

# **Visitors' Prior Knowledge and Interests in Marine Microbes and Metagenomics**

*Living Liquid* Front-End Evaluation

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January 2011

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 in Marine Microbes and Metagenomics

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## SUMMARY OF KEY FINDINGS

The following summarizes the key findings from this study and their implications for the design of an initial set of visualization prototypes to foster investigation of marine metagenomics datasets.

### Prior Knowledge

- A large majority (95%) of people who had just visited the Exploratorium's collection on marine microfauna were aware that there are microscopic organisms living in the water, a foundational concept for understanding marine metagenomics.

Design Implication ⇨ Situating the *Living Liquid* visualization prototypes within the larger marine exhibit collection may provide a good context for visitors to begin their investigations of marine metagenomics.

- Most visitors (71%) were not surprised that microbes have genetic material (e.g., DNA, genes, RNA). Furthermore, 28%, though initially surprised, found this idea easy to believe.

Design Implication ⇨ The idea that small, microscopic marine creatures have genetic material may not require extensive treatment in the prototypes' labels or other interpretative supports.

- About one-third of the visitors interviewed described small marine creatures according to a category of living things, such as plankton or single-celled organism. However, many of these classifications did not have the scientific specificity used by researchers<sup>1</sup>.

Design Implication ⇨ Datasets that focus on taxonomic classifications, especially those used by scientists, may have little meaning to visitors.

- On the other hand, when visitors were asked what microscopic marine creatures do, a large majority (96%) named at least one role that they believed these small living things had in the larger environment. In particular, many visitors talked about the creatures' place in the larger food chain (86%).

Design Implication ⇨ Focusing on microbial roles and functions may help visitors make sense of the metagenomics data.

- Most (92%) visitors believed that marine microbes are somehow connected to their own lives. Close to half (45%) specifically mentioned eating seafood that depend on the small living things in the water, and 30% talked about the idea that everything, which includes microbes and themselves, is interconnected. To a much smaller degree (less than 15%), visitors described how the microbes are important in the earth's gas cycles and in cleaning and filtering water and how microbes may cause disease and are in the water we drink and the food we eat.

<sup>1</sup> e.g., *Prochlorococcus*, SAR11, *Synechococcus*.

Design Implication ⇨ Referring to the roles visitors believe marine microbes play in their lives (e.g. food for their food, producing oxygen) may help establish personal relevance for the content material.

- Thirty-eight percent to 50% of the visitors reported some familiarity with a research topic in microbial oceanography they thought was interesting, that was described in recent issues of *Nature* or *Science*.

Design Implication ⇨ Visitors' familiarity with some of the current metagenomics research efforts may provide opportunities to better tie the visitor experience to scientific practice and to make their experience more authentic.

### Visitors' Interests

- When presented with a map and asked where they would like to explore for marine microbes, over half (59%) of the visitors wanted to look in an area that they thought had a special environmental characteristic. This finding suggests that some visitors do distinguish between different parts of the oceans and are aware of possible connections between the physical conditions of a place and the small organisms that may be found there.

Design Implication ⇨ Datasets that include information about the physical characteristics of a place may help engage visitors with investigating metagenomics data.

- A majority (71%) of the visitors we interviewed valued research that can be directly applied to solving a problem, such as pollution cleanup, as opposed to the 22% of visitors who valued basic research, conducted to advance our understanding of the world.

Design Implication ⇨ Referring to the practical implications of investigating metagenomics data may make the prototypes more relevant and engaging to visitors.

## BACKGROUND

*Living Liquid* is an NSF-funded pathways project that seeks to identify promising strategies for using visualization tools to engage museum visitors in asking and answering their own questions about the ocean's microbes with metagenomics data. As part of this project the Exploratorium, working with scientists from the Center for Microbial Oceanography Research and Education (C-MORE) and data visualizers from the Visualization Interface and Design Innovation group (ViDi) at the University of California at Davis, will create low-tech visualization prototypes and study how to support visitors' investigations of scientific data with these prototypes. Lessons learned will inform (1) the Exploratorium on the development of a fully functioning, multi-user, multimedia interactive exhibit to be included in the marine life collection at our museum, and (2) the broader field on how to engage visitors with large datasets that have become increasingly common in scientific practice.

## PURPOSE

To begin this work, the Exploratorium's Visitor Research and Evaluation Department conducted this front-end evaluation (1) to identify visitors' **prior knowledge** of microbial oceanography, and (2) to determine **visitors' interest** in the different research conducted by microbial oceanographers with metagenomics data:

### Prior Knowledge

- Do visitors know that there are very small organisms in the oceans?
- Are visitors aware that microbes have genetic material?
- How do visitors describe very small marine life (e.g., by function, by size, by appearance)?
- What do visitors think marine microbes do?
- What connection(s) do visitors see between themselves and marine microbes?
- Are visitors familiar with current research on marine microbes?

### Visitors' Interests

- What parts of the ocean are visitors interested in exploring?
- Which research topic(s) do visitors find interesting? Do visitors find more value in some questions as opposed to others?

The findings from this study are intended to inform prototype development by (1) guiding the selection of scientific datasets that are meaningful to visitors, (2) suggesting areas of interest to highlight, and (3) identifying information or explanations visitors may need to make sense of the content they will investigate.

## METHOD

For this front-end study, we decided to interview visitors as they were exiting the Exploratorium's marine life collection<sup>2</sup>, which focuses on the microfauna and flora of San Francisco Bay and the larger oceans. This meant that the study's participants would likely be more interested and knowledgeable in microbial oceanography than the 'typical' Exploratorium visitor. Nonetheless, because the *Living Liquid* prototypes and final build-out would be situated in a larger marine life collection and would, therefore, have a similar audience, we opted to sample from this self-selected population.

An evaluator approached every third visitor as s/he exited the marine life collection and asked for an interview of the people who reported having spent time looking at the exhibits in that collection. If the visitor selected was a minor, we also asked the accompanying adult for permission to talk with the child and confirmed that the minor was at least 11 years old, in keeping with the target audience of the project.

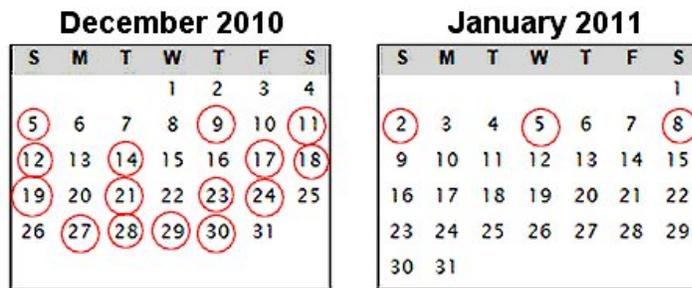
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<sup>2</sup> At the time of this study, there were 11 exhibit prototypes in the marine life collection.

Because metagenomics can be an unfamiliar and obscure area for many visitors, we designed the interview to progressively introduce key concepts (e.g., there are small living things in the ocean, scientists study these small creatures, scientists study these creatures by looking at their genes to find out what they are and what they do). At the same time, we provided visitors the opportunity to articulate their own thoughts before presenting a new concept. The interview questions are in Appendix A.

## DATA COLLECTED

$N = 136$  interviews were collected in December 2010 and January 2011 on the days circled in Figure 1.



*Figure 1. Interview days.*

The study participants' demographic information is shown in Table 1.

**Table 1. Demographic information of the visitors interviewed**

Gender	Count out of 136	Age Group	Count out of 136
Female	75 (55%)	Child	9 (7%)
Male	61 (45%)	Teen	22 (16%)
		Adult	93 (68%)
		Senior	12 (9%)

## RESULTS

### Visitors' Preconceptions

Characterizing visitors' prior knowledge of marine microbes and research helps identify concepts familiar to visitors, which can help ground their interpretation and understanding. Alternatively, the prototypes may need to provide adequate background to help visitors make sense of any unfamiliar ideas the prototypes introduce.



these visitors explained that the concept is easy to overlook or forget because microbes are so different from what they think of as life and very different from themselves.

This and the previous result give us some confidence that many visitors, who had visited the marine life exhibit collection, would have some familiarity with two ideas essential to understanding metagenomics: 1) There are small, microscopic marine creatures. 2) These creatures have genetic material.

#### *How did visitors describe very small marine life?*

When we asked visitors to describe the small living things in the oceans as if describing them to a friend, we found that most visitors talked about their size (e.g., small). However, this may be a result of the fact that the question itself used size as a descriptor. When we consider the other ways in which visitors described small marine life, we found that 33% of the visitors talked about the categories of organisms they might find in the oceans and a slightly smaller 27% talked about the connections, or the roles, small marine life have within the larger environment.

Table 3 lists the different types of visitors' descriptions and gives examples for each and the tally of visitors who described small marine life in that manner.

**Table 3. How visitors described the very small living things in the oceans**

Description Type	Count out of 132 <sup>+</sup>	Example Visitor Descriptions
<b>Size</b> – The visitor talks about the size of the living things.	88 (67%)	<u>infinitely small tiny</u> plants and animals You can't see it. <u>Microscopic</u> . It's practically invisible.
<b>Category</b> – The response includes a scientific or layman's classification for the organisms being described that is more specific than "living things", "creature", or "organism."	43 (33%)	<u>single or few cells</u> , and... <u>autotrophic Plankton</u> are forms of <u>algae</u> that make oxygen. <u>one celled organisms</u> little <u>animals</u> that swarm in the sea.
<b>Connection</b> – The visitor talks about how small marine life interacts with or fits into the larger environment.	36 (27%)	They <u>feed on algae</u> . <u>They make up a big part of the food chain</u> . <u>Some provide nutrients or minerals to other animals</u> . <u>It's all necessary. It's all connected.</u>
<b>"Like a"</b> – The visitor uses a simile.	32 (24%)	<u>like little bugs underwater</u> . <u>like tiny grains of sand or salt</u> but smaller <u>bug-like</u>

Description Type	Count out of 132 <sup>+</sup>	Example Visitor Descriptions
<b>Behavior</b> – The visitor describes how the life forms act and behave.	27 (20%)	They <u>have no control over where they go</u> . They <u>float</u> . tiny <u>swimming</u> bugs
<b>Appearance</b> – The visitor mentions superficial features such as shape and color.	19 (14%)	floating <u>balls</u> Most are <u>little circles that are green</u> .
<b>Abundance</b> – The response includes talk about the abundance or scarcity of life.	15 (11%)	<u>There are lots of them</u> . <u>Bacteria are everywhere</u> .
<b>Parts</b> – The response includes talk about a structural part of the organism.	12 (9%)	crazy shapes and <u>antennas</u>
<b>Variety</b> – The visitor talks about the variety or diversity of the life forms	9 (7%)	<u>various, many types</u>
<b>Other</b> – The description does not fall into any of the other categories.	6 (5%)	really <u>gross</u> and <u>interesting</u>
<b>No thought</b> – The visitor has no idea how to describe these living things.	6 (5%)	<u>I don't know [anything?]</u> <u>I don't know</u>

<sup>+</sup> The number of visitors who named a tiny marine organism.

These findings give us an initial indication of how we should talk about the small marine life featured in the prototype and the types of information (e.g., species versus microbial functions) the dataset should include.

#### *What did visitors think marine microbes do?*

Some (27%) visitors talked about the roles the small marine life have in the oceans. This was a particularly promising finding because metagenomics research often entails identifying specific functions marine microbes perform in the environment. To better gauge how visitors talk about the roles microbes play, we further asked all the visitors interviewed what they thought these microbes might do. The results are tabulated in Table 4.

**Table 4. What visitors thought the very small living things in the oceans do**

<b>Roles of Small Marine Life</b>	<b>Count out of 132<sup>+</sup></b>	<b>Examples of Visitors' Responses</b>
<b>Food Chain</b> – The visitor talk about how small marine life are part of the food chain.	113 (86%)	They are <u>part of the food chain</u> the <u>food chain</u> . [They] <u>eat, just eat</u> . [They] <u>eat</u> mold and algae. <u>Big things eat plankton and bacteria</u> . <u>It could feed other things</u> . <u>They're food</u> . <u>The food web, zooplankton are eaten by krill or small fish, and it keeps going and going</u> .
<b>Web of Life</b> – The visitor describes in general and oftentimes vague terms about how everything is interconnected.	52 (39%)	It's got to have a relationship. <u>Everything has to do with everything else</u> . <u>keep a balanced ecosystem</u> <u>They are all a part of the big sea; everything is connected. They share an ocean</u> . They're a key or detrimental part of <u>the chain of life</u> . <u>Without them other creatures can't survive</u> . But <u>with them, creatures are affected for good or bad</u> .
<b>Filter and Clean</b> – The visitor talks about how small life forms filter and clean the oceans.	44 (33%)	<u>cleaning up fecal matter</u> of the fish <u>eat bad chemicals in water</u> <u>Some algae can digest oil</u> .
<b>Gas Exchange</b> – The visitor describes how small marine life participate in gas exchange.	21 (16%)	[They] <u>exchange gases or whatever they do to breathe</u> . [It] <u>produces oxygen</u> at high levels.
<b>Photosynthesis</b> – The visitor mentions photosynthesis. This was pulled out as a category separate from the energy and the food cycle since it is not clear from the interviews with which cycle, if any, visitors think photosynthesis belongs.	18 (14%)	They swim, eat. <u>Photosynthesize</u> . Get eaten.
<b>Parasitism</b> – The visitor comments on how the small marine life hurts other living things.	10 (8%)	<u>living off of other things and infecting them</u> .

<b>Roles of Small Marine Life</b>	<b>Count</b> out of 132 <sup>+</sup>	<b>Examples of Visitors' Responses</b>
<b>Co-existence</b> – The visitor describes how small life co-exists with other life forms.	6 (5%)	<u>They live on animals that eat bacteria.</u>
<b>Other</b> – The description does not fall into any of the other categories.	6 (5%)	<u>They define the local area.</u> For example in Yellowstone, there's sulfur and different animals grow in that temperature. And that's different than the Bay Area.
<b>Decomposition</b> – The visitor mentions the decomposition process.	5 (4%)	[It] <u>breaks down other things.</u>
<b>Energy Cycle</b> – The visitor talks about how microbes make energy	5 (4%)	<u>Some make power</u> because they secrete oil.
<b>Provides Protection</b> – The talks about how small marine life protects other organisms.	5 (4%)	<u>protect them from other bacteria</u>
<b>No Role</b> – The visitor does not articulate any roles these living things may play.	5 (4%)	<u>I don't know.</u> They swim around.

<sup>+</sup> The number of visitors who named a tiny marine organism.

Overall, a large majority (96%) talked about at least one role that they believed marine microbes had in the larger environment, with 86% of the visitors talking about the microbes' part in the food chain. We were surprised to find that some visitors, albeit a much smaller minority, described microbes as playing a part in cleaning and filtering the oceans.

#### *Do visitors think marine microbes are connected to or play a role in their own lives?*

One of the key challenges in creating engaging prototypes for investigating metagenomics data is to make the somewhat removed and obscure subject matter personally relevant to visitors. To identify potential points of personal connection, we asked visitors a series of questions about how microscopic marine life are connected to other living things and to the visitors themselves. We found that 92% of the visitors saw some sort of connection to themselves. More specifically, visitors mentioned eating seafood that depend on the marine microbes and the interconnectedness of all life on earth. A few visitors talked about marine microorganisms producing oxygen, processing carbon and cleaning the oceans. A very small minority characterized the marine microbes as harmful to humans, while others talked about coming in contact with them whenever they eat, drink or go swimming. Table 5 lists the different categories of response along with examples and gives the tally for each type of personal connection.

**Table 5. The personal connection between marine microbes and us.**

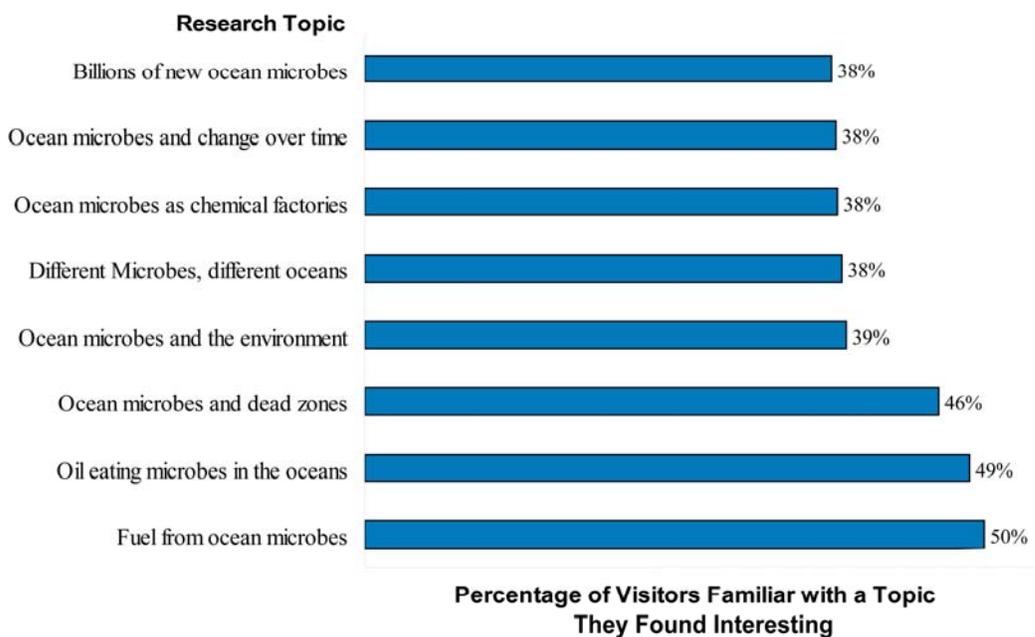
<b>Connection to Small Marine Life</b>	<b>Count out of 121<sup>+</sup></b>	<b>Examples of Visitors' Responses</b>
Visitors consume seafood that, in turn, depends on microscopic marine life.	55 (45%)	They're food for what we eat. We eat fish or crab or seafood. They serve as a food source for other living things and I am a direct recipient for those resources as well. They come up the food chain.
Everything is interconnected.	36 (30%)	We're all interconnected If things aren't there, it affects others. We rely on that web
Marine microbes produce the oxygen we breathe. They also reduce carbon dioxide.	14 (12%)	It's absorbing carbon dioxide and producing oxygen.
Marine microbes clean the oceans for us.	11 (9%)	They decay things and clean up things. And, if you leave your bucket in the water, it will get algae on it. I had a fish tank once with a lot of algae.
Marine microbes are in the food we eat and the water we drink.	9 (7%)	in the water we drink
No Further Information - Visitor is unable to give additional details.	9 (7%)	Yes. I don't know how.
Marine microbes can hurt humans.	9 (7%)	make people sick.
Visitors can come into physical contact with these creatures.	7 (6%)	We touch water, so we're exposed.
Microbes can affect the physical environment of the earth.	4 (3%)	They affect the weather, water temperature
We can use microbes as a resource.	4 (3%)	And then algae, we use it for things. They are using it to make energy, like in solar panels.
Humans and microbes are connected evolutionarily.	3 (2%)	I mean that is where we started, so we must be connected.
Other - The response did not fall into any of the other categories.	6 (4%)	They are connected, because like humans they have a life of their own.
Microbes photosynthesize.	3 (2%)	Algae does photosynthesis.

<sup>+</sup> The number of visitors saw a personal connection.

### *Are visitors familiar with current research on marine microbes?*

As part of the interview, we introduced visitors to some of the research topics microbial oceanographers are studying, limited to eight in total. These topics were selected based on a review of recent articles in *Science* and *Nature* and conversations with C-MORE scientists. Each topic was described with one to two sentences, checked by the science content expert, and presented on an index card. (The text for these cards is in Appendix B.) We asked visitors, of those topics that they found interesting, which have they heard about previously. We did not ask this of all the cards in order to keep the interview at a reasonable length, under 15 minutes. This compromise, however, meant that the data we collected could only identify topics that were *both* interesting and familiar to visitors.

The results are summarized in Figure 3. Thirty-eight percent to 50% of the visitors had heard of a particular topic that microbial oceanographers are investigating with metagenomics data that they also found interesting. This result indicates some familiarity with current investigations in the ocean sciences and suggests possible connections the prototype can highlight between visitors' investigations at the *Living Liquid* prototypes and current research in marine metagenomics that visitors more readily recognize and find interesting.



**Figure 3.** Percentage of visitors who reported being familiar with a metagenomics research topic that they also found interesting.

### **Visitors' Interests**

In addition to identifying prior knowledge, this study sought to gauge visitors' interest in the oceans' microbes and ocean research to help identify ways to engage visitors with investigating metagenomics data.



A majority (59%) of the visitors wanted to explore an area of the oceans that has a special physical or chemical characteristic (e.g., extreme temperature, current patterns). This suggests that some visitors have an awareness that physical and chemical factors are tied to the small organisms found in the waters.

**Table 7. Reasons visitors gave for the locations they preferred to explore**

Why that location	Count out of 132 <sup>+</sup>	Examples of Visitors' Responses
<b>Special Physical Factor</b> – There is something special about the physical or chemical environment at that location.	80 (59%)	The Bay Area is unique because <u>we have a delta area</u> <u>People float in it.</u> [The Dead Sea] I'm interested in <u>extreme environments</u> , <u>very cold</u> <u>the humidity</u> . I've heard there is a really important <u>nutrient upwelling</u> there.
<b>Different Location</b> – The location is different (from the local or common locations).	32 (24%)	It's ... <u>different from the ocean around here</u> . At Monterey Bay, you can already see fish from around here. It's <u>exotic</u> .
<b>Diversity and Abundance</b> – Visitors expect to find a diversity and abundance of life in that location.	30 (22%)	<u>vast amounts of wildlife</u> in the oceans there It has <u>all sorts of different animals</u> than here.
<b>Special Life-Forms</b> – The location has special organisms that visitors expect and want to find.	28 (21%)	<u>Halophiles and Thermophiles</u> . I know there are <u>corals</u> there.
<b>Human Impact</b> – It's a place near human habitation, which humans have likely overused.	25 (18%)	<u>It's getting destroyed</u> . <u>People get into the water</u> .
<b>Local Location</b> – It's in the San Francisco area.	22 (16%)	It's <u>close to here</u> . stuff that's <u>local...Because we're here</u> .
<b>Home</b> – It's close to the visitor's home.	19 (14%)	<u>I live there</u> , and I know there are corals there.
<b>New Discoveries</b> – Visitors think they will find something new that was previously unknown. Oftentimes, these remarks are made about remote areas.	15 (11%)	because you might <u>see something you never knew</u> is there.

Why that location	Count out of 132 <sup>+</sup>	Examples of Visitors' Responses
<b>Personal Connection</b> – The visitor has had some personal connection to the location, other than living there.	8 (6%)	<u>I want to go there</u>
<b>Pristine</b> – The location is untouched by humans.	8 (6%)	Other oceans are near lots of people. The southern ocean is arctic <u>with not many people around.</u>
<b>Media coverage</b> – The place was in the news or popular discourse	6 (4%)	<u>You hear a lot about it,</u> the coral reefs.
<b>Other</b> – The explanation did not fall under any other category.	7 (5%)	It's the only one with its own name.
<b>No Explanation</b> – The visitor offered no explanation	16 (12%)	<u>Just because.</u>

<sup>+</sup> The number of visitors who identified a location.

We also asked visitors what they wanted to know about the tiny life that they find in the locations they selected. In order to gauge the overlap between the types of questions visitors ask and those that scientists ask, we coded the questions visitors generated as descriptive (survey, function, or other), comparative, relational, causal, or human impact questions.

Our analysis of visitor-generated questions suggests some, though limited, overlap between visitors' questions and those currently pursued by the scientific community. (A recent review of the marine metagenomics (Gilbert & Dupont, 2011) characterizes recent research efforts in the field as being dominated by descriptive studies with some comparative research, and few correlation or causal studies.) This was, nonetheless, a promising finding since the *Living Liquid* project is trying to help visitors answer their own questions with real scientific datasets. A future analysis, to be conducted after more in-depth conversations with C-MORE scientists, will map visitor questions to those that can and cannot be answered given the current state of metagenomics research and available datasets.

**Table 8. Types of questions visitors asked about the tiny organisms at a marine location**

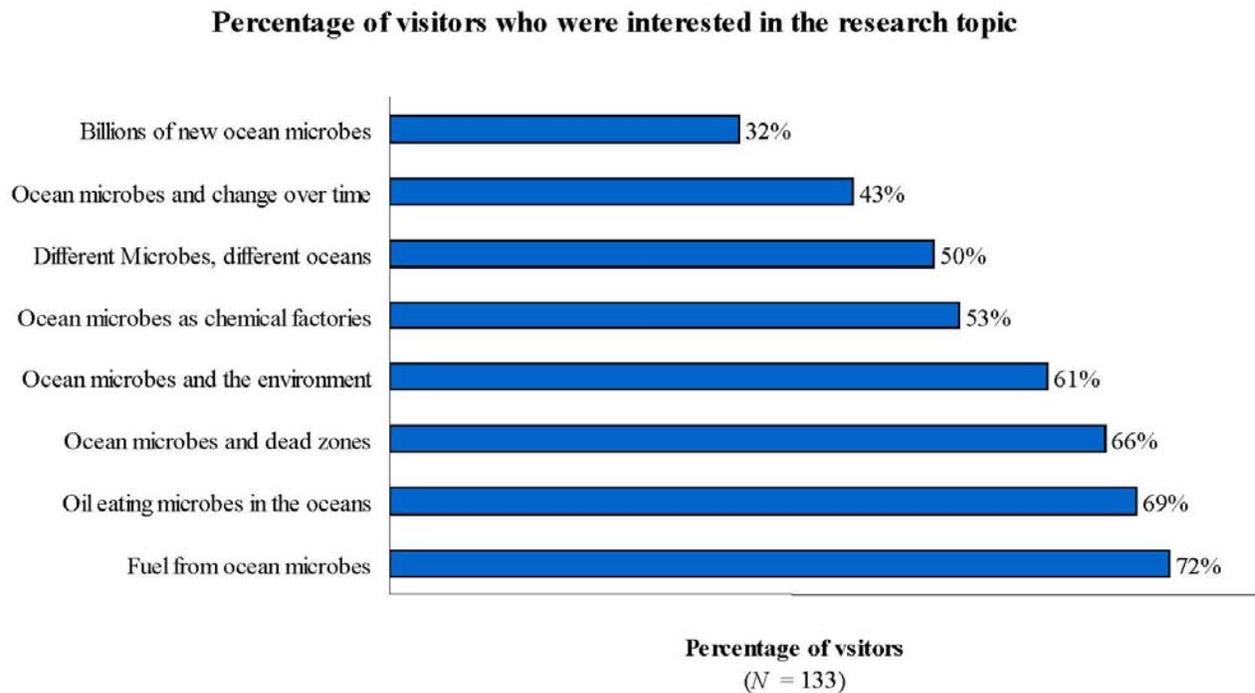
<b>Question Type</b>	<b>Count out of 423 questions</b>	<b>Examples of Visitors' Questions</b>
<b>Descriptive</b>		
<b>Survey</b> – Questions about what's at a location that are answerable with a sampling survey.	75 (18%)	What does live there? How many are there in a given volume of water? What types of creatures are in that area? Is there any life? How many there are?
<b>Function</b> – Questions about what the organisms do or how they do it.	47 (11%)	what they mainly do How do they survive the cold? how they are able to survive in extreme environments
<b>Other Descriptive</b> – What and how questions that are neither about what organisms there are or what those organisms do.	61 (14%)	to know more about sea urchins visually what they look like what they develop into How was the reef created?
<b>Comparative</b> – Questions that compare different organisms, different locations, or different times.	77 (18%)	What differences there are in different places? How much has changed over time? How different are they? What makes their structure different from others near the equator? Do they do different things, or the same?
<b>Relational</b> – Questions about the relationship between one organism or group of organisms with other organisms or the larger environment. (No causality is inferred.)	47 (11%)	Who eats them? the interrelationship between the microscopic and the larger organisms How do they interact with the reef? what integral part of the ecosystem they play

Question Type	Count out of 423 questions	Examples of Visitors' Questions
<b>Causal</b> – Cause and effect questions.	89 (21%)	It's salty so not a lot of things live there? When you drain the wetlands, what impact would it have? Does climate affect water? Are there less (things) because of the temperature? What the effect of that (plankton) is on the coral How they impact the environment around them If we lost them, how would it affect the rest of the world?
<b>Human Impact</b> – Questions about the potential ramification on human welfare.	27 (6%)	if they influence people Is it harmful to humans if we consume the water?

*Which research topic(s) do visitors find interesting?*

We also presented the visitors with a set of topic cards (Appendix B), each of which briefly described a current area of metagenomics research, and asked visitors to select those that were interesting to them. The results are shown in Figure 5.

These are topics currently under investigation, and in most cases, the metagenomics data used in these research areas are still to be collected and analyzed. Gauging visitors' interest in these topics, therefore, does not directly inform the selection of one dataset over another, but instead may help identify how to make the investigation of metagenomics data more relevant to visitors. Towards this end, we coded visitors' explanations for what made a particular topic, in their opinion, important to study. We found that a majority (71% out of 131 respondents) valued a research topic because they felt that the research findings could be applied to solving a problem, such as to better the human condition. This is in contrast to 22% of the visitors interviewed who valued the research as basic research, conducted mainly to understand more about the world. This suggests that the prototypes we develop should refer, if possible, to the practical implications of investigating metagenomics data.



*Figure 5. Research topics visitors found interesting.*

### NEXT STEPS

This front-end study gauged visitors' prior knowledge and interest in marine microbes and metagenomics research. Its findings serve to inform the design of an initial set of prototypes for the *Living Liquid* project that support and engage visitors in exploring metagenomics data. More specifically, this study's results suggest:

- Focusing on microbial roles and functions instead of taxonomic classification schemes used by scientist may be more meaningful to visitors. The findings from this study give an initial indication of what roles and functions visitors are familiar with, but further evaluation will be necessary to determine if the roles we highlight in the prototypes are meaningful to visitors.
- Highlighting the roles visitors believe marine microbes play in their lives (e.g. food for their food, producing oxygen) may help establish personal relevance to the content material.
- Tying visitors' explorations to research that visitors are familiar with, may help them make connections between their own investigations and current questions researchers are tackling with metagenomics data. This in turn can make for a more authentic visitors experience tied to scientific practice.
- Although we have only preliminary data, map-based activities may be a promising way for visitors to begin their metagenomics data explorations. This speculation is based on the

observation that when study participants were shown a map, almost every person picked a place. Only two visitors had no thoughts as to where they would want to start to look.

- Datasets that include the physical or chemical parameters of different locations may help engage visitors in their investigations.
- Referring to the practical implications of investigating metagenomics data may further lend relevancy to the visitors' experiences at the exhibit prototypes.

Further formative evaluation with the prototypes we develop will better identify which approaches are effective in creating a compelling and meaningful tool by which visitors can explore metagenomics data.

### ACKNOWLEDGEMENTS

The author would like to thank Lisa Sindorf, Leah Johnson, and Emily Leighton for conducting the interviews for this study. Lisa and Leah also helped code the interview responses. The study also benefited from Chris Parsons' insightful comments and careful review.

This material is based upon work supported by the National Science Foundation under Grant number 1011084. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.



### REFERENCE

Gilbert, J.A. and Dupont, C.L. (2011). Microbial Metagenomics: Beyond the Genome. *Annual Review of Marine Science*, 3, 347–371.

## APPENDIX A

### INTERVIEW QUESTIONS

Note that visitors' responses for the questions in grey were not analyzed in this study.

This is a drop of water from the San Francisco Bay. That exhibit there [*point to Microscope Imaging Station*] gives you a chance to look at it with a powerful microscope.

1. Have you had a chance to use that exhibit?      YES    NO
2. Can you make a guess? What kinds of living things do you think you'll find in this drop of water?
3. Pretend that you're talking to a friend who has never thought about the small things living in the ocean. How would you describe these living things to your friend?
4. I know I'm not giving you very much information right now, but can you make a guess as to what < *these living things – use their words* > do?
  - a. Are they connected to other living things? How so?
  - b. Are they connected to your own life? How so?

With the new exhibit we're thinking of building, we'd like to give people a chance to explore the tiny organisms in different parts of the oceans. Here is a map of the world. [*Show color map*]

5. Is there any part of the oceans that you would be interested in exploring – finding the tiny living things there? [*Circle and number location on map*]



[*For each location up to 3*]

Map  
number Is there any reason why there?

What would you want to know about the tiny  
things in the ocean there?

Scientists are studying the very small living things in the oceans –microbes that include bacteria, viruses, and other microscopic creatures in the oceans. Here are some things that they have started to research: [*Present fact cards.*]

6. Are there any that are particularly interesting to you? [*Note card no.*]

[*Take away those that were not of interest. Lay out the interesting ones.*]

a. [*Point to each in turn.*] Have you heard about this before now?

Card No. a. heard before?

b. [*Gesture to them all.*] Of these, which two do you find the most interesting? [*Move the others aside*] Is there anything in particular that made those interesting to you?

c. Is there anything more you would like to know about either of these? [*Probe*]

CardNo.

b. why interesting

c. more you'd like to know

7. [*Gesture to entire interest set*] Are there any that are particularly important to you for scientists to answer? Can you put them in order with the most important to answer first?

Order by card number:

a. [*Pick most important one*] Can you say a little bit about why do you feel that one is important for scientists to answer?

8. Do you have any questions on other topics about the oceans' microbes that you would like to ask a scientist?

The new exhibit we're thinking of building allows people to look at the very small things in the ocean in a new way by looking not with a microscope but with very different equipment that looks at genes, DNA and RNA.

9. It is surprising to you to hear that microbes have genes, DNA or RNA?      YES    NO  
 [if confused...Do those words mean anything to you?]

a. [Ask only if genes, DNA, RNA means something to them] Can you say a little about why you find that (not) surprising?

When scientists look, they look for different types of living things according to what genes and DNA they share. But they also look for signs of what these small living things can do. Here are some examples [*Present function cards.*]

10. Are there any that you would like to know more about?

Card

Number

What would you like to know more about?

11. Is there anything else that you'd like to share with me about this new exhibit?

## APPENDIX B

### RESEARCH TOPIC DESCRIPTIONS

#### **Billions of new ocean microbes**

Researchers estimate that there must be at least 20 million different types of ocean microbes. The real number may even be billions (or trillions!) of new microbes.

#### **Ocean microbes and dead zones**

Researchers are trying to understand dead zones – ocean areas so low in oxygen that fish and other sea life cannot live. Ocean microbes may be involved.

#### **Ocean microbes and the environment**

Scientists are learning how ocean microbes affect the earth's atmosphere and environment. For instance, half the oxygen in the air is made by ocean bacteria.

#### **Ocean microbes as chemical factories**

Ocean microbes are like tiny chemical factories. Researchers are studying what ocean microbes can do - absorb carbon dioxide, make oxygen, and many other things.

#### **Different microbes, different oceans**

Researchers are studying how different parts of the oceans can have different microbes. For instance, the microbes in San Francisco Bay can be very different from those near Hawaii.

#### **Fuel from ocean microbes**

Researchers are looking for microbes in the oceans that can make new fuels that we can use.

#### **Oil-eating microbes in the oceans**

Scientists think that microbes in the Gulf of Mexico are eating the oil from the Deepwater Horizon oil spill, helping with its cleanup.

#### **Ocean microbes and change over time**

Scientists are studying how ocean microbes change, from month to month, from year to year. This may tell us how the environment is changing.