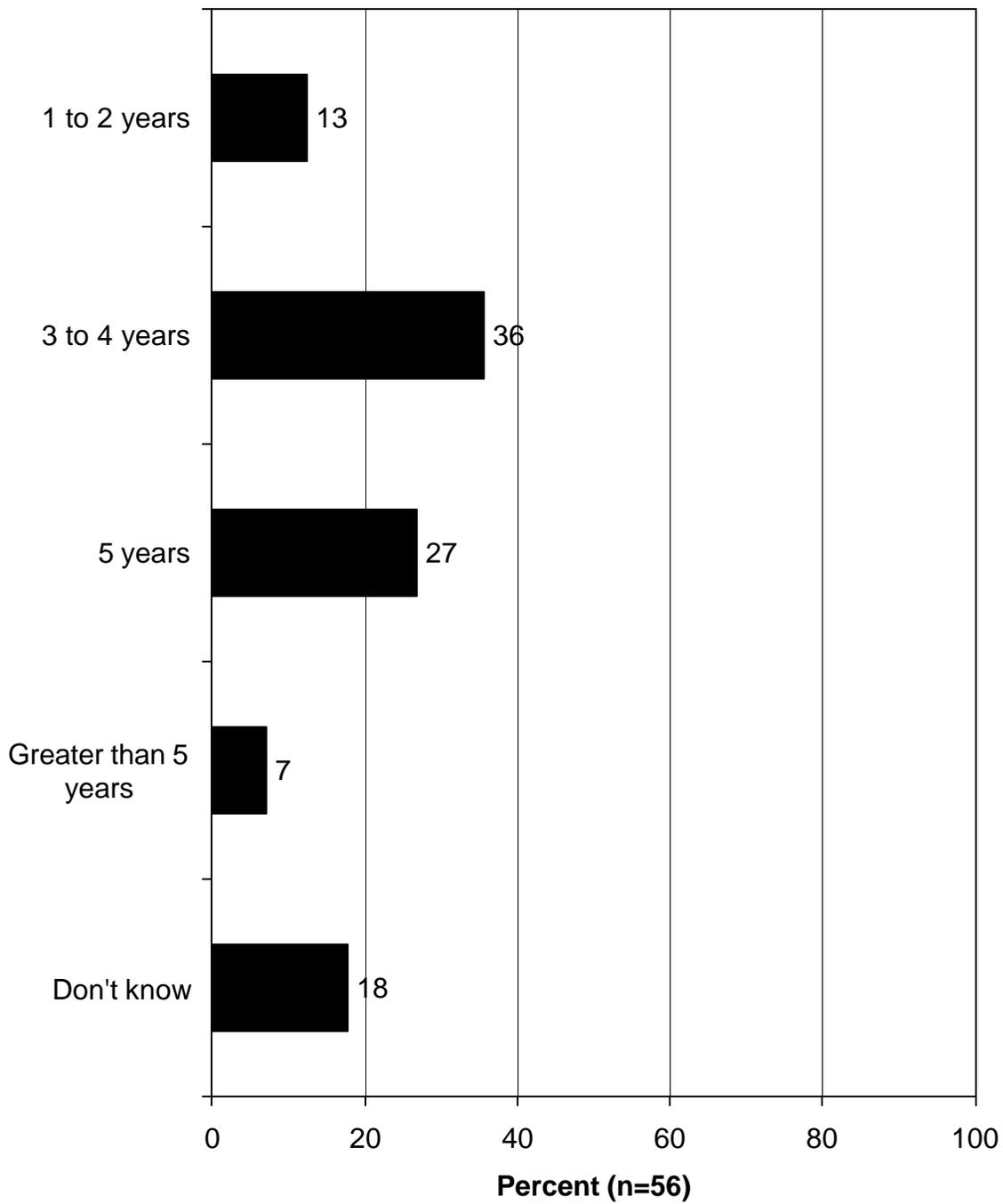
Scale is 1 to 5, with 5 being the highest importance.

**Q212-213. Other Characteristics of Interest in Nutrient Sensors and Rating**

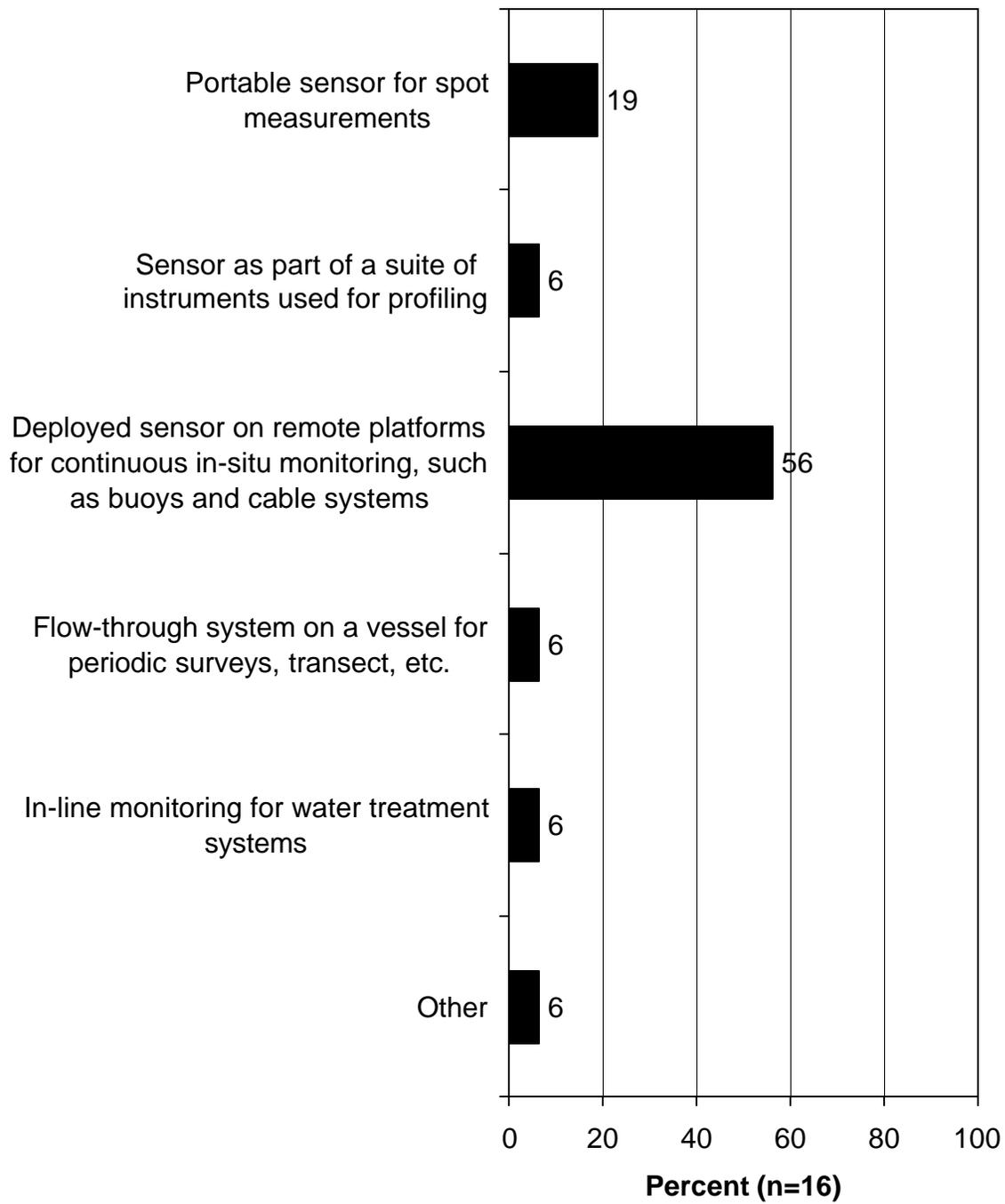
<b>Characteristic</b>	<b>Rating by the Respondent for the Given Other Characteristic</b>
Acceptability	5
Approved method	5
Biofouling	5
Durability	4
Flexibility	4
Ground water sensors	5
More commercially available	4
Multiple nutrient capability	4
Problems with biofouling	5
Reliability of the sensors and plug and play	5
Salinity	4

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

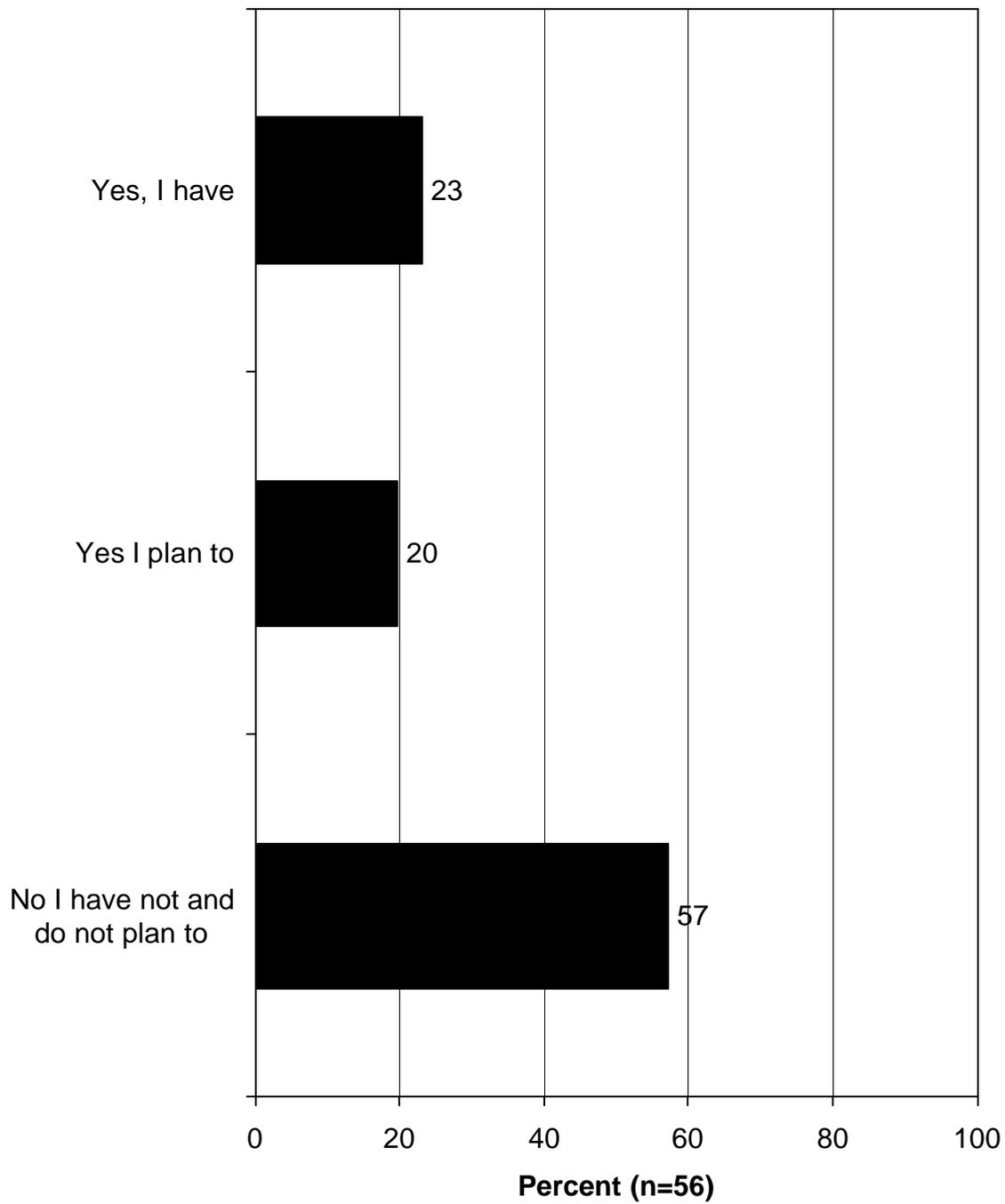
**Q226. What 'lifetime' or length of efficient use do you require for an in-situ nutrient sensor?**



**Q111. What is your most common application?  
(Asked of those who currently use in-situ nutrient  
sensors.)**



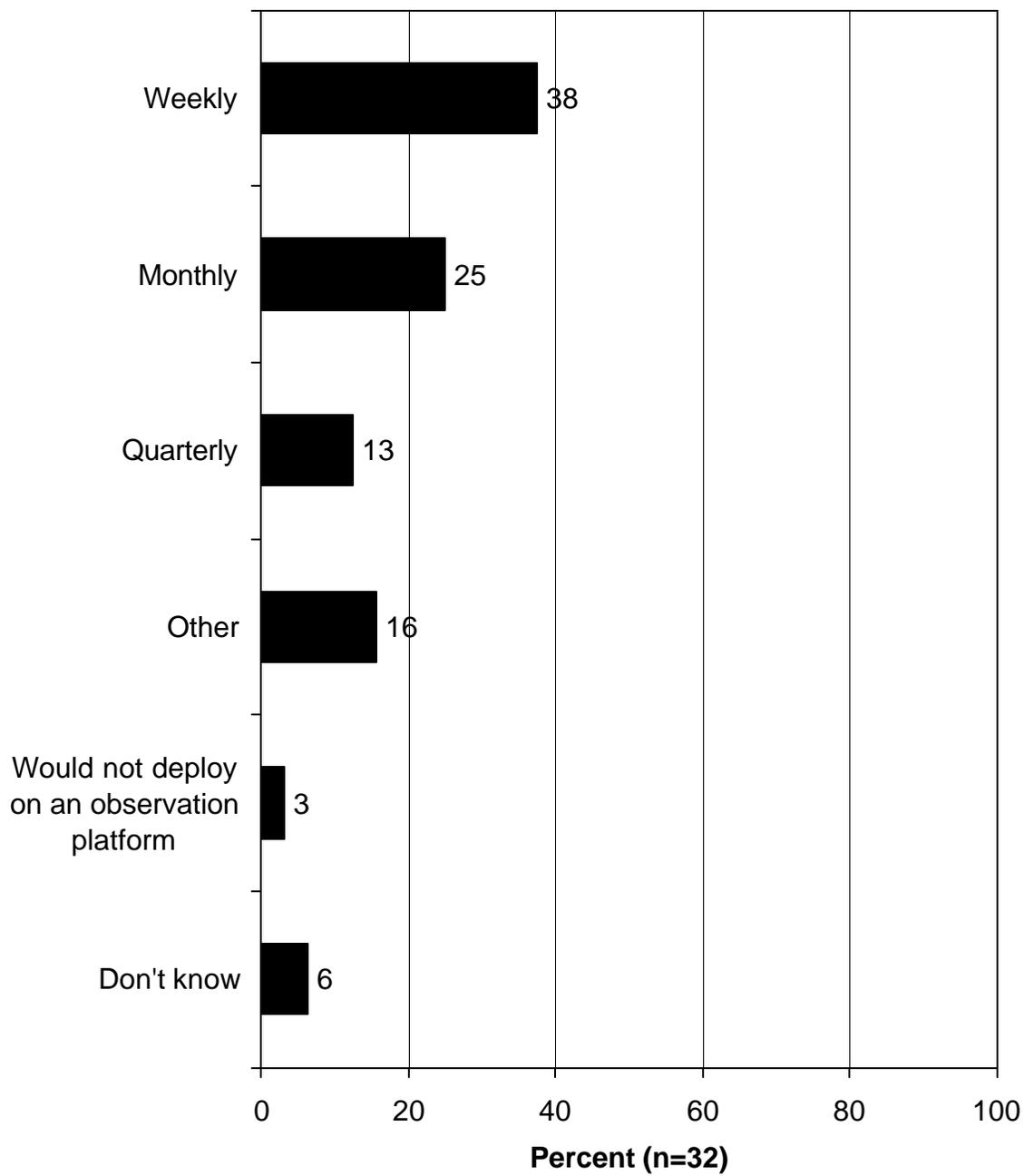
**Q223. Have you or do you plan to integrate an in-situ nutrient sensor into a buoy or cable observation system?**



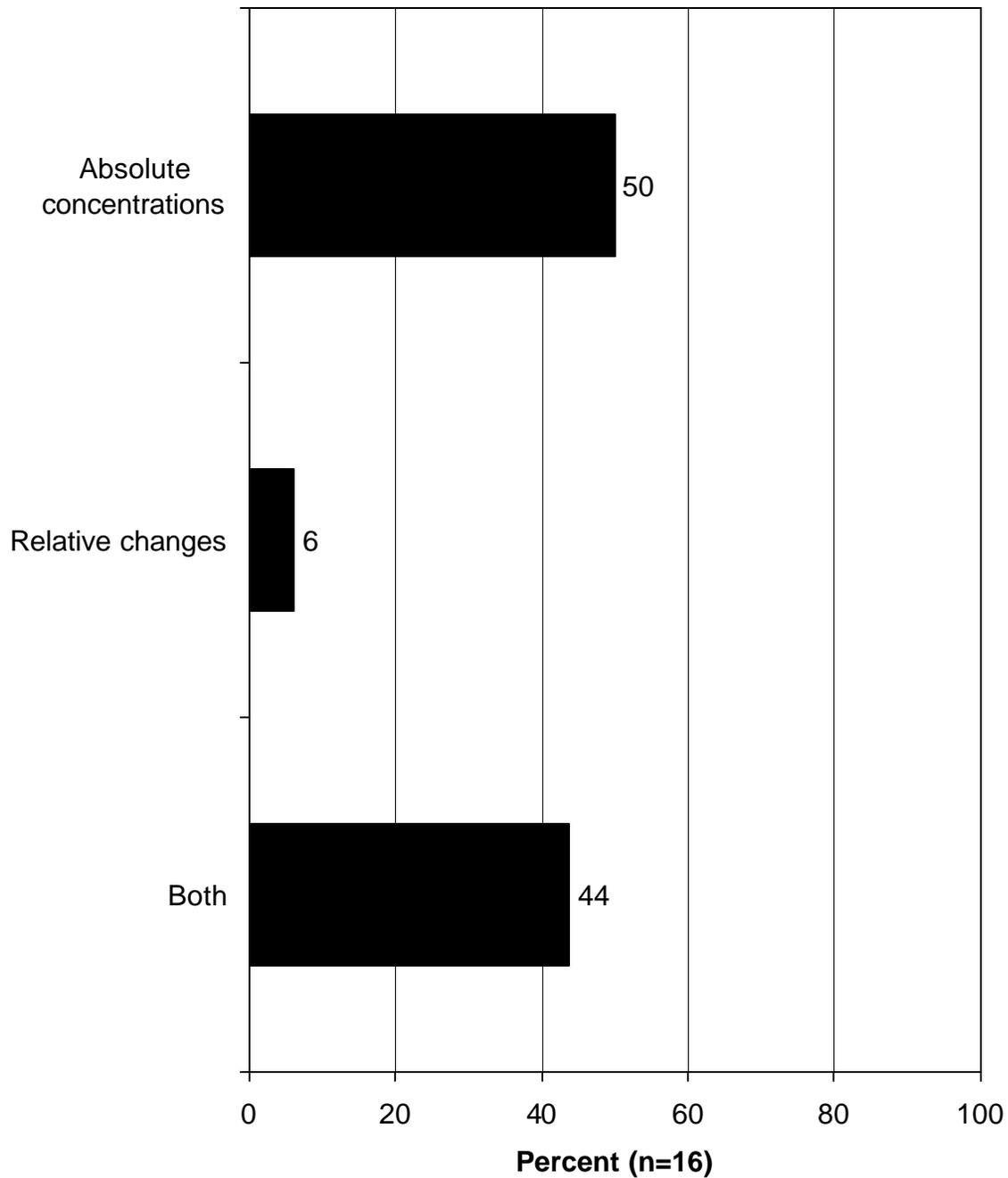
**Q113. How often do you add, remove, replace, or service in-situ nutrient sensors that have been deployed on an observation platform? (Asked of those who use in-situ nutrient sensors and deploy them on observation platforms.)**

<b>Frequency</b>	<b>Number of Respondents</b>
Weekly	1
Monthly	2
Quarterly	1
Other	3
Don't know	2

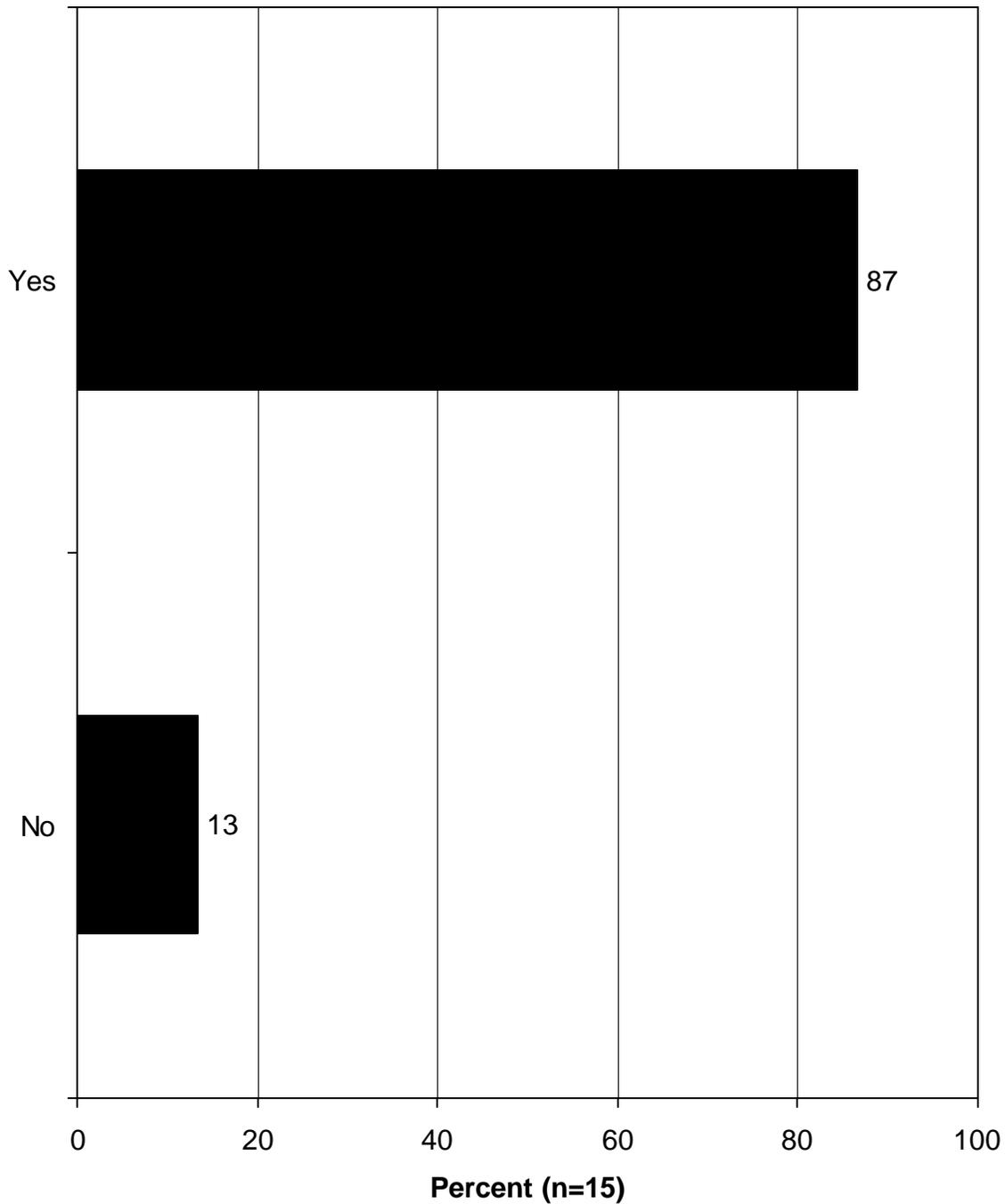
**Q221. How often do you expect to add, remove, replace, or service the new in-situ nutrient sensor when it has been deployed on an observation platform? (Asked of those who currently use in-situ nutrient sensors and/or plan on acquiring new commercial sensors within the next 2 years.)**



**Q227. Do you use your in-situ nutrient sensor to determine absolute concentrations or relative changes? (Asked of those who have already or plan to integrate an in-situ nutrient sensor into a buoy or cable observation system.)**



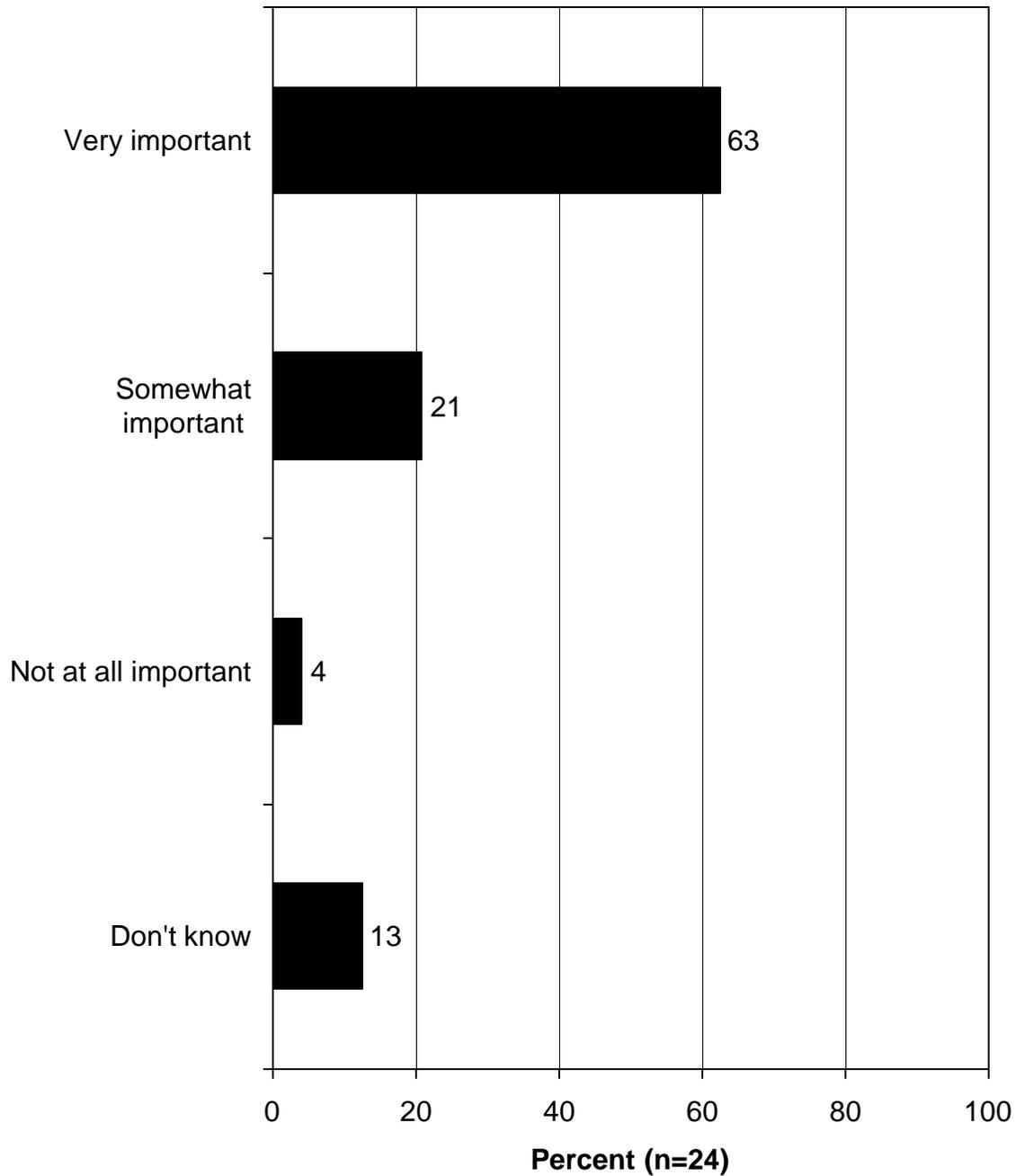
**Q228. Do you conduct your own absolute calibrations? (Asked of those who have already or plan to integrate an in-situ nutrient sensor into a buoy or cable observation system.)**



**Q229. What method do you use to calibrate? (Asked of those who have already or plan to integrate an in-situ nutrient sensor into a buoy or cable observation system and who conduct their own absolute calibrations.)**

Auto analyzer
Calibration tank
Depends on the sensor but generally known standards
Flow injection analysis
In house
None
Standard methods for our lab
Standard qualitative
Typical calibration curve
Wet chemistry

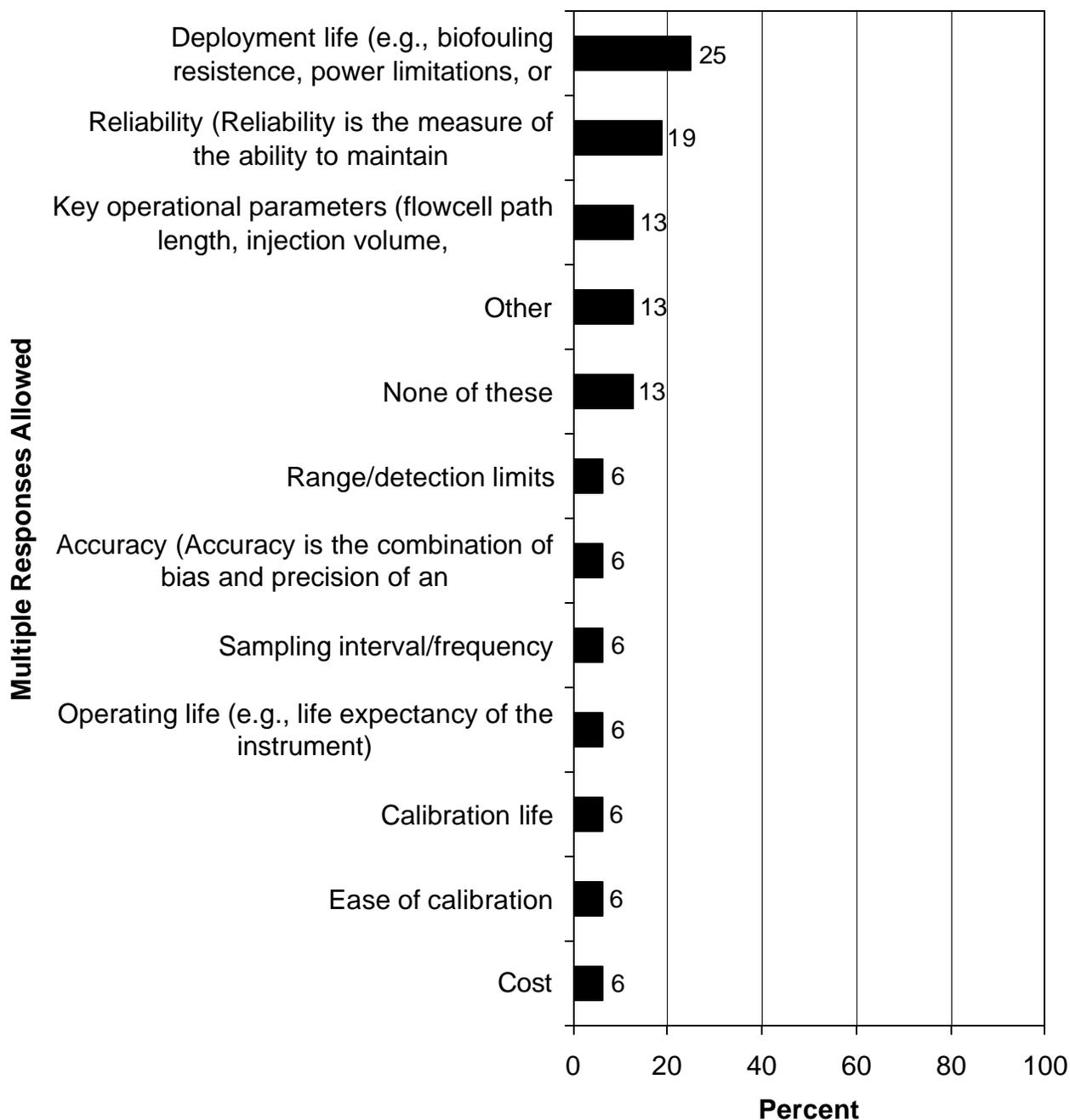
**Q224. How important are protocol/interface details for using sensors on multiple systems to you? (Asked of those who have or plan to integrate an in-situ nutrient sensor into a buoy or cable observation system.)**



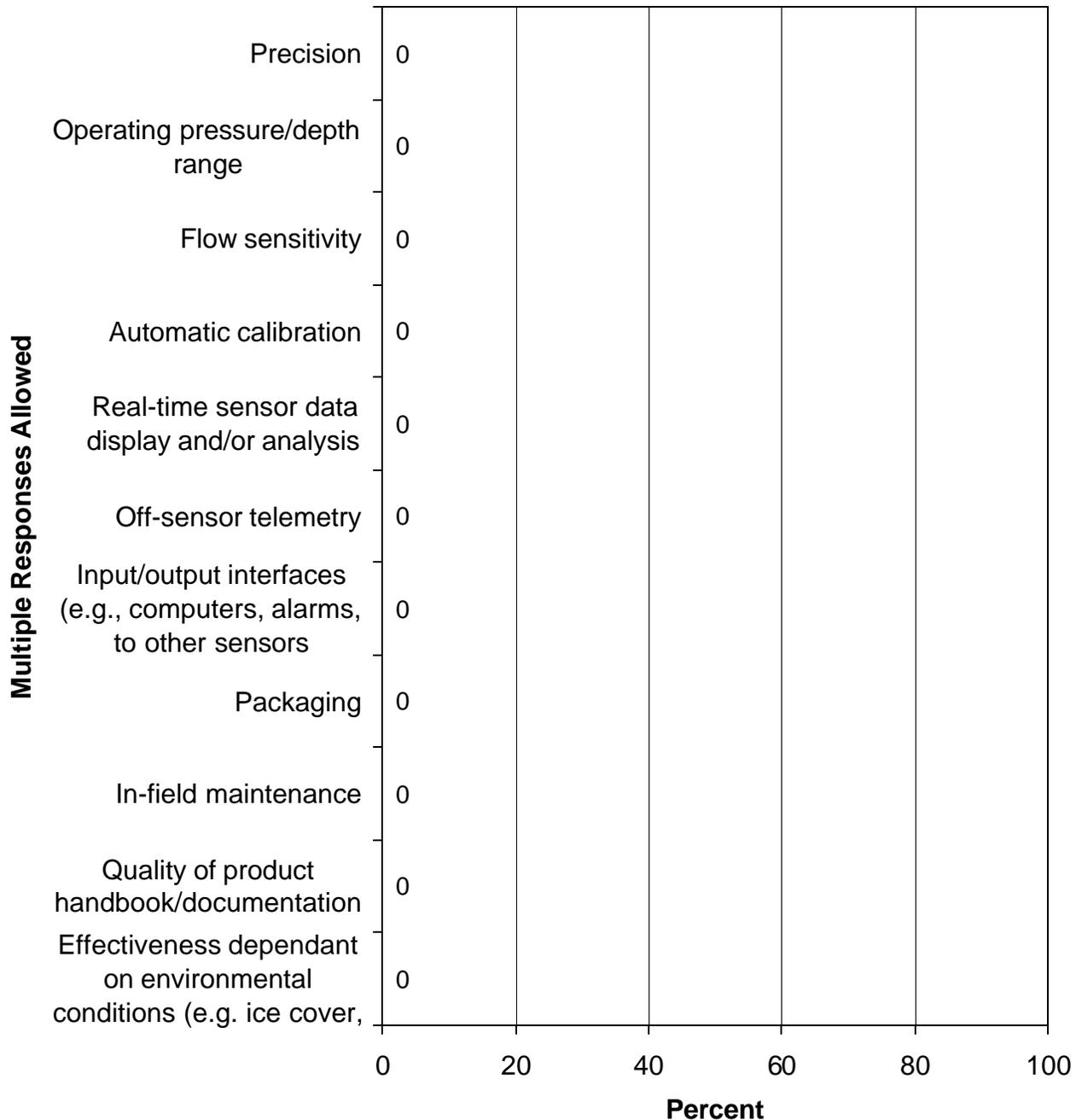
## **LIMITATIONS OF SENSORS**

- Deployment life, reliability, and key operational parameters are the top areas in which current in-situ nutrient sensors have limitations, do not meet expectations, or do not meet needs.

**Q118 and 120. 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.**



**Q118 and 120. 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.**



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

**Q122. 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?**

More decent phosphate sensor

Some analysis are more difficult

**Q123. 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?**

Mid shelf the signal is very low; hard to get a signal

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

Accuracy is not what it should be

**Q126. 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?**

Takes too long to take a sample

**Q127. What were the issues with reliability of the sensor(s) that had significant limitations or did not live up to specifications or expectations?**

Filtration and biofouling

Lots of glitches; breaks down

Still have times when equipment doesn't work right

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

Could be better in estuaries

Filtration and biofouling

Like to deploy for longer period of time

**Q129. What were the issues with operating life of the sensor(s) that had significant limitations or did not live up to specifications or expectations?**

Filtration and biofouling

**Q132. What were the issues with calibration life of the sensor(s) that had significant limitations or did not live up to specifications or expectations?**

Long time life of the calibration

**Q134. 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?**

Takes a lot of babying

**Q141. What were the issues with cost of the sensor(s) that had significant limitations or did not live up to specifications or expectations?**

Cost reliability

**Q135. What were the issues with the other areas that had significant limitations or did not live up to specifications or expectations?**

Have to service them a lot
Just that

Finally, the tabulation below shows comments regarding current shortfalls/future desires in terms of in-situ nutrient analyzers (all respondents were asked; 34 responded).

- 6 respondents wanted a smaller sensor.
- 4 respondents mentioned issues with reliability
- 4 respondents mentioned cost.
- 4 respondents mentioned issues regarding fouling or biofouling.

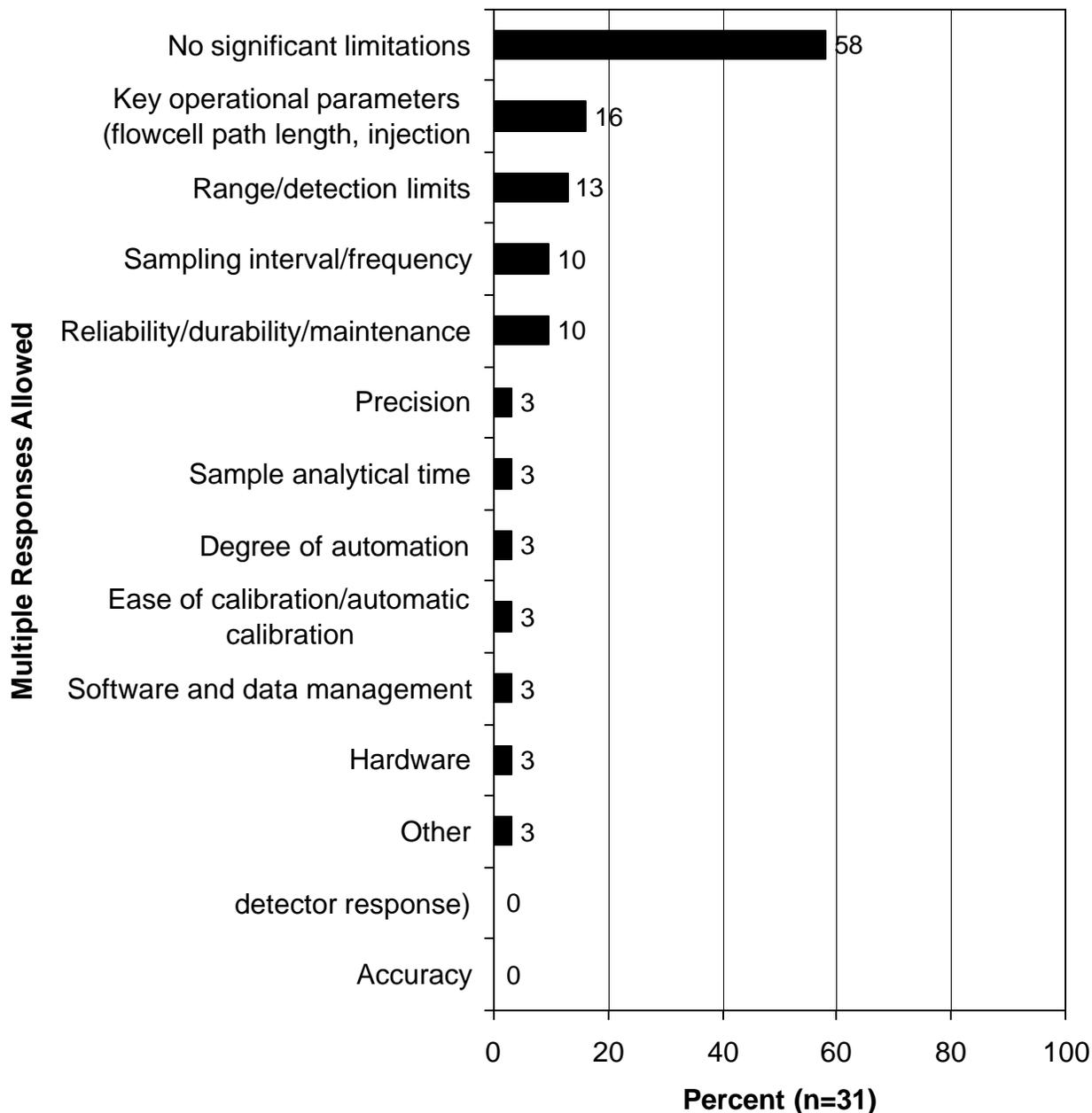
**Q230. Based on your experience with in-situ nutrient analyzers, are there any shortfalls in current designs or additions you'd like to see in future designs?**

Ability to take a grab sample, web interfacing
Better accuracy, telemetry
Better biofouling
Better detection limits
Better reliability and plug and play. Better pins.
Broader range within one instrument
Challenging to measure phosphorus loads
Cost, reliability
Difficult to use and maintain
Don't trust them personally
Durable and real time data
Expensive
Fish biting through the reusion bags
Fouling and degradation
General maintenance is lacking. Make them smaller; something that doesn't have to be submerged.
Has limitations
Haven't been reliable
Longer deployment capability. Better learning curve.
Make them smaller
Need progress with reducing biofouling and better calibration
Not mature enough, needs a lot more developement
Not that easy to use, smaller in size
Not using reagents, doing it optically
Power consumption, fouling, operating ranges
Problems with auto analyzers
Problems with interfacing
Short life-span accuracy
Size, cost, reliability
Smaller and more durable
Too big, very heavy
Too expensive, too big
User friendliness
Wet chemistry needs improvement
Wider awareness of compatibility

## **LIMITATIONS OF IN-HOUSE AND CONTRACTED ANALYSES**

- A slight majority of those who use in-house sample analyses indicated that the analysis system they are currently using does not have any significant limitations. Otherwise, key operational parameters (16% of those who use in-house sample analyses gave this response) and range/detection limits (13%) are the top areas in which in-house sample analyses have limitations, do not meet expectations, or do not meet needs.
  
- Analytical time is the top limitation on contracted laboratory analyses.
  - 36% indicated that their contracted laboratory analyses had no significant limitations.

**Q157. In which of the following areas does the analytical system you are currently using have significant limitations, not live up to specification or expectations, or not meet your needs? (Asked of those who do not currently use an in-situ nutrient sensor and who use in-house sample analysis.)**



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

**Q159. 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?**

Flowcell path length
Improved frequency of measurement
Just getting low enough detection limits
Not low enough
Sample volume, ease of operation

**Q160. 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?**

Lower detection limits
Prefer lower
Trying to get lower detection limits

**Q162. What were the issues with precision of the analytical system(s) that had significant limitations or did not live up to specifications or expectations?**

Greater level of precision over would be good
---

**Q163. What were the issues with sampling interval/frequency of the analytical system(s) that had significant limitations or did not live up to specifications or expectations?**

Expensive to send people out
Manual sampling, not possible to collect
Not frequent enough

**Q164. 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?**

Takes too long to get feedback
--------------------------------

**Q165. 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?**

Expensive to send people out
------------------------------

**Q166. 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?**

Wet chemistry
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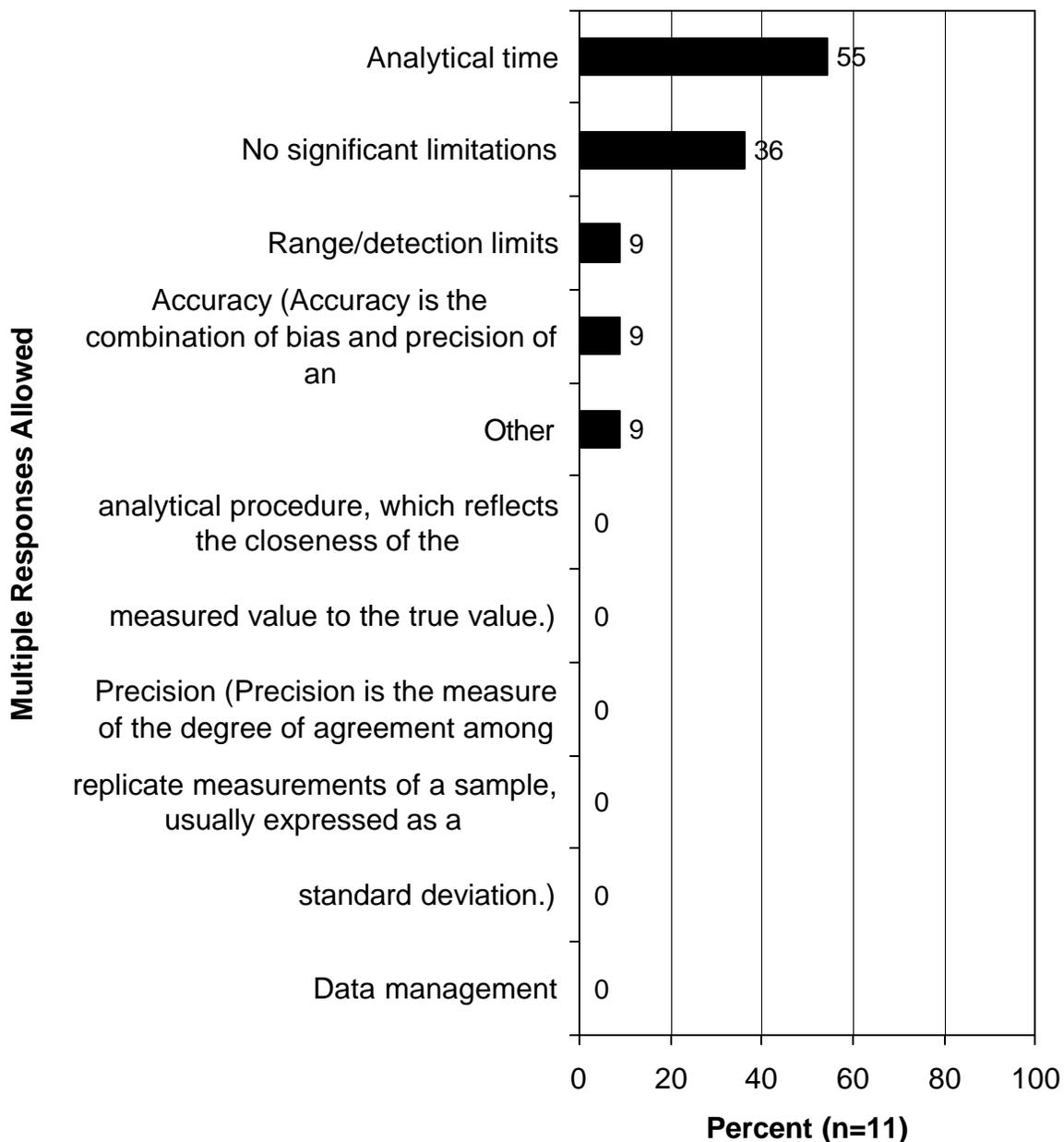
**Q168. What were the issues with hardware of the analytical system(s) that had significant limitations or did not live up to specifications or expectations?**

Size, could be redesigned, accessibility
--

**Q169. 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?**

Need to be tougher
Reliability with robotic arm
Too much maintenance

**Q172. 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 do not currently use an in-situ nutrient sensor and who subcontract the analysis.)**

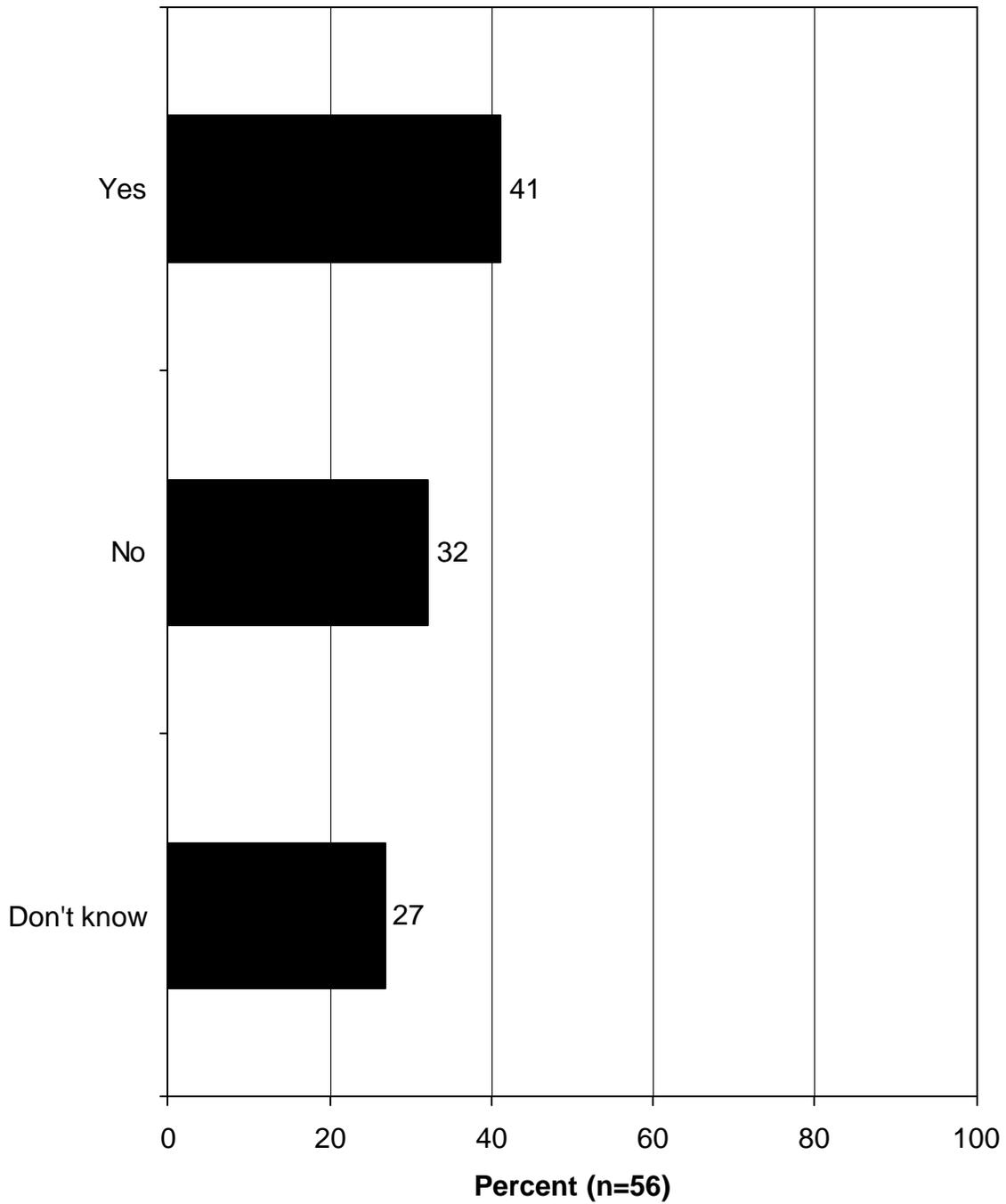


## PURCHASING NEW SENSORS

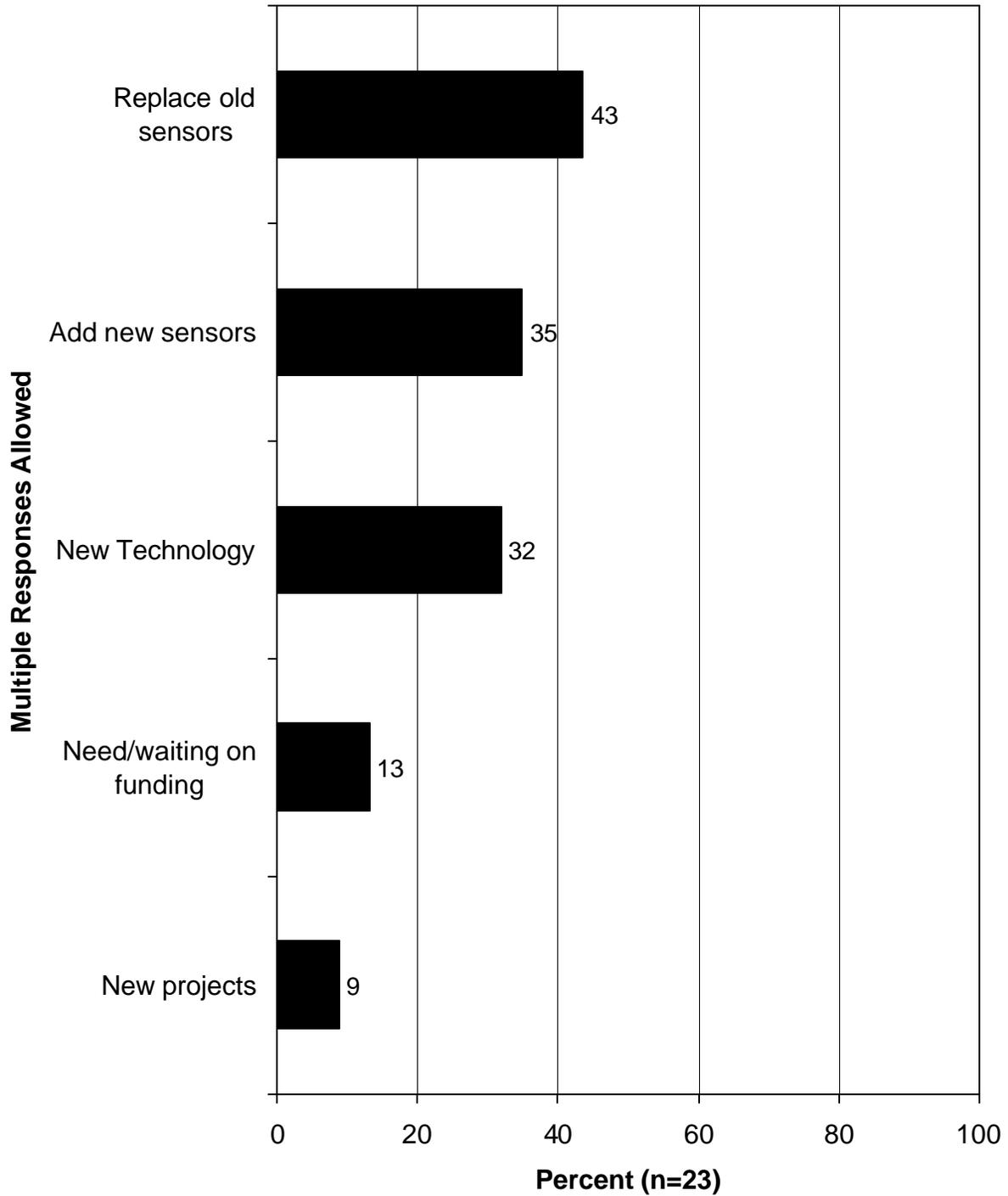
- Slightly less than half of respondents (41%) indicated plans to purchase new commercial sensors within the next 2 years.
  - Common reasons for planning to purchase new commercial sensors include replacing old sensors, increasing the number of sensors used, and acquiring new technology.
  - The most common constraint to the purchase of new commercial sensors is a lack of need.
  - All (7) respondents who use in-situ sensors and who plan to purchase a new commercial sensor indicated that they will consider a different type of sensor type than the one they are currently using.
  - Common reasons for considering a different type of sensor than the one currently used include an interest in new or better technology and capabilities. A tabulation shows all the responses regarding reasons respondents will consider using a different sensor type than the one currently being used.
  - A majority of respondents (64%) indicated that if they were to purchase and use a new nutrient sensor, they would use a multi-channel system.
  
- The majority of those who plan to purchase new commercial sensors within the next 2 years (65%) will *need* personnel with previous training for sensor technology to operate the new sensor; 43% say they will need a science technician with a master's degree.
  - In a related question, those who plan on acquiring new commercial sensors within the next 2 years gave similar responses when asked what type of personnel they would most likely *have* to operate the new sensor.
  
- 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.
  - 9 of the 19 respondents mentioned the need for training of some kind, and 3 specifically said on-site, in-field, or hands-on training.
  - 4 respondents specifically mentioned customer support, and 1 mentioned technical assistance by telephone.

- 7 mentioned ongoing support (4 wanted telephone support, 1 wanted on-line support, and 2 did not specify medium of support).
- 3 mentioned a good manual or documentation.

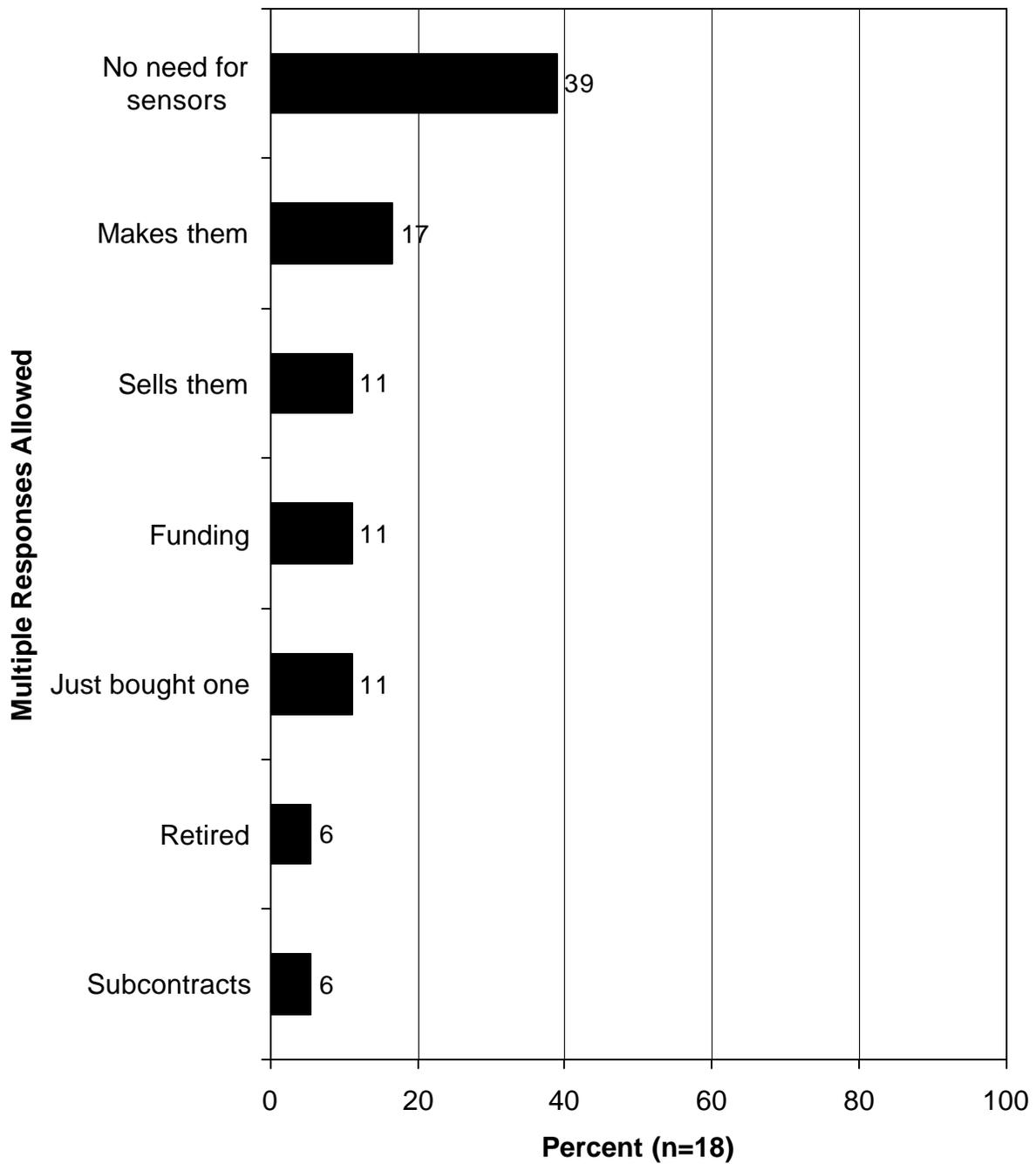
**Q180. Do you plan on acquiring new commercial sensors within the next 2 years?**



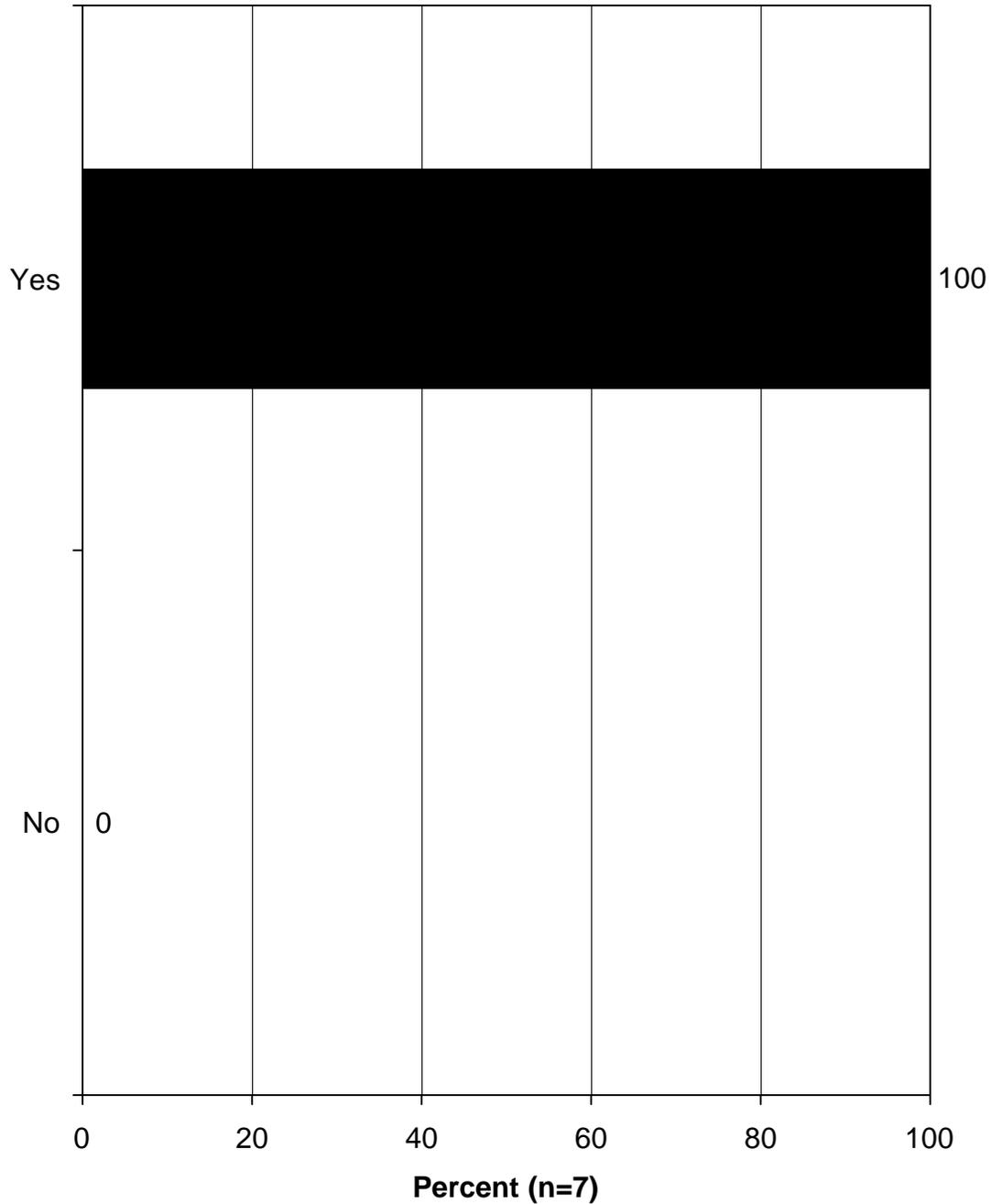
**Q181. Please explain why you plan on acquiring new commercial sensors within the next 2 years.**



**Q182. Please explain why you do NOT plan on acquiring new commercial sensors within the next 2 years.**



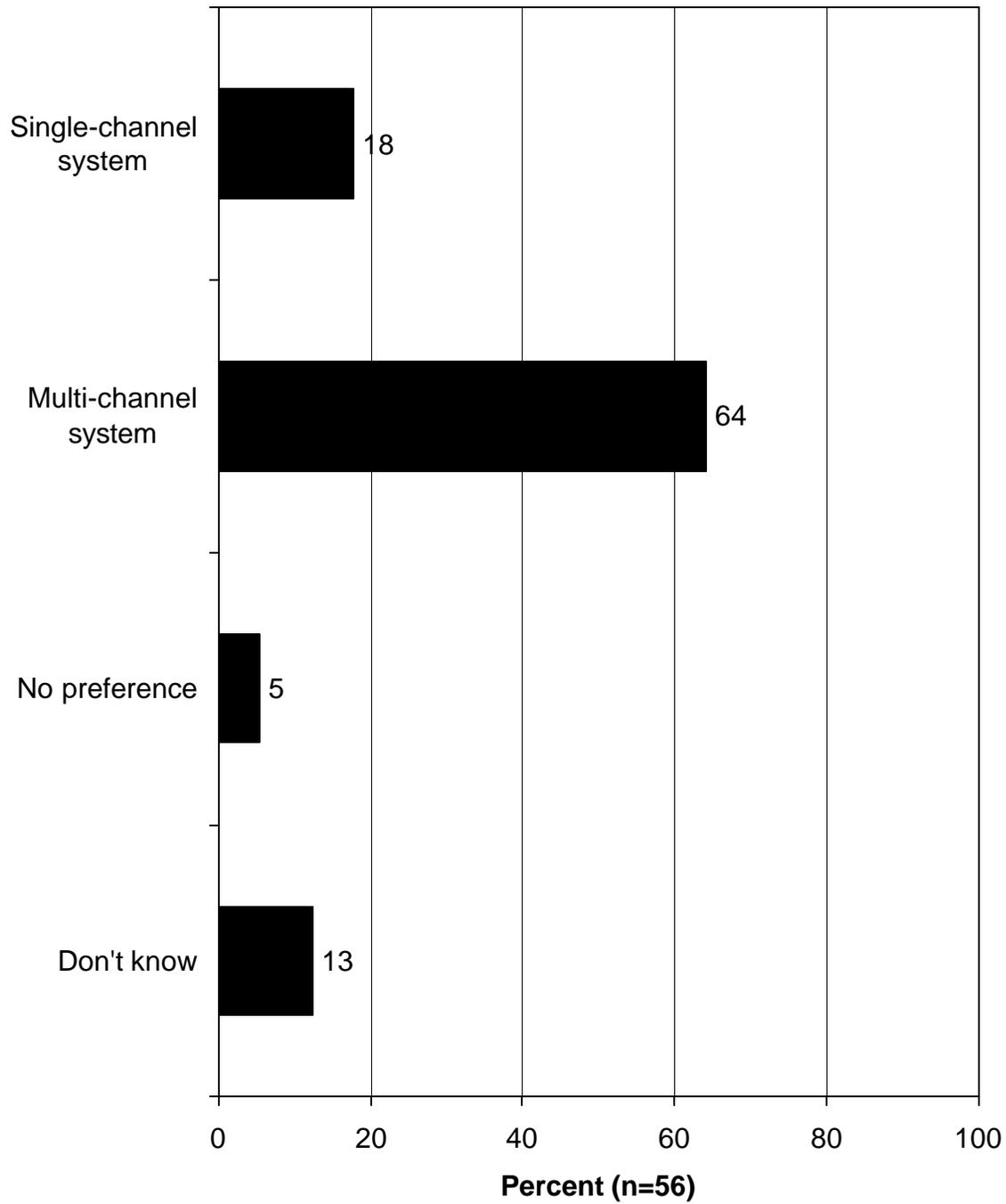
**Q183. Will you consider a different sensor type than the one you are currently using to measure in-situ nutrients? (Asked of those who plan on acquiring new commercial sensors within the next 2 years.)**



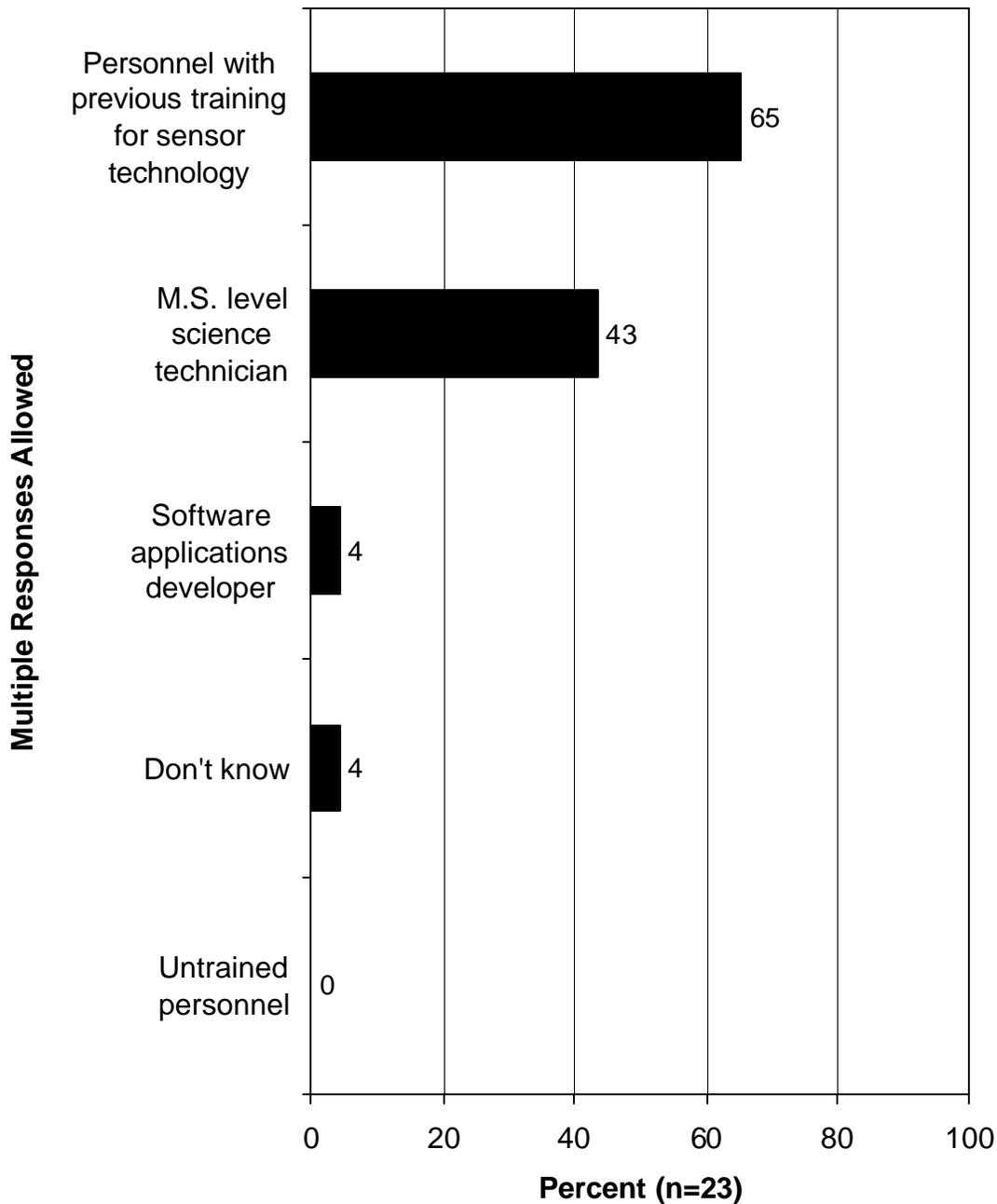
**Q184. Please explain why you will consider a different sensor type than the one you are currently using to measure in-situ nutrients.**

If something better came out
ISIS is the best; will be getting more of those
Looking at what the market has to offer
Ones with better capabilities
To see what is out there
To try different options
To try new technology

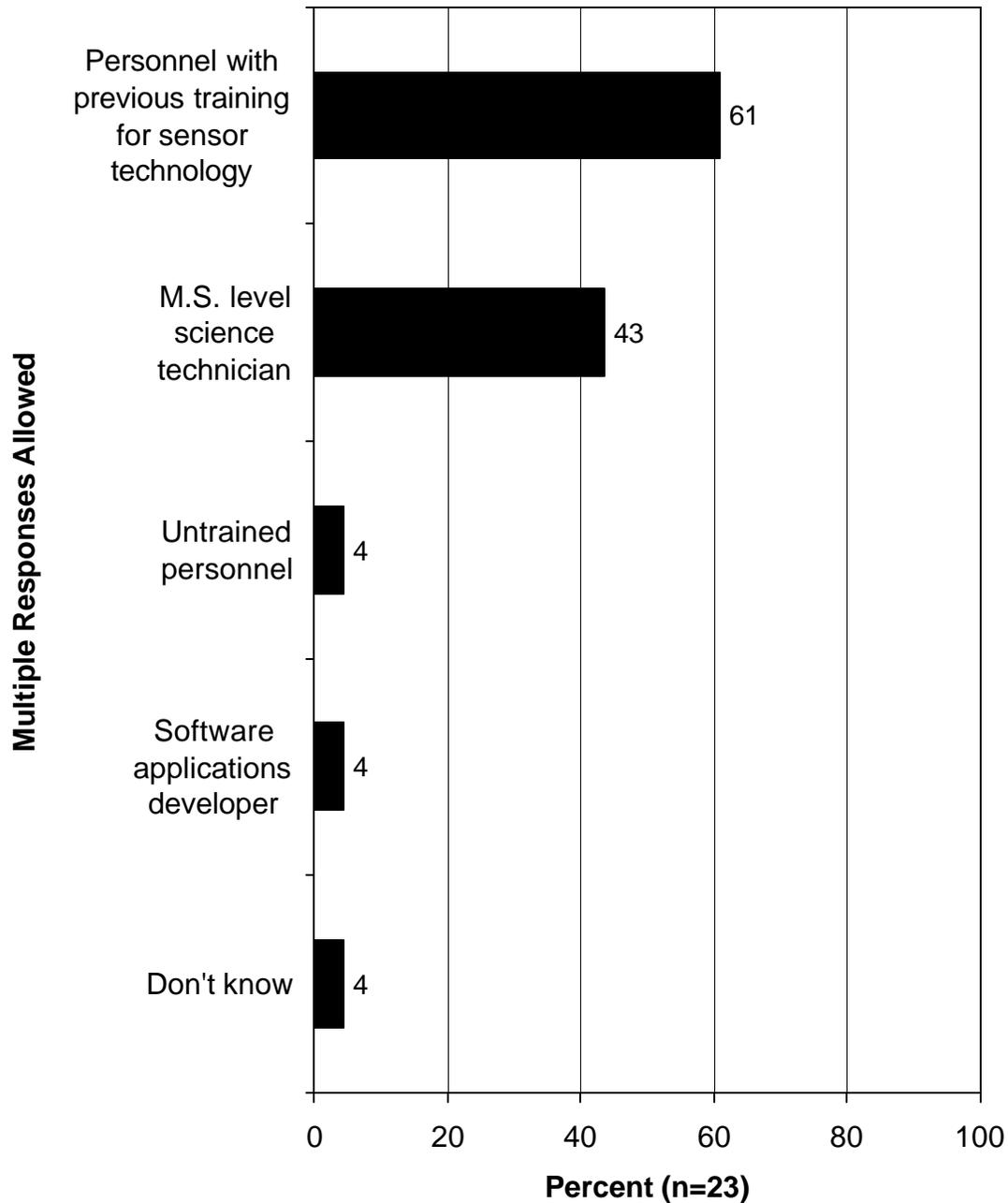
**Q220. If you were to purchase and use a new nutrient sensor, would you use a single-channel or multi-channel system?**



**Q187. Which of the following types of personnel would you need 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.)**



**Q189. Which of the following types of personnel would you most likely have 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.)**



**Q190. What would you require or suggest in terms of training and customer support?**

Can't have too much training on these sensors
Documentation of competency
Easy to use programs that can be customized
Engineers and IT people
Good communication with vendor
Hands on training, available customer support
In field training
Minimal
On-site demo
On-site training from manufacturer. Regional training
One day class and well written manual
One day training seminar
Online how to guide. Customer support
Provide tech assistance over the phone
Send a trainer or have a workshop, available customer support
Solid documentation of the sensor
Training and support for calibration
Workshops, available customer support, dedicated staff
Would require at least some training, and available customer support

## CHARACTERISTICS OF SAMPLE

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

Organization	Number of Respondents
ACE Basin National Estuarine Research Reserve	1
ACT - Skidaway Institute of Oceanography	2
Bermuda Institute of Ocean Sciences	1
College of William and Mary, Chesapeake Bay National Estuarine Research Reserve	1
Environmental Protection Commission of Hillsborough County	1
Envirotech	1
Florida Department of Environmental Protection	1
Hudson River NERR	1
In-Situ	1
King County Department of Natural Resources	3
Los Angeles County Sanitation Districts	1
Louisiana University Marine Consortium	1
Maryland Department of Natural Resources	1
Monterey Bay Aquarium Research Institute	1
National Estuarine Research Reserve (NERR)	1
National Oceanic and Atmospheric Administration (NOAA)	2
NOAA - NOS	1
Old Dominion University	1
Princeton University	1
Puget Sound Water Quality Action Team	1
San Francisco Bay National Estuarine Research Reserve	1
San Francisco State University, Romberg Tiburon Center for Environmental Studies	1
South Florida Water Management District	2
Southern California Coastal Water Research Project	1
State of California Department of Water	1
State of Florida, Department Watershed Monitoring	1
Texas A&M University at Galveston	1
Texas Department of Health	1
University of Alaska Fairbanks	1
University of Delaware, College of Marine Studies	1
University of Georgia	1
University of Maine	1
University of Maryland	1
University of Maryland, Center for Environmental Science Horn Point Lab	2
University of Minnesota Natural Resources Research Institute	1
University of South Florida	2
University of Vermont	1
University of Washington	1
University of West Florida	1
University of Wisconsin, Milwaukee	1
U.S. Environmental Protection Agency	1
U.S. Environmental Protection Agency, Great Lakes	1

Organization	Number of Respondents
U.S. Geological Survey	2
U.S. Geological Survey, Center for Coastal and Watershed Studies	1
Virginia Tech	1
Wet Labs	1
YSI	1

➤ The sample was 77% male.

**Q235. OBSERVE AND RECORD RESPONDENT'S**

