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The Trouble with Oil

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Rationale

As a teacher and resident of New Haven for the past 22 years, I have had an increasing concern about the future of the community and its environment. My goal has been to educate New Haven youth about their local ecosystems and their role in preserving the integrity of their natural surroundings and resources for generations to come. I represent a tool to guide them through a series of discovery activities that provokes thoughtful analysis and leads to careful decision making concerning everyday needs and long term lifelong goals and dreams.

With a weak economy, it is certainly no surprise that fuel costs and energy sources are often front-page news. People are struggling to heat their houses and keep their cars on the road. More talk of energy reform is hopeful in the near future. Residents wait for incentives to switch to alternative energy sources and make us less dependent on non-renewable fuel sources such as oil. We all hope that this will lead to a reduction in greenhouse gases and perhaps slow down the effects of climate change. The threat of oil disasters such as the BP spill in the Gulf begs to be a forgone memory of our past.

The Sound School Regional Aquaculture Center literally sits on the shores of New Haven Harbor which leads into Long Island Sound. Tankers carry fuel in and out of the harbor to and from fuel tanks stored in the inner harbor. Oil companies run trucks with this fuel to local residents and businesses. The United Illuminating stack, visible from the campus, is a reminder that it burns that oil to provide its residents with electricity while adding to the local pollution problem.

The students at the Sound School are fortunate to have easy access to such a wonderful educational classroom as Long Island Sound. They have the use of a fleet of boats for study and for play. They learn to operate a variety of vessels from small traditional sail boats used for oystering, to rowing gigs, to a large passenger vessel that serves as our science research vessel. Our students have a great love and respect for this natural resource and are concerned about its future "well being". The harbor and Sound will be the setting for implementing what I hope to accomplish with this project.

The goals of this curriculum are to introduce the students to the world of oil and the issues surrounding it. They will first gain an understanding of how oil is located drilled harvested and transported to their homes.

Then they will explore the environmental challenges of off shore drilling and take a close look at the Deepwater Horizon Spill and its effects on the ocean ecosystem and its coast. They will do this through various directed labs, research and student driven activities. Finally, they will start a long-term study relating the burning of oil and other fossil fuels and the connection to changing parameters in the marine environment.

Background

The Where, What and How of Oil Drilling

When many of us hear the word oil, it conjures up for us a picture of Jed and Granny in the opening of the show the "Beverly Hillbillies". (1) If only things were that simple and wholesome! The process of locating, drilling, extracting and refining oil is a long, time-consuming, energy- demanding process. The various steps of this process and the resulting use of an array of petroleum products, raises havoc with the earth's fragile environment.

The meaning of the word petroleum translates to "rock oil" or "oil from the earth". Oil results from decaying marine organisms that formed into anaerobic sedimentary layers between ten and six hundred million years ago. Anaerobic bacteria decomposed the detritus into rich organic material, which blend with sediments to form these layers of shale. As these layers form and build, heat and pressure transform the organic material into crude oil and natural gas. The oil flows into more porous rock called the reservoir rock, where the oil and gas become trapped between more impermeable types of rock called cap rock. Geologists are skilled in finding oil based on their knowledge of how these rocks form and looking at surface rock features and soil types in conjunction with satellite images. More recently, the technique of finding flowing oil through the use of equipment that measures the earth's magnetic field has been employed. The reasoning is that the movement of the oil creates a change in the magnetic field. The most recognized method of detection of oil is through seismic activity. Everything from explosives to air guns are used to create a shock wave through the buried rock layers. When the waves are returned to the surface, seismologists interpret them to help the geologist determine if the site is a feasible drilling site. (2)

Once a site has been deemed a drilling site and given coordinates, the legalities of the use of the land or off -shore sites must be dealt with. This may be followed by required or requested studies to be completed to determine what the impacts might be on the environment from the drilling process and all of its associated activities. Roads to the site are built and plans for any by-products of the operation must be made. In the case of land drilling, a water source must be located and available due to the fact that it is essential in the process of drilling for oil on land. To prepare for the drilling, a cellar is dug around the actual drill hole to make room for the workers and their equipment. (3)

In the case of off –shore drilling, the sensitivity of approval of a site may be more intense. This is where the Exclusive Economic Zone (EEZ) comes into play. This designated area which is a two hundred-mile border from the shores edge out to sea, was claimed by the United States in 1983. Other countries followed suit; being granted the same privileges based on international sea laws. The U.S. federal government manages these areas through the Bureau of Ocean Energy Management, Regulation and Enforcement, which leases these areas to companies. The companies also pay royalties for the oil they harvest from the sea. (4)

The Rig (Use fuel to get fuel.)

Oil for energy cannot be extracted without using a substantial amount of energy. The power system, which drives the mechanics of the rig, is powered by electricity, which is provided by a generator, fueled by diesel engines. A drill bit, which is appropriate for the type of rock, is located at the end of the drill, which works in a rotating motion. The drill pipe is surrounded by a collar, which puts weight on the drill bit. The drill hole is lined with cement to prevent the hole from collapsing and the mud used for the drilling to move through the system. The "mud" is water and clay mixed with chemicals and "weighting materials" that help to move the rock to the surface. A derrick is the structural frame that holds the drill, and last but not least the blowout preventer consists of valves that seal the high- pressure lines and vent excessive pressure to prevent a blowout of gas or oil that will rise to the waters surface as it did at the Deepwater Horizon site, causing a deadly fire. To extract oil, a pump is installed after the rig is removed. Offshore drilling comes with increased risks. Mobile Offshore Drilling Units (MODU) are used to dig the original well and then some of them are converted to pumping production rigs. (5)

Oil Products

The crude oil obtained through drilling is then transported to refineries to be converted into various petroleum products. When crude oil is refined a 6% product gain is obtained through the process. A barrel of refined crude oil usually results in a variety of products including diesel and jet fuel, gasoline and other distillates. Harvested oil is put through hot furnaces where it separates into liquids and vapors which further separate by weight in distillation towers. The heavier products are then manipulated to produce a lighter more valuable product, like gasoline. After these conversions, various degrees of final treatments are performed depending on the desired product. These products are then transported through pipelines, by tankers and land transportation vehicles. Each one of these transportation methods opens up the possibility of oil spilling into various environments. (6)

History of Gulf Oil

The oil industry in Louisiana intensified in the early 1900s. Fisherman traded their jobs for money in the field of oil, with little education. They shared the Gulf grounds with the oil platforms to make their living. Oil and gas were plentiful due to the large, long-term sediment deposits from the Mississippi River and the salt layers of the Gulf. Challenges associated with moving offshore made the progression slow and costly. Concerns ranged from everyday issues such as the work environment to acute situations including blowouts and platform destruction as a result of storms.

As demands for oil skyrocketed following the close of fuel rations at the end of World War II, the drive for technological advancement soared. (7) Exxon pioneered the use of "jackets" on the platforms, which resulted in a stronger structure, less likely to be damaged by the elements. Mobile submersibles appeared in the 1950s, and were leased per Diem, resulting in the development of two of the Gulf's biggest oil fields. (7A) Off shore wells were proving to have higher returns than their on shore partners. By the late 1950s, advancement into deep waters was delayed when the reality of these rigs not handling conditions in deeper waters became a reality. In the early sixties a "floating drilling platform" was introduced by Shell. The" semi-submersible" was expected to allow exploration up to six hundred feet deep. Shell opened up the industry by sharing their technology. This resulted in vast tracts of land being leased by many companies in search of a fortune in oil. The Gulf's total harvests rose from approximately 350,000 barrels/day in 1962, to 915,000 barrels/day in 1968. (7B) But as the end of the 60s approached, leases were not as productive and it become more and more difficult to make a decent profit with oil bringing in such a low price per barrel.

As the race to bring in product intensified, the focus on safety blurred. Mobile units meant more potential for accidents. Inspections were not routine due to lack of money and inspectors. Lack of equipment inspections meant more frequent accidents. The blowout of a California well in 69 resulted in the Interior Department implementing the first "rules" controlling the leasing of land in areas that the department deemed environmentally risky. (7C) As more accidents occurred, more revisions were made to these rules. More inspectors ere hired and an inspection program was put into place with new guidelines and standards for mobile drilling. Through the 70s and 80s the number of blowouts remained constant, but the severity of the blowouts lessened. The reduction in the number of explosions meant fewer injuries and deaths. (7D)

In 1973 the OPEC oil embargo inspired domestic companies to further develop offshore sites. In 1975 Shell developed a new technique allowing them to drill in 1000 feet of water. But in 1980 the average drilling depth was still only 200 feet. Many of the new leases did not produce expected results. (7E) Then geologists discovered "turbidites" or "mini-basins" of oil at the edge of the continental shelf and predicted offshore basins to be larger in volume. These findings prompted the Department of Interior to launch a system of "area-wide offshore leasings". (7F) But by 1986 oil prices hit rock bottom at $10/barrel due to several years of citizens slowly reducing their dependency on oil as a response to peak prices in the early eighties. (7G) With a lack of funds for further exploration, Shell brings on British petroleum (BP) as a partner in a major project. (7H) As technology advanced in techniques and materials, drilling capabilities increased by thousands of feet and oil flowed from individual deepwater wells at rates of tens of thousands of barrels/day. By the late 90s, one third of the Gulf wells were more than 1500feet deep. (7I) In the late 1990s BP became the largest producer in the Gulf. (7J) As wells moved deeper and deeper into Gulf waters, older platforms on the shelf were dropped to the ocean floor with the intention of providing natural reefs for marine organisms. It appeared as though nothing could stop BP's success, but environmental and safety challenges plagued them as they pushed deeper and deeper, the Macondo blowout being the worst accident in the history of Gulf oil.

Activity: Student created Board Game/ from Field to Furnace

The objective of this activity is for students to create a board game through researching what it takes to move oil from its source to their homes, vehicles and area industries. Each group of four students will create a game to be played by four other students.

Then students will demonstrate their knowledge of the drilling, harvesting, refining, transport and use of oil, through successfully going from the start to the finish of the game.

Student Materials

From Field to Furnace/How Oil Travels from It's Source to You

You have been given the challenge of creating a board game that will give your classmates a fun and interactive way to learn about all aspects of using oil as an energy source. Using some or all of the materials below, your group will lead your peers on a journey from an off- shore oil rig, to the refinery and ultimately to "their hometown".

Materials

Cardboard boxes/foam core		assorted colored and white paper	pens/markers
Tape/clear contact paper		old game pieces modeling clay	index cards
Toothpicks	metal wire	foam pieces requested materials, within reason	

First, your teacher will arrange the class into groups of four. Then decide the role that each member of your group will play in making the game. Perhaps one of you likes to draw, while two of you are more comfortable with researching information on the computer. The fourth member can be an overall organizer or fill in where-ever necessary. Once all of your research is complete, the entire team should work on creating the information cards that will be used in the game. When making the board, remember to be creative! Make it visually appealing and add steps that may make it more of a challenge. You can add structures if you want as long as they are removable. When writing out the information cards that will move players around the board, keep in mind that every team may find slightly different variations of information during their research, so try to provide a range when expressing numeric data. Remember to vary the format and difficulty of the questions on the information cards. Keep in mind that the playing of the game should take four players a minimum of 30 minutes and maximum of 60 minutes to complete. This should be confirmed by your group test playing the game before submitting it. Each member of the class will fill out an evaluation of each game that they play. These evaluations will be submitted to both the teacher and the team members that created the game.

The following topics should be researched and included in the making of the game: geology of oil; history of oil in the gulf; off-shore oil rigs/drilling; refining oil/oil products; transporting oil; oil use/effects of use on environment.

Background on Gulf Spill

Deepwater Horizon/The Macondo Well, "A Hole at the Bottom of the Sea"

Deepwater horizon was a Mobile Offshore Drilling Unit (MODU) which used thrusters, computerized GPS units and manpower to monitor the floating rigs position. (8) It started as an exploration mission and proved to be a well estimating a 50 million-barrel find. The well was then plugged, so the Horizon could go in search of other promising sites. British Petroleum (BP) paid Transocean $525,000 a day to lease the Horizon Rig which cost approximately one million dollars a day to operate. BP was the largest producer of oil in the US.

The Macondo Well Inferno

"Take care of the little things. Pay attention to the stuff that doesn't quite make sense. Don't ignore those anomalies and hope they'll go away of their own volition. Respect the rules. Follow proper procedures. Don't ignore low-probability, high-consequence scenarios. Hope for the best, but plan for the worst."(9)

The Deepwater horizon, Macondo well blow out could be compared to other accidents, where lack of attention to details and a series of mistakes led to such a disaster. The fact that this accident occurred a mile below the ocean's surface made it more difficult to assess the situation let alone initiate a remedy. As oil companies moved further and further off shore, they didn't plan for the reality of a blow out or how to handle it. BP used the same hardware and skills that were meant for shallower waters. Sealing the blowout could cause an underground version that could dump even more oil into the Gulf by tapping the entire reservoir. With such a high profile and massive situation facing the company and its engineers, no one wanted to make another mistake so the oil flowed for weeks and weeks. (10)

It wasn't long before Macondo earned the name, "well from hell". (11) The first rig was damaged by a hurricane in October 2009 and Horizon took over four months later. Drilling was problematic with friable rock and gas pocketing. The original drill hole was abandoned and a new one started. Another indication that this well was a potential trouble was the excessive amount of "mud" needed as a "drilling fluid". (12) This all-purpose fluid helps the driller diagnose potential problems after having run through the well and back again. They can detect gas in the mud, which is actually acting as a counterbalance to its pressure. In the Macondo well, the mud was getting lost in the porous rock, which meant that a lot of time and money was used to make constant adjustments. As it turned out, the reason for the trouble was a non-uniform reservoir of oil. Instead of one large pool of oil, there were several layers consisting of various pressures, which resulted in the uneven utilization and distribution of the mud. It was an engineering nightmare that led to a temporary abandonment of the well. On April nineteenth, workers cemented the well with a lighter weight nitrogen-foamed cement mixture. (13)But many mistakes were made and corners cut when cementing the well. They skipped a "curing process" for the cement, which entails circulating heavy mud outside the casing before cementing. There was also a lack of centralizers used to be sure a proper seal was formed. (14) After the cementing was finished they neglected to conduct a twelve-hour test, called a cement bond log, that would confirm the integrity of the cement job. This test would have detected any gaps in the cement through an instrument that did acoustic readings. Next, a pressure test called a negative test was conducted that would allow the oil to enter the well if the cement plug was not there. If the plug is sealed properly, the oil will not pass. When the crew ran the test, the drill pipe filled with seawater and the pressure did not drop off, as it should. The closure of the pipe caused an immense pressure build up. When they repeated the inspection, the resulting pressure increased. Assuming a gauge wasn't working, they performed a second pressure test on the line connecting the rig to the blowout preventer. This test indicated no problem, even though they still had a high pressure on the drill pipe. (15)

Ironically, several executives from Transocean were visiting the rig for the purpose of safety. (16) As they operated a simulator which put them in the middle of a fake hurricane, gas emerged from the well, entered an engine room and an explosion occurred; then fire. An engineer was in the process of activating the Emergency Disconnect System when the Captain delayed him. This move would have disconnected the rig from the well, slicing the drill pipe and preventing the oil and gas from flowing up. Without knowing who was in charge in this situation, conditions deteriorated until the fire forced most of the crew to evacuate the rig. (17) The blown out well took eleven lives. (18)

Now the race was on to put out the fire and control the leak. There was concern about sealing the well and then the build up of pressure causing an "underground blowout" which would mean the escape of the entire reservoir of oil. (19) Engineers decided there was no other choice but to use a remotely operated vehicle (ROV) to install a "hot stab" into the blowout preventer, triggering it to seal the well. (20) A glitch in the plan was that Deepwater's ROV and the tools were on the burning rig. (21) They could borrow an ROV, but the fire burned on while they searched for the appropriate hot stab for Horizon's preventer. Eventually officials watched as the ROV used the hot stab to seal the well but the pressure gauge confirmed an unsuccessful attempt. (22) A second ROV ship repeated the same mission as the first without success. A third attempt to cut through a trigger pin to activate an "auto shear mechanism" was made, but the grinder could not cut the pin. After repeated tries, the pin was cut but the fire still burned. . In the meantime the rig deck was inundated with seawater and eventually collapsed and sank five thousand feet. The fire gradually subsided and the oil began to disperse. (23)

The Spill

Early reports told the public there was no spill, but the ROV confirmed a leak at the end of the drill pipe. (24) According to the National Contingency Plan spawned from the Oil Pollution Act of 1990, the polluter was responsible for cleaning up the oil with the feds supervising. The National Oceanic and Atmospheric Administration (NOAA) estimated a one thousand-barrel a day leak. So for the time being, there was a confidence that this spill would be handled without huge consequences. They felt that the *Exxon Valdez* spill left them with the experiential knowledge to effectively and efficiently clean up the spill. Skimmers were deployed and dispersants applied to the spill. (25)

By the end of April, the spill covered over 2400 square miles of the Gulf. This would call into question the initial flow rate of the spill. A computer model, developed by Oscar Garcia and based on satellite imagery, calculated that the spill was averaging over 26,000 barrels a day. NOAA on the other hand released in late April their estimates of only 5000 barrels a day. BP engineers estimated a worse case scenario of 60,000 barrels a day, but agreed that NOAA's estimate of 5000 barrels a day was more likely. (26)

At this point the ROV revealed three small leaks. With President Obama announcing to the public that the spill "could take many days to stop", it became a reality that the spill could reach and surpass the magnitude of the *Valdez* spill. As the spill spread, it reached closer towards the shores of Louisiana dealing the residents there their next disaster since hurricane Katrina. There was also the prediction of the oil getting taken by the Loop Current and delivered to Florida beaches and potentially reaching the Gulf Stream. (27)

Seventeen days into the spill an attempt was made to lower a dome called a cofferdam over the leak to stop the flow. It too failed, rising up from the flow of the oil and then sinking to the ocean floor. (28) A new Flow Rate Technical Group now estimated the flow rates between 12,000 and 25,000 barrels a day. (29) Enter Steven Chu, Nobel Prize winner, Secretary of Energy. He called for a team of scientists with the hope of designing a creative remedy for the leak. Weeks passed with blame being passed back and forth between Chu and BP engineers. The estimates had risen to between 25,000 and 30,000 barrels a day. (30)

In June, the *Discover Enterprise* and *Q4000* started to collect 25,000 barrels a day from the blowout preventer and successfully capped in July, the well leaving a spill of 4.9 million barrels over the course of twelve weeks, while off shore drilling's future was thrown into question. (31)

Activity: Timeline of BP Deepwater Horizon Accident

The creating of timelines can be an effective technique used in various area of someone's everyday life. Adults may use them as a record of achieving goals either in their personal life or at work. Students are asked to create them in school to chronicle the history of certain events and then use them as a study guide.

The objective of this timeline is to chronicle the events that led to the blowout of the BP Deepwater Horizon well in the Gulf.

Student materials:

Timeline of BP Deepwater Horizon Accident

As a teenager you have probably kept a journal that chronicles some part of your life. Perhaps it concerns a long-term relationship, a family vacation or a day to day record of your life. Looking back at it may give you insight on how to proceed with some of these life experiences and help you with making choices in the future. Even the simple act of looking back at the chronology of your text messaging may make you stop and think about the next text you send. Most often, in education, timelines are used in history and perhaps science classes, but could be easily used in any area of study. Timelines can cross days or decades when recording historic events. It is critical that historians use these timelines as tools to review the past and help influence future decisions and trends.

The BP Deepwater Horizon accident and resulting oil spill claimed 11 lives and has raised havoc with areas of the gulf coast and its communities. The National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling Report to the President, released in January 2011, was dedicated to the 11 workers that lost their lives on April 20, 2010 as a result of the accident. One of the ultimate goals of the investigation and revealing report is to hopefully prevent a repeat occurrence of such an accident or anything remotely like it.

Your task is to create a timeline that chronicles the events that led to the accident and oil spill of the BP Deepwater Horizon Well in the gulf.

Materials:

Blank paper/poster board, ruler, pencil, markers (Alternative: Timeline Computer Program), Copy of Chapter 1 of "Deepwater; The Gulf Oil Disaster and the Future of Offshore Drilling, pages 1-19.

Procedure:

- Create you're blank linear timeline. This could be something as simple as a horizontal line with established points that will correspond with a time and event.
- Read chapter 1 of the Deepwater report provided by your teacher and record the chain of events of April 20, 2010 in chronological order from left to right
- Correspond what you feel are the most important events leading up to the accident,
- with the time and points on the line.
- After completing the timeline, go back and read it through and see if there is anything

you want to adjust or change. If needed, create a new final edited timeline.

*Remember, the idea here is not to write an essay. Write what is most important in conveying what led to the end result displayed at the end of the timeline.

When you are satisfied with your timeline, answer the following questions:

What did you interpret as the most critical moment in the time line? Why?

What could have prevented this accident?

How can you take what you have learned in this exercise and apply it to your life?

Activity: Remotely Operated Vehicle (ROV)"Undersea Heroes"

Students will observe and perhaps try to operate an ROV owned by the Sound School Robotic and Marine Engineering group. They will compare the use of the ROV in an indoor tank where water conditions are calm and clear, to the conditions in New Haven Harbor/Long Island Sound where conditions are less than ideal.

Activity: Studying Ocean Currents

Possible activity using GIS (Geographic Information System) to study the predicted flow of oil, based on ocean currents.

The Clean-up

The spill leaves BP with an estimated fourteen to twenty three billion-dollar cleanup bill. This does not include the billions of dollars of damage claims that will be rolling in for years to come. (32)A tool called the Oil Budget Calculator was developed by NOAA and the Department of the Interior in order to estimate what percentage of the oil was recovered, burned, skimmed, evaporated, dissolved or dispersed. Seventeen percent of the oil was recovered directly from the well head, five percent burned and three percent skimmed. Twenty four percent of the oil was either chemically or naturally dispersed while twenty five percent of it evaporated or dissolved. That left another twenty six percent as residual oil which became part of the sediment, washed up as tar balls or remained as surface or subsurface deposits. (33)

There were and still remain varying opinions of just how bad the repercussions would be from the spill. The spill discharged more that twenty times the amount of oil created by the *Valdez* accident and the coastal environment was very different. According to a group of scientists interviewed by Time magazine, some of them felt that the severity of the spill might have been blown out of proportion. The oil from the Macondo well was much lighter than the product from *Valdez,* which means it would be more likely to have the properties to allow it to evaporate. This is coupled with the fact that the water of the Gulf is much warmer that that of Prince William Sound. The warmth of the water could also mean that the natural occurring bacteria of the Gulf would do a better job at breaking down the oil. There was also the belief that the flow of the Mississippi may have helped in pushing the oil away from the shore, helping to protect the marsh ecosystem. (34) Mark Ploen, a spill consultant on the Gulf spill who worked on the Valdez accident, supervised response teams that used skimmers to pick up a daily average of fifteen thousand barrels a day. Dozens of vessels, including local shrimp boats, used booms to collect the oil and then set it on fire to burn. Wes Tunnell, a coral reef expert from Texas A and M questioned how long the oil had the porential of remaining in and impacting the Gulf. He revisited a spill he worked in the in the Bay of Campeche, Mexico in 1979 to see if oil was still present. What he discovered gave him some insight on how the Gulf spill may be different in the long haul. On the calm, sheltered side of the Enmideo reef he found a three inch mat of oil contaminated sediment. On the unprotected side of the reef that was exposed to ocean currents and waves, he could not find evidence of the oil's presence. His thought was that if there is wave action then there is ample oxygen for the Gulf's bacteria to break down the oil readily. It is when the oil is allowed to sink to the sediments or get incorporated into the marshlands that there is a concern about it remaining in the environment long term, potentially spreading its harmful toxicity to the ecosystems inhabitants. A French biologist, Philippe Bodin who studied a tanker spill in 1978 off the coast of France actually believes that the waters of the Gulf are at greater risk of long-term effects from the oil. He believes that the combination of the less oxygenated Gulf waters in combination with the use of Corexit 9500, a dispersant, will be toxic to the plankton which serve as the base of the food chain, and therefore to the developing young organisms that feed on them. Bodin and other scientists believe that some dispersants are more toxic to wildlife that the oil itself. (35) Mandy Joye, a biochemist from the

University of Georgia, found borderline hypoxic oxygen levels associated with a large oil and gas plume from Macondo that remained well below the surface where pelagic organisms reside. Again the concern is over the dispersants that were actually pumped into the water at the level of the leaking well and bacteria depleting oxygen in the process of breaking down the dispersed oil.(36)

Although there appeared to be differences of opinion concerning which methods were the best to use in remediation, one thing was for certain, everyone had concerns about the fragile breeding grounds, the marshes. The marshes are not only home to thousands of endangered and threatened birds, and an array of other wildlife, they serve as the nurseries for the fish and crustaceans that support the livelihood of so many along the southern coast. The oil floated north on currents to the marshes sticking to and covering grasses and mangroves. Past oil spills and remediation practices have proven that trying to remove contaminated sediments, burning or cutting in the marshes only damaged the marshes, putting them at the risk of no recovery. Local SCAT(Shoreline Cleanup Assessment Technique) teams organized by BP, traveled the Louisiana coast daily to determine the damage and potential progress of the spill. The tides and wave action appeared to be helping the hydrophobic booms in keeping the oil somewhat contained, preventing its spread deeper into the marshes. In places where there were barrier islands, this method was less effective and more intensive cleanup was needed. Dozens of oiled birds and turtles needed to be rescued. As federal officials and BP argued over jurisdiction, brown pelicans ran the risk of dying from hyperthermia due to the lack of insulation caused by the oil-soaked feathers. (37)

Of course the threat of the toxic oil and dispersants in the waters threatened to bring the local seafood industry to a grinding halt. With the evidence that beaches in Prince William Sound still carried the remnants of the *Exxon Valdez* spill, consumers were afraid to partake in Louisiana's offerings. But Kerry St. Pe', a local who worked for twenty-five years managing oil spill cleanups for the Louisiana Department of Environmental Quality, believes that the southern coast could recover more naturally with this spill. The weathered, travelling oil from off shore to the marshes is more likely to have lost some of its toxicity in the move. He also believes that there are already large communities of "oil eating" bacteria that have been established as a response to frequent, less severe spills over the years. This would decrease the need to use extensive bioremediation. He also points out that much of the marsh vegetation that looks dead and is covered in oil, will regenerate from underground rhizomes. (38)

The Animals

You may have seen the heart-warming commercials on television about the Dawn dish detergent to the rescue of oil covered birds in the Gulf. Dawn along with other natural and man-made surfactants, (Surface Active Agents), have been used in treating oil-covered animals for decades. They basically work by reducing the surface tension of water to allow the water and oil to mix, resulting in the oil being washed away from the animals body. The super secret ingredient in the "Dawn Power Dissolver" allows this to be done without leaving behind a soap residue. This washing process requires a lot of man-hours and large amounts of warm water. (39) Various surfactant products are easily obtained and widely used in spills both in the water and on land.

An update in April 2011 suggests that high mortality rates of bottlenose dolphins in the Gulf over the past year may be associated with the spill. Although the number of deaths last year was four times the yearly average from the previous ten years, officials are not convinced that the spill is the primary reason. Several of the dead dolphins had traces of the BP oil on them, but according to NOAA, the greater mortality rate occurred a few months before the spill. Along with an unusually high number of sea turtle deaths, it is suspected that a high incidence of algal blooms may be associated with this sudden change in death rates. (40)

The Fisheries

On April 19, 2011, according to Restore the Gulf, NOAA announced that all of the Gulf waters that were closed due to the spill, were now open to recreational and commercial fishing. Following a sampling period spanning from November to April, NOAA in conjunction with the Food and Drug Administration, deemed finfish, oysters, crabs and shrimp safe to harvest. According to reports, no oil or sheen had been seen since the previous August following the spill, and tests revealing trace amounts of oil or dispersants found in the fish were one-thousand times lower than the FDA's levels of concern.(41)

Just a few months prior to this testing, local restaurants were serving freshwater crawfish instead of shrimp due to the hesitation of consumers. Shrimp boats were no longer catching shrimp because no one would by them. Many of these boats became part of the clean-up effort dragging booms instead of nets. This feeling of no turning back, was shared by several Louisiana State University scientists and their students who predicted it would be a long time before the oil disappeared from the picture. They sampled fish close to shore, knowing that many of them start their lives in the marshes and then move further offshore as they grow into adults. Their concern was that the oil and dispersants would slowly work their way into various food chains and become part of a more complex food web that stretched from shore to open waters. In addition, they shared concerns stemming from the fact that the dispersants were used at the well head, which means they may remain in the water column for extended periods of time, making it easy to penetrate the food web from many angles. (42) One can only ponder the possibility that the subtle consequences of this spill could go forever unpredicted, undetected and most likely unproven.

Activity: Field Trip/Visit from local company such as Sea Support in New Haven or the nationwide company, www.cleanharbors.

Activity: The Skinny on Surfactants (Adapted from University of Maryland Biotechnology Institute and Maryland Sea Grant Extension Program activity: Industrial Strength Microbes.) Students will design and conduct a scientific investigation based on their knowledge of the use of surfactants on cleaning oil from feathers.

Objectives/ Students will:

- use technology to research the various surfactants that have been used in oil removal from wildlife and gain an understanding of how they work.
- predict which of the surfactants will be most effective in removing the oil from feathers.
- design and run an experiment that will determine the effectiveness of each surfactant.
- collect and analyze data ; draw conclusions on the effectiveness of the surfactants.

Student Materials:

The Skinny on Surfactants

In your short time on this earth, you most likely have been aware of two major oil spills that occurred off the coast of North America. The first one involved the grounding of the oil tanker, *Exxon Valdez,* off the coast of Prince William Sound in 1989. The more recent and closer to home spill occurred in April 2010 in the Gulf of

Mexico. Much was learned from the spill associated with the *Valdez* including how to deal with the thousands of birds and mammals that were covered in oil from the spill. Advances in Biotechnology were key in developing products that would be used to save wildlife from slow, cruel deaths. Time and the efforts of volunteers were crucial in rescuing and treating afflicted animals before they died of exposure due to the loss of insulating and waterproofing abilities, caused by being coated in oil. Surfactants of all types started to pop up from companies all over the world. They work in the similar way in which Dawn dish detergent cuts the grease in your dishwater at home. In fact, you have probably seen the commercials boasting the role of Dawn dish detergent in cleaning animals that were victims of oil spills.

Your task is to determine the effectiveness of various surfactants on the removal of oil from bird feathers **.** First, you should conduct any research you think is necessary to learn about how surfactants work and the various types of surfactants available, including Dawn dish detergent. Next, predict what you believe will be the most effective surfactant(s) in removing the oil from the feathers backing your prediction with your research. Then, design and conduct your experiment (after getting design approval from your teacher), using any of the materials listed below. If your design calls for something not listed, ask your teacher if other materials are available. Finally, analyze your data and report your findings, drawing conclusions about, which of the surfactants was most effective.

Materials

Bird feathers	test tube racks	scissors
Clean motor oil or sesame oil	vortex mixer	stirring rods
Balance/scale	pipettes	
Water	graduated cylinders	
Test tubes	metric ruler	
Petri dishes	Dawn dish detergent	
Test tubes	surfactants X,Y,Z	

Use the following outline to write a report of your findings:

I. *Problem statement* : Problem statement should be in the form of a question and the Independent Variable and Dependent variable should be identified.

II. Prediction/Hypothesis: This should be based on research conducted before the experiment and not changed based on your results.

III. Experimental Design: Written in paragraph form and detailed enough so that it may be repeated in the future. A control group should be described when applicable and all constant variables included in the procedure.

IV. Recording/reporting of data: Data must be provided in the form of a chart, table and or graph that is properly labeled and dated.

V. Analysis/Conclusion: Analyze data and make a conclusive statement that answers the problem statement, supported by your data.

VI. Validity: Discuss anything about your experiment that may have made your data less valid and how your would improve on your design.

VII. Recommendation/Application: Give your recommendation based on your findings. Discuss any applications other than the obvious.

The Burn/ Acidification of the Oceans

Of course one of the more far- reaching issues with oil is its consumption as a fuel source. Most are aware of its acute and long-term effects on the environment and its inhabitants. Controlled burning techniques were used to try to remove as much of the oil from the marine environment during and after the Gulf spill. The EPA monitored the air quality for particulate matter and volatile organic compounds (VOCs). (43) Although the fires that burned as the result of the spill created temporary symptoms and concerns, our long-term concerns with burning oil should focus on climate change and the accompanying effects on the oceans.

Most of the general population, whether they believe it is happening or not, are aware of the concept of climate change. If they believe it is happening, most, when prodded, will admit that our consumption of fossil fuels has been a great contribution to global warming, caused by gases that trap the heat close to earth. They hear repeatedly about the threat of rising sea levels and gradual changes of regions based on precipitation and other climatic factors that will eventually affect where we can live and practice agriculture. What they may not be aware of is that the carbon dioxide released into the atmosphere as a result of carbon combustion is changing our oceans.

Although the chemistry of our oceans has changed over the past two hundred years, the concept of acidification of the oceans has just started to hit the headlines in magazines like *Popular Science* . According to the May 2011 issue, what was once thought of as a good thing for global warming reduction, is now taking its toll on organisms that serve as the basis of food chains in polar regions. The oceans have been considered carbon sinks, absorbing more than twenty-five percent of the carbon dioxide released into the atmosphere. Although this means that it is no longer in the air, it results in the formation of weak carbonic acid, which over time has resulted in the oceans becoming more than thirty percent more acidic. Polar snails, oysters in the Pacific Northwest and most likely other marine organisms are paying the price. Oysters die soon after spawning due to the acidic nature of the water, while other organism's shells are underdeveloped, too thin and deformed.

Is there a solution to this slowly encroaching problem? One thing is for certain, there is no quick fix. Hauke Kite-Powell, a Woods Hole Oceanographic Institution researcher, believes that the best chance is by imposing a "carbon tax". Instead of promoting the burning of fossil fuels through lower costs than the more expensive cleaner sources, a price should be put on carbon. One prediction reduces carbon dioxide emissions by thirty percent if a $12.50 per ton of carbon dioxide tax was implemented. This would keep tons of pollution from entering the oceans, slowing down the acidification process. (44)

Long-term Study: Monitoring of pH/CO2/Alkalinity levels of New Haven Harbor/Long Island Sound Oceanography and Freshman Aquascience and Natural Resource classes will monitor these parameters and maintain data collection for the next several years to determine if there is an acidification process taking place in Long Island Sound.

Objectives / students will:

- Understand the connection between pH, alkalinity and carbon dioxide levels and how this relates to the potential acidification of Long Island Sound
- Collect surface and subsurface water samples with a Wildco sampling device.
- Accurately conduct chemical titrations to determine carbon dioxide and alkalinity levels.
- Successfully operate a pH meter to determine pH levels
- Successfully use a GPS to determine sampling site locations.

· Compile and analyze data collected when applicable.

Student materials:

Monitoring Acidity Levels of Long Island Sound

The acidity levels of the worlds oceans have been slowly changing. We know this by measuring pH levels. pH is the measure of positive hydrogen ions and negative hydroxide ions in water. If these ions are present in equal amounts, the water should be neutral with a pH of 7. If there are more hydrogen ions it will be acidic. (Less than 7) A greater concentration of hydroxide ions will make it basic. (Greater than 7) For most aquatic organisms, the ideal pH levels should fall between 6 and 9. Any levels outside of this range could cause stress for the organisms and prevent them from properly growing or reaching sexual maturity, preventing them from reproducing.

Carbon Dioxide levels play a role in the pH of bodies of water on earth. When carbon dioxide dissolves in water, it creates a weak carbonic acid. Carbon dioxide and pH levels can vary based on the time of day and fluctuating inputs. For instance, during darkness, you would expect carbon dioxide levels to rise while animals are going through respiration, but decrease during sunlight hours when plants use it during photosynthesis. Scientists are looking at the overall increase in ocean acidity levels, (Lower pH), due to vast amounts of carbon dioxide entering waters through atmospheric pollutants from the burning of fossil fuels.

Alkalinity is another parameter that ties into ocean acidification. Alkalinity is the ability of a body of water to buffer against an excess of hydrogen ions therefor preventing the build up of acids and a resulting drop in pH. Salt water generally has a greater natural ability to act as a buffer than fresh water.

Area environmental groups and scientists have concerns about whether or not this acidification process is taking place in Long Island Sound and what effects it could have on the shellfish and crustaceans that inhabit the waters. You and your classmates will be pioneers in a long- term study that will involve monitoring pH, alkalinity and carbon dioxide levels in Long Island Sound. Data will be compiled for the next several years to determine whether or not there is a trend of acidification in the Sound.

Materials:

Wildco sampling bottle	distilled water	science vessel/operator
Lamotte salt water chemistry kit	safety goggles	waste bucket
(Carbon dioxide, alkalinity)	GPS	emergency eye wash
pH meter	data sheets/pencil	Personal Flotation Devices
wash bottle	float plan	vessel safety box
bucket with line	computer	chart and charting instruments

Sampling and testing protocol:

· Prepare apparatus and equipment for sampling/testing/recording data
· Submit float plan to main office/water-front safety officer
· Put on Personal Flotation Devices/board science vessel
· Pilot to sampling location(s)/enter location in GPS and mark location
· Take a surface sample with the bucket and a bottom sample with the Wildco Bottle

· Perform three carbon dioxide titrations and three alkalinity titrations on each sample
· Use the pH meter to test the pH of the samples
· Record all data on provided data sheets.
· Chart sampling location(s) on chart of Long Island Sound
· Transfer all data to spread sheet in all access folder

Testing will be repeated several times throughout the year. Can you think of any strategies in terms of determining where and when(time of day) to sample? Explain your reasoning.

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End Notes

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Appendix A

Implementing District Standards

The following state standards will be implemented by the completion of the student driven activity: The Skinny on Surfactants. This is an inquiry-based activity that mirrors the CAPT embedded tasks developed by the state.

DINQ1 Identify questions that can be answered through scientific investigation.

DINQ2 Read, interpret and examine the credibility and validity of scientific claims in different sources of information.

DINQ3 Formulate a testable hypothesis and demonstrate logical connections between the scientific concepts guiding the hypothesis and the design of the experiment.

DINQ4 Design and conduct appropriate types of scientific investigations to answer different questions.

DINQ5 Identify independent and dependent variables, including those that are kept constant and those used as controls.

DINQ6 Use appropriate tools and techniques to make observations and gather data.

DINQ8 Use mathematical operations to analyze and interpret data, and present relationships between variables in appropriate forms.

DINQ9 Articulate conclusions and explanations based on research data, and assess results based on the design of the investigation.

DINQ10 Communicate about science in different formats, using relevant science vocabulary, supporting evidence and clear logic.

The following standards will be implemented through student research as they prepare materials for student created board games concerning the use of oil as a natural resource.

D14 - Describe combustion reactions of hydrocarbons and their resulting by-products.

D19 - Explain how chemical and physical processes cause carbon to cycle through the major earth reservoirs.

D25* - Explain how land development, transportation options and consumption of resources may affect the environment.

D26 - Describe human efforts to reduce the consumption of raw materials and improve air and water quality

The following standard will be implemented during the long-term study conducted on the effects of carbon dioxide and climate change on Long Island Sound.

D23 - Explain how the accumulation of carbon dioxide (CO_2) in the atmosphere increases Earth's "greenhouse" effect and may cause climate changes