The Ocean’s Recipe for Success

Summary:
About 70% of the Earth’s surface is covered in ocean which many living organisms, including humans, depend on for their survival. The health of the ocean is in jeopardy because of the change in its recipe due to additional carbon dioxide that is dissolved into sea water from the burning of fossil fuels. This change in the ocean’s recipe disrupts the food web by throwing it out of balance. We can reduce our carbon footprint to help maintain a healthy ocean now and into the future.

Value:
Interdependence – The Earth is a blue planet and the ocean gives us life by providing us food.
Stewardship – It is our responsibility to take care of the ocean now so that it remains healthy for future generations.

Simplifying models – the ocean’s recipe

Causal chain – burning fossil fuels emits CO_2 → the ocean absorbs CO_2 → the ocean becomes more acidic → calcium carbonate is not readily available → calcifying animals are unable to build their shells/skeletons → the food web is disrupted

Solutions:
Community Level Solutions – Local farmers’ markets; CSAs
Individual/Household Solutions – Go meatless one day a week (Meatless Mondays; www.meatlessmonday.com)

Objectives:
- *Guests understand and value the importance of how human activities influence the health of the ocean ecosystem.*
- *Guests understand and value the importance of how changes in the ocean ecosystem affect marine life and human life.*

Key Messages:
- *Oceans play a vital part in the Earth’s ecosystem and are a home to marine life that contributes to the health of human life on our planet.*
- *Human actions are changing the ocean’s chemistry which is causing life below the surface to suffer and food chains to collapse.*
- *We want to make sure that marine life remain healthy for generations to come.*
- *Together, we can work as stewards of our planet’s oceans and make changes to leave the world a better place for our children.*

Materials:
- Globe
- Chemical equation visuals
- TUMS
- Vinegar
- Flask 1/3 full with bay water
- Beaker
- Straw
- pH probe
- artifacts of affected animals
- PowerPoint slides

Presentation Write-up:

Slide 1

Introducing the presentation

If you came to the Aquarium today because you love the ocean then come on over to the Bay Lab and learn about the ocean's recipe for success.

Slide 2

Setting up the value

Before we get too much into the ocean's recipe, let's take a look at this globe and consider this: Who can tell me how much of the Earth is covered by the ocean? It is about 70% of the earth's surface. So in a way, we live on a blue planet rather than a green one. Well, the ocean is full of life with many different types of plants and animals that depend on each other for food and habitat. Each animal plays an important role in maintaining the balance of the marine communities that they belong to. In front of me are some examples of animals that are important to this balance: abalone, mussels, snails, and corals. Though you see them as individuals here, they are a part of a whole system working to keep the health of marine life in balance.

Slide 3

The ocean's food web – interdependence and future generations

Part of this balance is a functioning food web that sustains living things above and below the surface. All of the plants and animals in the ocean are part of an interconnected food web—and people are part of that web too! Let's explore the connections. I want to introduce you to the "potato chip of the sea," a pteropod, a swimming snail just half an inch across. These tiny animals are a big part of the marine food web: in fact, many fish that we eat, like salmon, rely on pteropods as their main meal ticket. Salmon and other fishes in the ocean provide about 25% of the protein we eat worldwide (Drivers of Change: Oceans), so anything that happens to these little pteropods can travel up the chain to us. We have an opportunity to make sure that our marine ecosystems, from the big salmon to the tiny pteropods, remain full of life for generations to come. We will see the "potato chip of the sea" again so don't forget about him…

Slide 4

The ocean's recipe – calcium carbonate

And right now animals like the "potato chip of the sea" and these animals right in front of me are having trouble surviving on our blue planet. Animals like snails, sea stars, coral reefs all have something in common. Just by looking at and feeling these artifacts can you figure out what they have in common? They each have hard outer shells made from calcium carbonate, an important ingredient in the ocean's recipe for success. What are some other ingredients that make up the ocean's recipe? Salt and water are two important ingredients to this recipe.

Slide 5

The ocean's recipe – carbon dioxide

Another ingredient is carbon dioxide. Carbon dioxide (CO_2) is what animals like us breathe out. A fancy word for breathing is respiration (seen on the slide). The CO_2 emitted through respiration is either "eaten" by plants or absorbed into the ocean (I know, hard to imagine something invisible dissolving in the ocean. But think of sparkling water, that is CO_2 in a liquid). As animals breathe out CO_2, plants and the oceans take it in creating a nicely balanced cycle. **However, there is another source of CO_2 entering the ocean that is causing its recipe/chemistry to change.**

Carbon dioxide is also created through the burning of fossil fuels like oil and coal for fuel and electricity. Each year the ocean absorbs approximately 25% of the CO_2 we emit (Understanding Ocean Acidification website). When this extra CO_2 is absorbed into the ocean it changes the recipe of seawater. It is like adding several pinches of salt into your cookie batter instead of just one; the recipe would be off. The rate at which the ocean is changing is unprecedented in the last 55 million years (Understanding Ocean Acidification website).

Slide 6

Chemical equation and pH probe

So how does this improvised recipe affect our marine food web and these animals? We are going to take a look at this change in the ocean. Carbon dioxide mixes with water to create carbonic acid which disassociates to form hydrogen ions and bicarbonate. Hydrogen ions are what make something acidic. Let's see what happens when we add carbon dioxide into a sample of water. On the graph you'll see that our water sample is at a pH of about x.x, and as we add CO_2 into the sample it will change. I will need a couple volunteers to come on up and add CO_2 into this sample by blowing into the straws.

As we discussed earlier, when you add more CO_2 to the ocean, the recipe changes. Specifically, the pH changes- that's a measure of how acidic or basic a substance is. This probe is measuring the pH of the water sample. What do you notice? As you can see, when we add more CO_2 into this water sample the water changes and becomes more acidic and the pH is lower. This process is called ocean acidification, a process that we know has increased 30% since the industrial revolution when the oceans started absorbing a greater amount of CO_2 as we started burning more coal and oil for electricity and transportation. (Understanding Ocean Acidification website)

Slide 7

The "frienemy" (hydrogen ions) steals carbonate from calcium and TUMS/vinegar demo

Okay so now that we've seen the effects of adding CO_2 into the water, we are going to do a demonstration of how a more acidic ocean will affect marine life (and its food web) like the ones on the countertop. When carbonic acid dissociates into hydrogen ions and bicarbonate the extra hydrogen ions (the "frienemy") steal carbonate from calcium which leaves very little calcium carbonate available for many animals to form their shells and skeletons. Do you remember what these organisms all had in common? Yes, a hard outer shell. This outer shell is made up of calcium carbonate. What inside our bodies contains calcium? And like our bones, these animals need their calcium carbonate "skeletons" for their structure and to stay strong.

For this demonstration, we are going to see how a more acidic environment affects a mystery item made of calcium carbonate. We are going to use a very acidic mystery liquid for this demonstration, it is more acidic than ocean water. Let's do a smell test to figure out what the mystery liquid is that we will be using for this demonstration. It's vinegar! We are also going to use a mystery substance to demonstrate a shelled animal. Here is a household item you probably have in your medicine cabinet that is made of calcium carbonate. You can even check the active ingredients to confirm!

All right, let's test and see how our calcium carbonate does in a very acidic environment. Do you guys have a prediction for what will happen? What we can see immediately is that the calcium carbonate is dissolving in this acidic environment.

Slide 8

We can see the effect on calcifying organisms like pteropods

Slide shows a pteropod breaking down in a more acidic environment

Like the antacid tablets that dissolve in this very acidic environment, animals with calcium carbonate structures are finding it harder to keep their shells intact because of the change in the ocean's recipe. Scientists are already observing a drop in the pH of surface ocean. If we continue on the expected course for fossil-fuel use and rising atmospheric CO_2, over the next century, ocean acidification is expected to reduce surface ocean pH by 0.3-0.5 units, faster than ever in the past 650,000 years, drastically changing the ocean's recipe for success. (Drivers of Change: Oceans)

Silde 9

It is our responsibility to take care of the ocean for all the living things that depend on it
It is important to be aware of the amount of carbon dioxide that is emitted into the atmosphere because the ocean absorbs a lot of it and changes the chemistry. We know that the ocean provides life for many living organisms that create the food web that we are a part of as well. If these animals, many of which (like the potato chip of the sea) are at the bottom of the food chain, end up becoming weaker, then we will be weaker as well.

Slide 10

Reduce food miles, buy local
Luckily, we have the opportunity to be a part of a movement that will help slow down ocean acidification, and it directly relates to the foods we eat. If you support local farmers by purchasing food at farmers' markets then you are buying food that has not travelled many miles which emits lots of CO_2 into the atmosphere that is absorbed by the ocean. Buying fresh and buying local will decrease your food miles and CO_2 emissions keeping the ocean full of life for generations to come.

Resources
Channel Islands National Marine Sanctuary – Understanding Ocean Acidification: http://cisanctuary.org/acidocean/

Mission Blue – Drivers of Change: Oceans (A set of cards identifiying some of the leading drivers of change that affect the future of the oceans)

Woods Hole Oceanographic Institute – FAQs about ocean acidification: http://www.whoi.edu/OCB-OA/FAQs/

Background information

The increase of carbon output is affecting not only our atmosphere, but our oceans as well. Oceans are sometimes referred to as carbon sinks, a helpful buffer against global climate change. In fact, oceans absorb approximately 1/3 of all CO_2 emissions. However, once dissolved in the ocean, CO_2 still makes a significant impact. It binds to water molecules to produce carbonic acid (H_2CO_3), which can then disassociate into H^+ and HCO_3 (bicarbonate).

$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3$

So, what does this mean? More H^+ ions mean a lower pH, or, in other words, a more acidic ocean. PH is measured by the number of H^+ ions present in a solution and can range from 1-14, with 1 being the most acidic and 14 being alkaline (basic). Distilled water is neutral, with a pH of 7.0. In pre-industrial times, ocean water had a pH of 8.2. Today, the ocean's pH is 8.0, and it is projected that if we maintain our current CO_2 emissions, pH will drop to 7.7 by the year 2100. If that does not seem overly drastic, consider this: a drop of one pH unit represents a 10-fold increase in acidic H^+ ions.

An increase in H^+ ions creates two problems. Not only is the ocean's pH dropping, which can cause the corrosion of the shells and skeletons of many marine animals, such as snails and corals, but the extra H^+ ions also tie up carbonate (CO_3). When available, carbonate can combine with calcium to form calcium carbonate ($CaCO_3$), an important compound used by many organisms as a building material for their shells and skeletons. Currently, coralline algae, corals, some species of snails, and many important planktonic species are being affected the most drastically by the reduced availability of this important building compound. Perhaps the most abundant organism in decline are coccolithophorids, a type of phytoplankton covered in calcium carbonate plates. Their decline greatly affects the marine food chain by reducing the amount of food available to filter feeders and other primary consumers. As corals and coralline algae disappear, so do the many marine animals that rely on them for habitat.

While we can talk definitely about the effects of more acidic water and less available calcium carbonate on certain species, we also know that the repercussions of dissolved CO_2 in our oceans do not end there. A change in pH can affect respiration and reproduction. It can cause stress to organisms, and affects the nitrogen cycle. Most aquatic species are adapted to a specific range of pH, and the current anthropogenic change is happening more rapidly than any natural flux ever has, including a low pH interval some 55 million years ago, known as the Paleocene-Eocene Thermal Maximum, which caused a major marine die off. The effects of our carbon emissions on the ocean will therefore be amplified by the simple fact that organisms do not have time to evolve with the change.

AQUARIUM OF THE BAY AT PIER 39

Ocean's Recipe for Success
Bay Lab Visitor Program Script
Aquarium of the Bay
www.aquariumofthebay.org

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