Playing with plankton: engaging the public with phytoplankton, harmful algal blooms and CeNCOOS

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ABSTRACT

Presented here are results from a 10-week project to develop engagement activities around phytoplankton, harmful algal blooms and the work of CeNCOOS and partners to monitor the oceans and coasts in Central and Northern California. The resulting activities are layered, multifunctional activities that can be used to engage a range of audiences – particularly families – with phytoplankton and harmful algal blooms and the importance of monitoring and studying our oceans. This includes 3D-printed objects, a matching activity, coloring sheets and posters, and descriptive narrative text and images. These activities can be run by experts, non-experts and other CeNCOOS stakeholders for open house events, school workshops and other local learning sessions.

INTRODUCTION

The ocean covers more than 70% of the Earth, makes our planet habitable, regulates our climate, provides food, incomes and inspiration for billions of people. Nearly 40% of the world's population lives within 100 km of the coast, but the impact of the ocean goes beyond that, to affect every person and organism on Earth. In a time when the human impact on the planet, and particularly the ocean, is increasing and projected to increase still further, learning about our impact and encouraging more people to learn and care about our oceans is more important than ever. To maintain the climate and ecosystem services of the ocean, scientific information needs to be available to policy makers, but also to the public, enabling engagement between science and society to ensure that together we manage the tensions that emerge in using resources while also sustaining them for future generations. As stated by the Ocean Studies Board (2008) "Capacity-building for stewardship of the oceans and coasts is a complex multidisciplinary challenge and needs to be addressed as such. It requires interdisciplinary and multidisciplinary approaches to ensure that stakeholders develop the proper knowledge, skills, and attitudes to be effective stewards of the environment."

SCIENCE ENGAGEMENT

It is a particularly challenging time for science communication. 2016 was the year of post-truth, when scientific knowledge and expertise became less important than belief and emotional appeals for decision-making. Against a background of a post-truth world, inspiring curiosity about the world through science and a knowledge and understanding about scientific processes becomes even more important (Gomes da Costa, 2017). Science communication has to be relevant, inspiring and engage people with real scientific issues and data, a task made harder as there is no single audience for science, and the nature of scientific information and processes often makes communicating it even more complex (National Academies of Sciences, Engineering, and Medicine, 2017).

Within informal science engagement, such as activities at museums and science centers, best practice for science communication is to ensure that experiences and content are relevant to audiences, and engaging, interactive or fun, according to a 2012 report commissioned by the Wellcome Trust. The same report confirms that activities must also vary depending on the audience, including on the age targeted, for example providing different activities for young children compared with older children or adults.

To help with communicating ocean science, a framework for communicating about the oceans has been put forward by the Ocean Literacy Network. The concept of ocean literacy is “an understanding of the ocean’s influence on you and your influence on the ocean” (Ocean Literacy Network, 2015). The goal is ocean literate individuals who can communicate about the ocean, make informed and responsible decisions about the ocean and understand fundamental principles about the ocean. Four of the seven principles identified link closely to ocean observation and phytoplankton and are the basis of this project, informing the messages and communication: the ocean makes the Earth habitable, the ocean supports a great diversity of life and ecosystems, the ocean and humans are inextricably interconnected, and the ocean and life in the ocean shape the features of the Earth.

The availability of real ocean data is another benefit for this project. Adams and Matsumoto (2009) noted that using real data helps engage students by making concepts relevant to their lives, bringing the ocean closer and enabling students to act like scientists, asking questions and testing hypotheses. This project used real data to enabling visitors to explore what we do and don’t know about the ocean, as well as communicate the importance of ocean observation.

PHYTOPLANKTON

Phytoplankton are small plant-like organisms that live in marine and freshwater environments. Like plants, they carry out photosynthesis, which uses light, carbon dioxide and other nutrients to produce energy, as well as oxygen. They are essential for healthy oceans, and have a high diversity of types, including simple bacteria species, like cyanobacteria, and more complex single-celled organisms and algae, such as diatoms and dinoflagellates. Phytoplankton play a key role in supplying food to marine food webs and produce nearly 50% of the world's oxygen.

However, under certain circumstances, particular phytoplankton species can multiply at very high rates, leading to visible blooms. These blooms can involve species that have harmful effects on the ocean environment and ecosystems, known as harmful algal blooms (HABs). HABs can produce toxins that are damaging to marine organisms such as oysters, crabs and marine mammals, as well as humans. These toxins include those responsible for paralytic shellfish poisoning.

The current HAB event in Florida has lasted nine months to August 2018, affecting sea turtles, manatees, fish and sea birds and causing respiratory distress to humans up to 10 miles from the coast. (Adalbjornsson and Gomez, 2018) The economic effect of HABs across the US reaches millions of dollars each year in the fishing, restaurant and tourism industries and so research into detection, forecasting and response are all needed, as well as good ways to communicate about HABs to the public, government and industries (GCOOS, 2018). In California, 2015-2016 saw the closure of the Dungeness crab fishery for most of the season, as well as closures to the rock crab and razor clam fisheries. The loss in landing value compared to previous years was ~$20 million for Dungeness crab, with an even bigger economic impact across the state (California Ocean Science Trust, 2016).

Understanding the abundance and species types of phytoplankton in coastal waters enables us to better predict when these harmful algal blooms (HABs) might

occur, so that we have an early warning system and can work to keep beaches, people and our food safe.

CeNCOOS

The Central and Northern California Ocean Observing System (CeNCOOS) is a source for data, information, and expertise to inform wise use of the ocean and coast in Central and Northern California. CeNCOOS aims to enable sustained and coordinated measurements, model nowcasts and forecasts as well as integrated data products to inform decisions about the ocean off central and northern California. CeNCOOS is one of 11 regional parts of IOOS – the US Integrated Ocean Observing System working with regional partners to collect and manage data about the ocean off the coast of central and northern California. As part of this, CeNCOOS communicates at many levels, including regional data collectors and users, regional government and decision makers and nationally through IOOS. Key areas of research include ocean acidification, the development of standards for biological data, and phytoplankton and HABs.

CeNCOOS is collaborating with colleagues at UC Santa Cruz, the Exploratorium in San Francisco and the Seymour Discovery Centre in Santa Cruz to deploy in-situ flow cytometers to monitor phytoplankton. This new technology, combined with machine learning algorithms, will enable real-time detection and identification of phytoplankton species in San Francisco Bay and Monterey Bay. Images can be powerful tools for outreach, and machine learning and robotics are becoming regular news items internationally as technologies such as self-driving cars emerge. Ongoing work with CeNCOOS and its partners is outlining the data processing workflows to automatically classify phytoplankton and HAB event characteristics which can then be scaled up to the greater network of IOOS supported IFCB systems nationally (Fig. 1). Therefore, there is great potential to pair educational materials with the expansion of these systems.

Figure 1. Map of NOAA supported IFCB deployments. The Catalina Sea Ranch system is being moved to Moss Landing. (Marc Suddleson, NOAA)

PROJECT VISION

Safe beaches, safe seafood and safe coasts benefit the millions of coastal resource users in California each year, as well as supporting aquaculture, fisheries and related industries. HABs threaten to disrupt these.

A tiered, multifunctional exhibit has been designed to support communication about phytoplankton and HABs, as well as the work that CeNCOOS does to monitor, predict, and improve management decisions about HABs. The exhibit elements are modular, to enable different parts to be used in isolation or in combination with alternative engagement activities. This is designed to facilitate interactions between scientists and the public, for example at open houses or similar community events.

The modules include physical objects (models of phytoplankton), physical activities (coloring and matching activities) and displays (including posters and digital displays of live data views). Together, these can engage a range of participants with phytoplankton and HABs. The modules can then be readily adaptable to various uses. For example, initial uses are expected in Open House events throughout CeNCOOS, the Monterey Bay National Marine Sanctuary Exploration Center and other Sanctuary displays. This will be facilitated by scientists or CeNCOOS staff, with written signs and posters to signpost the content to participants.

MATERIALS AND METHODS

DEVELOPMENT PROCESS

A group problem solving exercise was run with CeNCOOS staff to help determine the scope of the project and a brief for the activities (Phytoplankton Exhibit Brief). Three key questions were asked, and answers collated to reveal similarities and themes;

- What are we trying to communicate?
- Who are we communicating with?
- How could we do this?

This fed into the Phytoplankton Exhibit Brief, which identified the target audience, messages and modular activities required. Prototypes for selected module elements were developed and trialed at the MBARI Open House weekend, on Saturday July 21, 2018. Activities trialed included posters, a sorting activity, 3D model and soft toys handling, and digital displays including (near) real time IFCB phytoplankton data.

Since then, informal interviews have been conducted with local engagement and subject experts to discuss the activities in the hope that they will be used in the future. The activities are available through CeNCOOS.

Following the open house and interviews, the activities have been refined to produce a selection of different activities and objects that can be used to engage a range of visitors with phytoplankton and HABs as well as the work of CeNCOOS in collecting data and making them available.

RESULTS AND DISCUSSION

AUDIENCE

The target audience for the exhibit is the general public, particularly families with children. The multifunctional exhibit is designed to have different elements that attract different sections of this audience, enabling each use to be tailored to a

more specific audience. For example, coloring sheets and soft toys to attract younger children, and 3D-printed models and live data displays of phytoplankton for an older or more scientifically literate audience.

MESSAGES

The exhibit communicates a range of messages about phytoplankton.

The main message for the exhibit is:

Phytoplankton are small organisms that are essential to healthy oceans, but certain species can bloom and cause problems for humans and for ocean ecosystems. CeNCOOS is working with researchers to develop tools to identify these harmful algal blooms and make predictions about harmful algal bloom events.

NARRATIVE

The main message is split into four sections on the printed information provided (posters and signs):

- What are phytoplankton?
- Why are they important (to me)?
- What are Harmful Algal Blooms?
- Why do we study them? How do we study them?

This exhibit uses a layered approach so that audiences with a range of knowledge about phytoplankton can still engage with the content. The narrative assumes no prior knowledge of phytoplankton, but visitors (and scientists delivering the content) can move between sections or skip through elements that they know.

LEARNING OUTCOMES

Visitors using the exhibit will show one or more of the following learning outcomes (based on the Generic Learning Outcomes for informal learning developed by the Arts Council, UK):

Knowledge and understanding	Visitors will: ● Understand that phytoplankton are important for a healthy world but can cause harmful events: we can monitor this ● Understand that the ocean is constantly changing and that we need to observe these changes – CeNCOOS does this
Skills	Visitors will: ● Build on skills in interpreting and reading data
Enjoyment, creativity and inspiration	Visitors will: ● Feel inspired by the beautiful shapes and patterns of these microscopic organisms ● Enjoy looking at the data and discovering what we know about our ocean
Attitudes and values	Visitors will: ● Think about the impact we are having on our oceans
Activity, behavior and progression	Visitors will: ● Visit the CeNCOOS website ● Feel inspired to find out more about the ocean in general or phytoplankton specifically

ACTIVITIES DEVELOPED

3D phytoplankton models

Accurate 3D-printed models of various species of phytoplankton were produced, including *Dinophysis*, *Alexandrium* and *Cheatoceros*, although these are not to scale compared with each other. These 3D models work well as attractors – to encourage people to engage with the activities. They can be used to show the range of different shapes of phytoplankton, or to talk about each species. They provide an alternative way into the content for participants, particularly for younger audiences.

Figure 2. Accurate 3D-printed models of phytoplankton, from left to right: *Ceratium*, *Alexandrium*, *Pseudo-nitzschia*, *Dinophysis*. Produced by Foundary IO from 3D Hubs.

Soft toys

Soft toy phytoplankton and other animals that make up an ocean food web, including *Alexandrium* and *Anabaena* (phytoplankton), and *Euphausia superba* (krill larva), work well as attractors to engage younger children with the content. These can be used as hooks to talk about phytoplankton and their predators, or ocean food webs more broadly. They can also be used as a food web activity, by asking visitors to make food webs from the different soft toys.

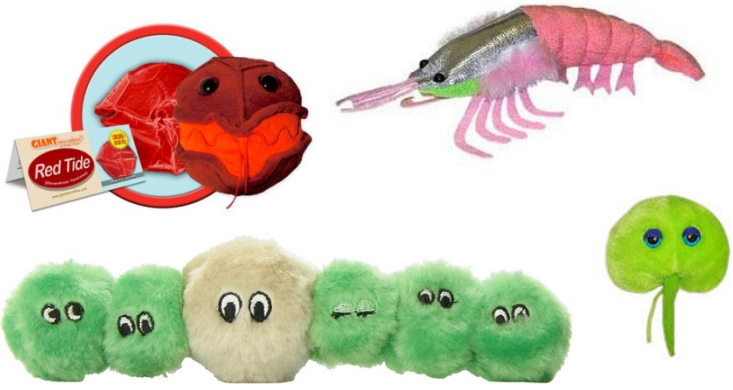

Figure 3. Soft toy phytoplankton and zooplankton worked well as hooks to engage visitors to MBARI's Open House. (giantmicrobes.com)

Phytoplankton and HABs posters and signs

Graphic posters and signs explaining briefly about phytoplankton, HABs and ocean observation followed the narrative listed above: what are phytoplankton, why are they important, what are Harmful Algal Blooms, and why/how do we study them. The images on these can be useful for showing visitors, for example, showing the IFCB or an image of red tides. At MBARI's Open House, these were used by a minority of visitors who preferred to read information rather than speak to a member of staff, and so provide an alternative way to engage with the content.

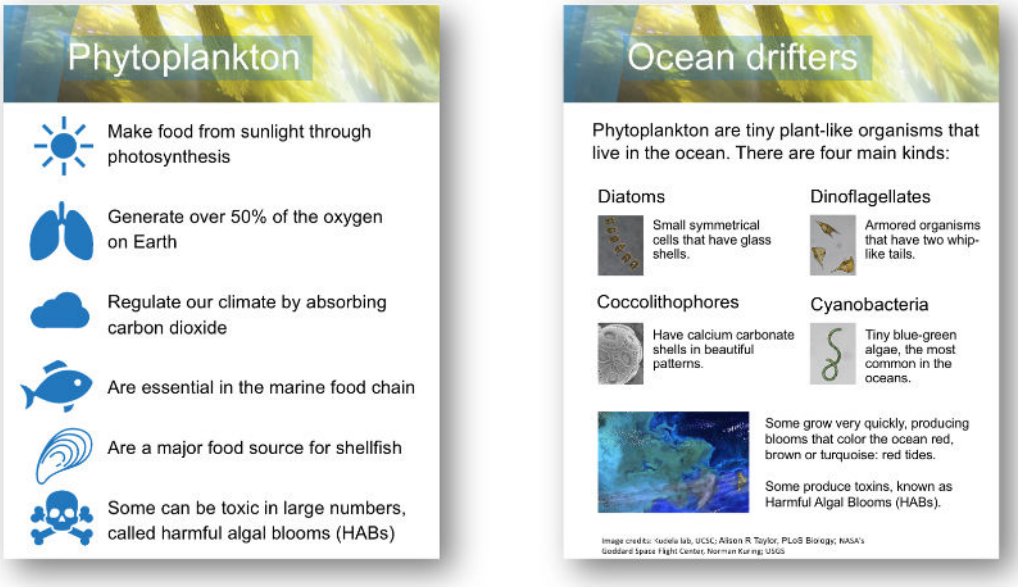

Figure 4. Posters about phytoplankton, HABs and monitoring produced in PDF and .ppt formats so they can be edited or reprinted in future (selection of several produced).

Phytoplankton data view

A live and interactive webpage displaying up-to-date data from the IFCB at Santa Cruz wharf (run by the Kudela lab, UCSC) enables facilitators or visitors to click through the data and see which phytoplankton are more common on particular days in Monterey Bay. This live data view can also be used in conjunction with the phytoplankton matching activity, so visitors can use the cards to identify the species of phytoplankton seen by the IFCB. Searching for tags enables

participants or facilitators to quickly find specific days that have been tagged as having certain species, for example, *Pseudo-nitzschia* or *Ceratium*.

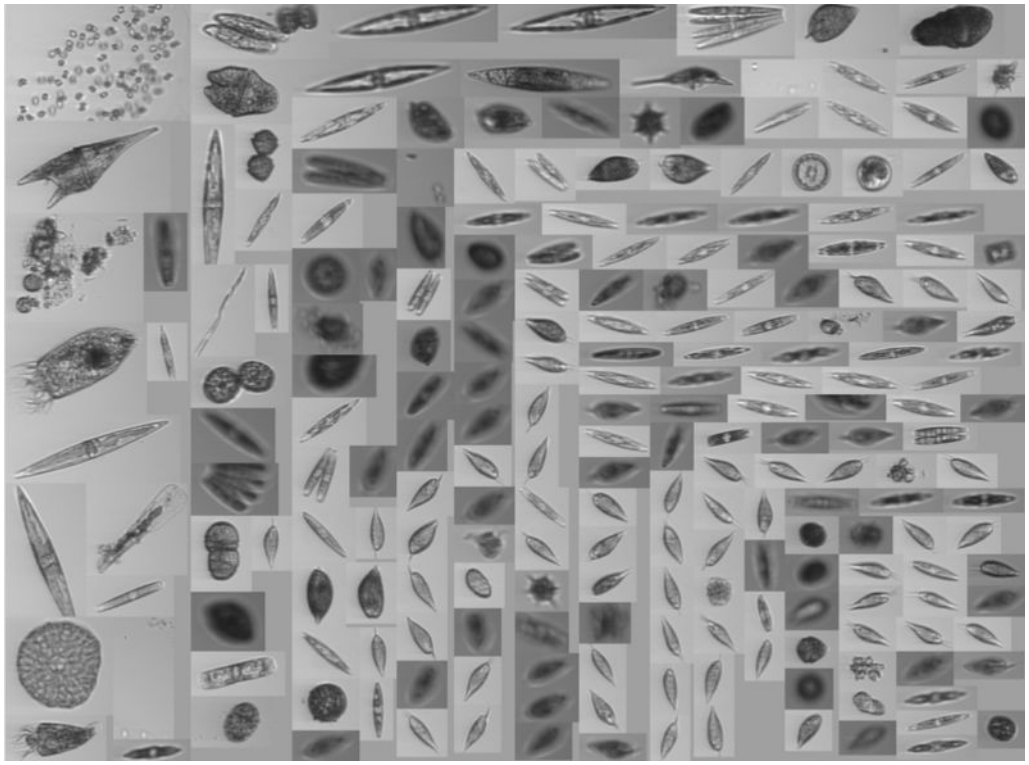

Figure 5. Data from the IFCB at Santa Cruz wharf – August 6, 2018.

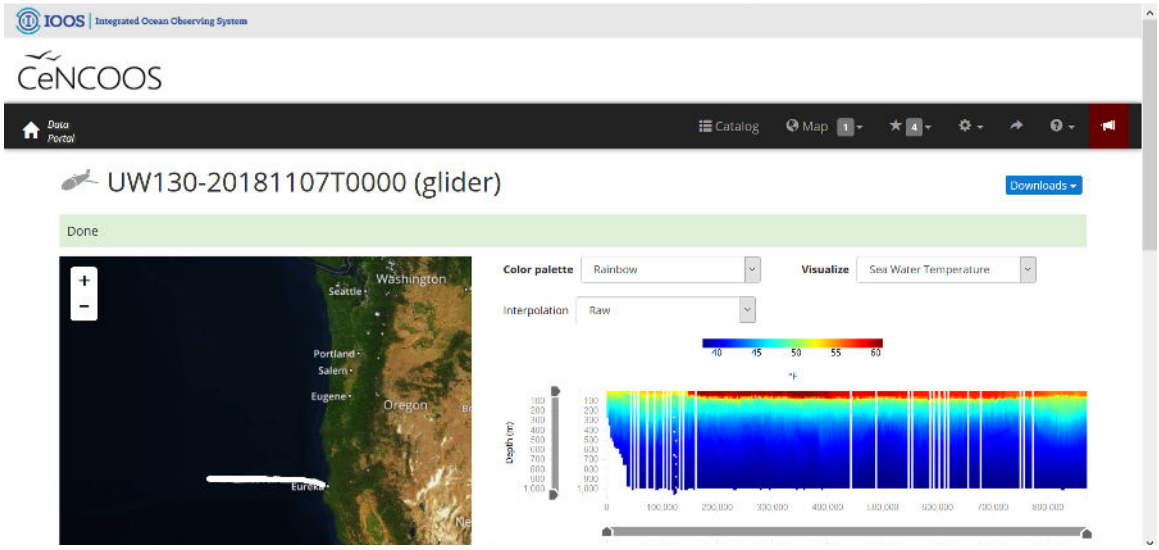

Figure 6. The CeNCOOS data portal, displaying data from a glider.

Phytoplankton matching/identification activity

Activity cards were produced featuring beautiful microscope images of phytoplankton as well as black and white images from the IFCB, along with key facts and information about each phytoplankton species. Visitors can match the microscope images to the IFCB images or this activity can be used with the 3D models to identify the different models. The species of phytoplankton on the cards were chosen to represent a range of species common in the Monterey Bay area. They represent the different types of phytoplankton groups (diatoms, dinoflagellates, coccolithophores and cyanobacteria) as well as harmful and non-harmful species. The matching game works well both to attract participants because of the beautiful images and for participants to start to talk about identification and the issues around this. The activity can be used to talk about harmful phytoplankton species, how we currently monitor these (with plankton nets) and how IFCBs can automate this process and make it easier and quicker to monitor phytoplankton activity.

Figure 7. Matching activity cards can be used to engage visitors with the different phytoplankton species.

Phytoplankton coloring sheets

Coloring sheets were produced for some of the key phytoplankton species as well as some of the more interesting-looking ones, which can be printed on demand. These were made by converting original illustrations by Corlis Baranyk from the Kudela lab, University of California, Santa Cruz (UCSC) into computerized line drawings on Adobe Illustrator. These can be used to engage visitors, particularly younger audiences, in activities relating to phytoplankton. Coloring sheets can be useful when talking about identifying species and the different features that they have to audiences of a range of ages. Having a take-away from an interaction, like a coloring sheet, is a simple way to keep visitors engaged in a topic or encourage them to continue an activity at home.

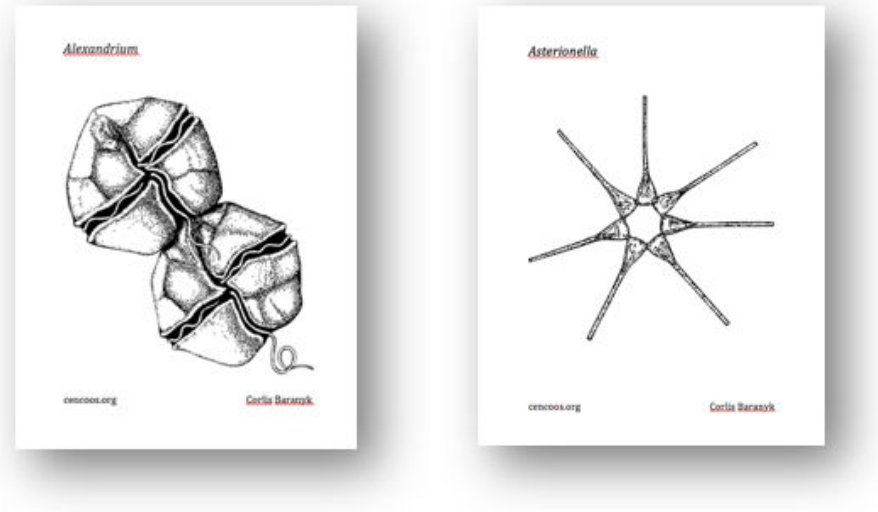

Figure 8. Coloring sheets produced from original illustrations by Corlis Baranyk.

OPEN HOUSE

The trial activities ran successfully at the MBARI Open House event on Saturday July 21, 2018. Over a thousand people visited MBARI on this day, and a good proportion of them were attracted to the CeNCOOS display, with a constant stream of people of all ages engaging with the activities and displays over 5 hours.

Several activities and prototypes were tested, including: 3D printed phytoplankton, soft toys, a sorting activity, posters, and data displays. These were all successful to some extent, with the following recommendations that fed into development of the final activities:

- The 3D printed phytoplankton worked well as a hook for people to start thinking about phytoplankton shapes and how to identify them. A greater variety of 3D printed plankton would help.
- The soft toys worked well to hook in families and small children. This could be even better if it was used as a food web activity, to ask visitors to create a food web (e.g., phytoplankton, shrimp, whale).
- The sorting activity worked but it was harder to get people to start this activity. An alternative approach was tested, where visitors were asked to match the 3D objects to the phytoplankton cards. This contributed to the final development of the matching activity. An alternative activity was developed, matching IFCB images to microscope images of phytoplankton.
- Talking to people about things they know was particularly useful to engage them with the content, reinforcing that making ocean science relevant to people is important when engaging them. For example, most visitors knew about shutting down the Dungeness crab fishery in 2015 as a result of a *Pseudo-nitzschia* bloom.
- Using words and phrases that people have heard of is important, e.g. red tides instead of harmful algal bloom.

Figure 9. Alisa Crisp talks about the importance of plankton to MBARI open house attendees, July 21, 2018.

ALTERNATIVE ACTIVITIES

The activities described above can be used in conjunction with other suggested activities for a fuller experience. In particular, the use of live phytoplankton specimens helps to engage visitors further, either using a digital microscope viewer and screen or a standard laboratory microscope.

At MBARI's Open House, having a piece of the technology used to collect the data was helpful as a hook to draw people in, in this case, a glider. Plankton nets, IFCBs, microscopes, AUVs and gliders would all work to help visitors engage with the collection of the data.

Figure 10: Spray glider acting as an attractor at the CeNCOOS stand at MBARI's Open House, July 21, 2018.

With more time or resources, fun-fair style games could be used. For example, a Splat the Rat-style fun fair game could be tweaked to mimic the IFCB taking an image of a phytoplankton; a 'Capture a Plankton' game. The facilitator challenges visitors to capture a plankton by hitting it with a bat as it reaches the bottom of an opaque tube, a physical game to explain how the IFCB takes images of phytoplankton.

Figure 11. Splat the rat fairground game, which could be adapted to mimic the IFCB imaging phytoplankton. (Better Fundraising Ideas, 2018)

Alternatively, images of various phytoplankton could be attached to magnets in a plankton-themed fishing game (for example, Carnival Savers, 2018) where participants have to 'fish' for phytoplankton and reveal whether or not they are harmful.

Figure 12. Example carnival fishing game that could be adapted to include phytoplankton. (Carnival Savers, 2018)

FUTURE RECOMMENDATIONS

These resources will be used by CeNCOOS staff, PIs, stakeholders and other local and regional educators to engage people with phytoplankton and HABs. Using the activities and resources in conjunction with the alternative activities listen above could shift the focus of the activity to suit the audience, or act as a bigger hook to attract participants (for example, a fun fair game).

Additionally, a digital and interactive data view of phytoplankton data could be produced to support the communications activities. This could include the live predictive model of HABs along the California coast (C-HARM), images of phytoplankton species from the IFCB, live data visualizations and 3D digital representations of the phytoplankton species.

A similar suite of activities could be developed around different CeNCOOS themes, for example, ocean acidification, El Niño and La Niña, or the different technologies used for ocean observing.

CONCLUSIONS AND RECOMMENDATIONS

Over 10 weeks, I have produced a series of activities and resources which can be used together to engage the public with phytoplankton, HABs, and the work that CeNCOOS does to monitor these issues.

The activities are easy to transport and set up and can be used by CeNCOOS staff and stakeholders to engage people with phytoplankton and HABs broadly, as well as the monitoring work that is being done along the coast of California.

Digital versions of the activities, products and instruction sheets are available through CeNCOOS for stakeholders or other interested educators and science communicators to use.

In the future, more engaging and resource-heavy activities could be produced, for example, creating a ‘splat the rat’ style fairground game in the form of an IFCB capturing images of cells. Alternatively, activities could focus on a different area of CeNCOOS activity – for example, the issue of ocean acidification.

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