Prince William's Oily Mess: A Tale of Recovery

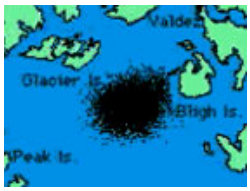
Welcome

How does an ecosystem recover from a major one-time insult such as an oil spill?

Photo credits: OR&R, NOAA; *Exxon Valdez* Oil Spill Trustee Council; Tri-State Bird Rescue & Research

As you will learn from this *Discovery Story*, the answer is not simple. It isn't easy to determine whether a particular area of shoreline has recovered from oiling during a spill, or how to expect it to look when it has.

In March 1989, the tanker *Exxon Valdez* grounded on Bligh Reef in Alaska's Prince William Sound, rupturing its hull and spilling nearly 11 million gallons of crude oil. It remains the largest oil spill ever to occur in U.S. waters.



Watch & Discover: An Oil Spill Trajectory Model - Computer simulation of how oil traveled across Prince William Sound during the first week after the *Exxon Valdez* oil spill.

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To learn how Prince William Sound is recovering from this environmental shock, NOAA scientists have conducted a monitoring study there since 1990. Even today, these scientists and others are trying to answer the following questions:

- ***How did the oil impact marine life and their habitats?***
- ***Did the massive cleanup operations actually cause more harm than good?***
- ***How much oil remains in Prince William Sound?***

All the facts aren't yet in, but here you can read about how NOAA biologists have been monitoring the long-term effects of this major spill on marine life, the various cleanup efforts, and the recovery of Prince William Sound ever since that unfortunate day.

- ***What did the Exxon Valdez teach us about oil spill response?***
- ***Has Prince William Sound recovered from the spill?***

You can analyze the Mearns Rock Time Series, which is a sequence of photos of the same oiled rock in Prince William Sound. The photos were taken once each year since the *Exxon Valdez* oil spill occurred there. You can try your hand at working with some real data collected by scientists at Mearns Rock, and answer the question:

- ***How did the Exxon Valdez oil spill affect the abundance of marine life on Mearns Rock?***

(top)

Prince William's Oily Mess: A Tale of Recovery

The Infamous *Exxon Valdez*

A lot can go wrong on the open sea. Heavy seas can drive a ship into dangerous waters. A miscalculation can cause ships to collide or begin a chain of events leading to an explosion or fire. An engine can falter, leaving a heavily loaded tanker to drift toward a rocky shore or reef. Just such an event occurred on March 24, 1989. En route from Valdez, Alaska, to Los Angeles, California, the tanker *Exxon Valdez* grounded on Bligh Reef in Alaska's Prince William Sound, rupturing its hull and spilling nearly 11 million gallons of crude oil into this remote, scenic and biologically productive body of water. The ship was traveling outside normal shipping lanes in an attempt to avoid an iceberg. The oil eventually affected over 1,100 miles of the Alaska coastline, making it the largest oil spill to occur in U.S. waters to date.

Shortly after leaving the Port of Valdez, the *Exxon Valdez* ran aground on Bligh Reef in Prince William Sound, Alaska. This photo was taken three days after the vessel grounded, just before a storm arrived, making the situation even worse. (Photo credit: OR&R, NOAA)

The images that Americans saw on television and descriptions they heard on the radio that spring were of heavily oiled shorelines, dead and dying wildlife, and thousands of workers mobilized to clean beaches. These images reflected what many people felt was a severe environmental insult to a relatively pristine, ecologically important area that was home to many species of wildlife endangered elsewhere. In the weeks and months that followed, the oil spread over a wide area in Prince William Sound and beyond, resulting in an unprecedented response and cleanup—in fact, the largest oil spill cleanup ever mobilized. Many local, state, federal, and private agencies and groups took part in the effort. Even today, scientists continue to study the affected shorelines to understand how an ecosystem like Prince William Sound responds to, and recovers from, an incident like the *Exxon Valdez* oil spill.

Oiled duck on the shore following the *Exxon Valdez* oil spill. (Photo credit: *Exxon Valdez* Oil Spill Trustee Council)

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Report a Spill

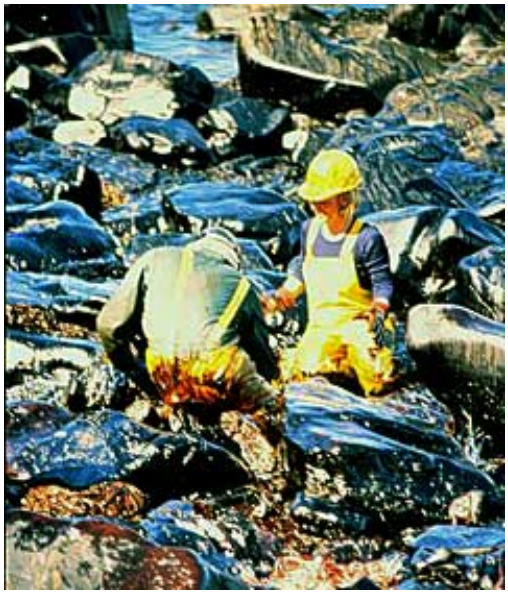
An Oil Spill Primer for Students - Learn the basics about oil spills!

To learn about how Prince William Sound is recovering from the *Exxon Valdez* oil spill, NOAA scientists have been conducting a monitoring study since 1990 (the year after the spill). They chose about 20 study sites around Prince William Sound, including (1) sites that had been oiled by the spill, but not cleaned up, (2) sites that had been oiled and cleaned, and (3) sites that were not oiled, which served as their control.

How Toxic is Oil? - Assessing Oil's Toxicity can be Tricky!

Each year, research crews visit each site to measure the numbers and kinds of species of intertidal plants and animals they find there (see photo, below left). Scientists use these observations to track changes in the biological communities over time.

A NOAA research crew collects data in an intertidal area of Prince William Sound, Alaska. By studying the biological effects of the oil spill, they hope to learn how to respond better to oil spills in the future. (Photo credit: OR&R, NOAA)



Beach cleanup workers in oil-splattered raingear use an oleophilic material called pom-poms to clean a heavily oiled beach on LaTouche Island in Prince William Sound. (Photo credit: *Exxon Valdez* Oil Spill Trustee Council)

Prince William's Oily Mess: A Tale of Recovery

Remaining Impacts of the Spill

How did the oil spill impact marine life and their habitats?

What scientists have found is that, despite the gloomy outlook in 1989, the intertidal habitats of Prince William Sound have proved to be surprisingly resilient. Many shorelines that were heavily oiled and then intensively cleaned now appear much as they did before the spill. Most gravel beaches where the oiled sediments were excavated and pushed into the surf zone for cleansing have returned to their normal shape and distribution on the shore. Beaches that had been stripped of plants and animals by the toxic effects of oil and by the intense cleanup efforts show extensive recolonization and are similar in appearance to areas that were unoiled.

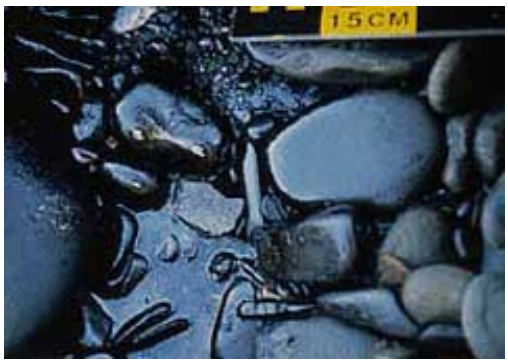
1989

1998

The photo on the left was taken in June 1989 in Northwest Bay, only months after the oil spill, and very soon after, this area had been cleaned with high-pressure hot water. Extensive areas of dead rockweed (*Fucus gardneri*) are visible in the photo. The photo on the right shows the same location in 1998. **Click on image** for larger view and more information.

Although the Sound has proved to be surprisingly resilient, impacts from the spill remain:

- Deeply penetrated oil continues to visibly leach from a few beaches, as on Smith Island.
- In some areas, intertidal animals, such as mussels, are still contaminated by oil, affecting not only the mussels but any animals (including people) that eat them.



Residual oil on a cobble beach on Smith Island, Prince William Sound, Alaska in 1997. Here, large volumes of oil have penetrated so deeply into this beach that substantial quantities continue to leach out. (Photo credit: OR&R, NOAA)

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- Some rocky sites that were stripped of heavy plant cover by high-pressure, hot-water cleaning remain mostly bare rock.

- Rich clam beds that suffered high mortalities from oil and extensive beach cleaning have not recolonized to their previous levels.

While these are isolated examples, they provide a basis for gaging the overall recovery of oiled areas. Prince William Sound has made a remarkable recovery from a severe injury, but it remains an *ecosystem in transition*.

(top)

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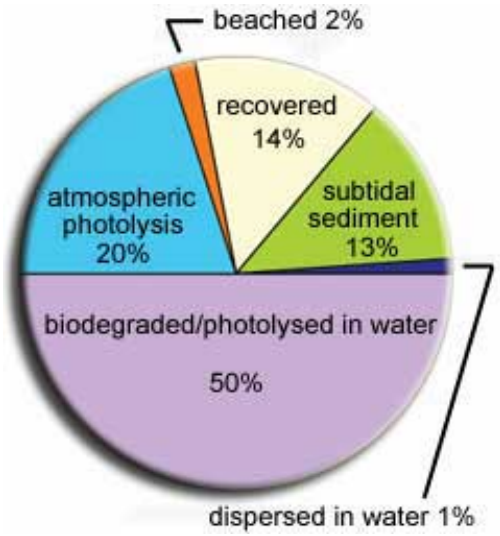
Prince William's Oily Mess: A Tale of Recovery

How Much Oil Remains?

What was the ultimate fate of the 10.8 million gallons of oil released from the Exxon Valdez?

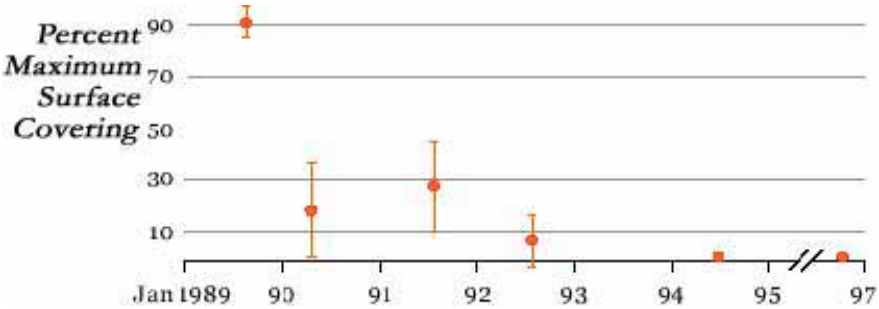
Nobody knows for sure, but based on the areas that were studied in the aftermath of the spill, scientists made estimates of the ultimate fate of the oil. A 1992 National Oceanic and Atmospheric Administration (NOAA) study provided some insight, estimating that the great majority of the oil photolysed in the atmosphere, dispersed into the water column or degraded naturally (biodegraded by microorganisms or photolysed in the water). Cleanup crews recovered about 14 percent of the oil, and approximately 13 percent sank to the sea floor. About 2 percent (some 216,000 gallons) remained on the beaches.



The ultimate fate of the 10.8 billion gallons of oil that leaked from the *Exxon Valdez*. NOAA scientists estimate that 2% of the oil remains on the beaches.

Whodunit? Fingerprinting Oil

Considering that nearly 11 million gallons escaped from the tanker, and that large quantities eventually fouled shorelines in the sound and elsewhere, very little remains. The graph below shows actual measurements made by NOAA scientists at their study sites in Prince William Sound from 1989 to 1997.



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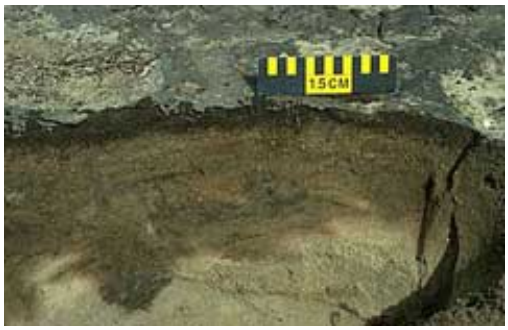
The observed maximum percent of the surface covered by oil at eight NOAA study sites in Prince William Sound, 1989-1997. Values are mean percent cover of oil.

Are the data what you expected? What data point on the graph seems out of place?

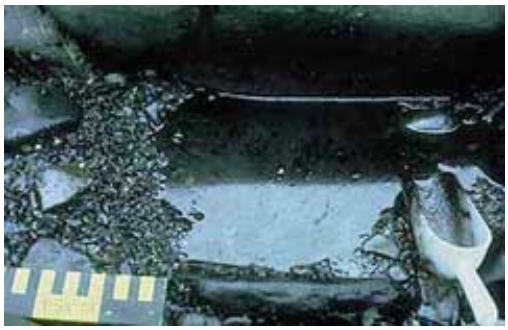
At the sites being studied by scientists, surface oil had all but disappeared by 1992, three years after the spill. The apparent increase in surface oiling in 1991 (two years after the spill) was likely to have been caused by heavy equipment digging up buried oil (called "berm relocation"), which was used as a remedial technique that year.



Residual oil below the surface of a beach. In some places in Prince William Sound the remaining oil is only evident below the surface. (Photo credit: OR&R, NOAA)

However, oily traces of the spill can still be found on some beaches**.** The remaining oil generally lies below the surface of the beaches in places that are very sheltered from the actions of wind and waves (which help to break down and remove stranded oil), and on beaches where oil initially penetrated very deeply and was not removed**.** At these beaches, there are signs of weathered oil on the surface and deposits of fresher oil buried beneath. Sometimes this oil makes its way to the surface and can be seen as a sheen on the water as the tide comes in. Interestingly, despite the fresh appearance of oil at these sites, chemical analysis and biological observations indicate that the oil is actually of such low toxicity that many intertidal organisms can tolerate its presence, even though it can accumulate in their tissues.

One of the scientists' goals is to determine whether this residual oil is causing environmental harm to organisms living there, since one of the most difficult questions to answer during any oil spill is, "How clean is clean?" That is, when does cleanup begin to cause more harm than simply leaving the oil in place to degrade naturally?



Residual oil on a cobble beach on Smith Island, Prince William Sound, Alaska in 1997. Here, large volumes of oil have penetrated so deeply into this beach that substantial quantities continue to leach out. Oil sheens were observed at this site in undisturbed tide pool water. (Photo credit: OR&R, NOAA)

In addition, reports both in the news and in scientific journals have stated that not all of the oil found in Prince William Sound can be traced back to the *Exxon Valdez***.** This is not surprising. Many potential alternate sources of hydrocarbons exist in the marine environment, even in a region that is relatively unpolluted. As examples:

- Some of the hydrocarbons are natural, coming from undersea oil seeps or forest fires.

- Others are definitely of human origin, such as the rupturing of oil storage tanks during the Alaskan earthquake of 1964, the pumping of ship ballast tanks, and fuel leakage from commercial ships and recreational boats traveling through the area.

Chemists who "fingerprinted" hydrocarbon residues in both beach sediments and in animal tissues found that not all of the oil came from the *Exxon Valdez*. More recently, the highest concentrations of oil in mussel tissues have come from small boat harbors and diesel fuel. However, scientists hypothesize that most of the oil contamination found in Prince William Sound does trace back to the *Exxon Valdez*.

Scientists dig for subsurface, residual oil on a beach in Prince William Sound. (Photo credit: OR&R, NOAA)

(top)

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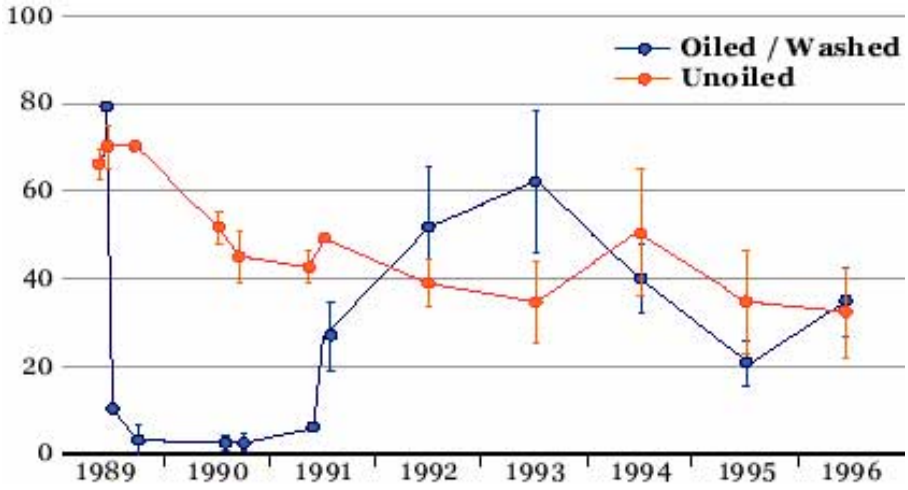
An Ecosystem in Transition

The graph below shows changes in the area covered by one of the most abundant alga on the shorelines of Prince William Sound, *Fucus gardneri*, commonly called "rockweed" or "popweed." Because this alga favors the middle part of the intertidal zone where much of the heavy oiling and cleanup occurred, its abundance declined in many areas of the Sound. Beginning in 1990, scientists saw the cover of rockweed increase steadily at oiled sites—until 1994, that is. From 1994 through 1995, there appeared to be a noticeable decline in cover, especially at sites that had been oiled.

A healthy stand of rockweed (*Fucus gardneri*) growing on a boulder in Prince William Sound. This site was oiled during the *Exxon Valdez* spill and has since been recolonized by these plants. (Photo credit: OR&R, NOAA)



Mean Percent Cover per 0.25 Sq Meter Quadrat by Year

Comparison of percent cover of rockweed in unoiled and oiled/washed rocky sites, 1989-1996. Note the steep decrease in percent cover at oiled/washed sites in 1989 after treatment, and the steady decline in percent cover at oiled/washed sites beginning in 1993. The washed sites were cleaned with hot water in the months after the spill.

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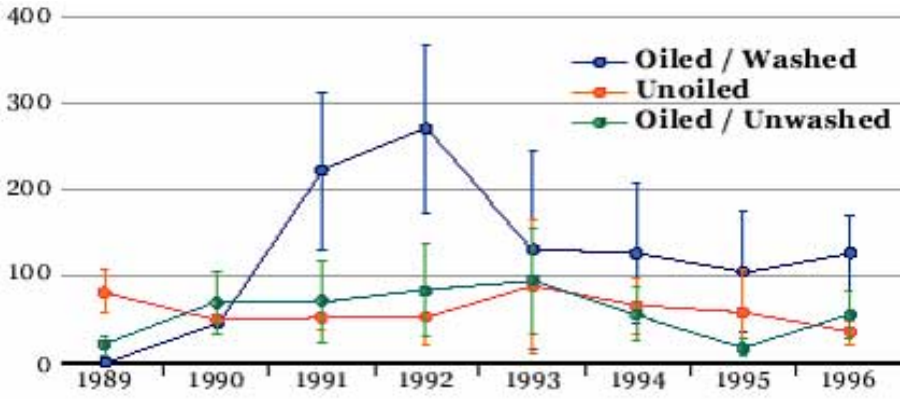
What caused the decline in 1994 and 1995?

Scientists don't know for certain. Here are some possibilities:

- It is possible that the oiling or cleanup (or both) in 1989 killed the original stands of rockweed, so that the normal mix of plants of different ages was not present. Instead, the areas became dominated by plants of all the same age because they were reestablished all at the same time after the spill. In 1994, all these plants would have reached the end of their life cycle at the same time, leading to the decrease evident in the graph. The die-off of plants of all the same age would not be noticeable under normal circumstances because plants of all different ages would be present.
- Alternatively, an explosion in the population of grazers (such as periwinkle snails) that feed on algae two and three years after the spill may have had something to do with the decline in rockweed (see graph below).
- Perhaps it is a subtle, longer-term toxic effect of oiling. Or, it might have nothing at all to do with the spill or cleanup. Data collected in the coming years will help shed light on these conditions.



Mean Abundance per 0.25 Sq Meter Quadrat by Year

Abundance of periwinkle snails (*Littorina scutulata*) at rocky sites, 1989-1996. The large increase in snails at oiled/washed sites in 1991 and 1992 was due to increased numbers of juveniles. Periwinkle snails are grazers that feed on algae, including *Fucus*.

What do these trends over time mean for recovery in Prince William Sound?

Scientists think they suggest that highs and lows in abundance of plants and animals will continue as the system adjusts itself. With time, natural controls will dampen the fluctuations in abundance of marine life. Most of these adjustments will not be

noticeable, and to the casual observer, conditions will continue to look much as expected in an area that remains a very beautiful place to visit. However, these subtle changes may have implications for how scientists view the process of recovery from the one-time stress of an oil spill. Eventually, the changes also may affect other parts of the ecosystem that are commercially and aesthetically important, such as the fisheries and tourist destinations. NOAA scientists will continue to study the sound until 2005 in an effort to answer these questions.

Close-up of periwinkle snails (*Littorina scutulata*), an algal grazer, and a newly-laid egg mass on a boulder in Prince William Sound. (Photo credit: OR&R, NOAA)

(top)

Prince William's Oily Mess: A Tale of Recovery

Lessons Learned From the *Exxon Valdez*

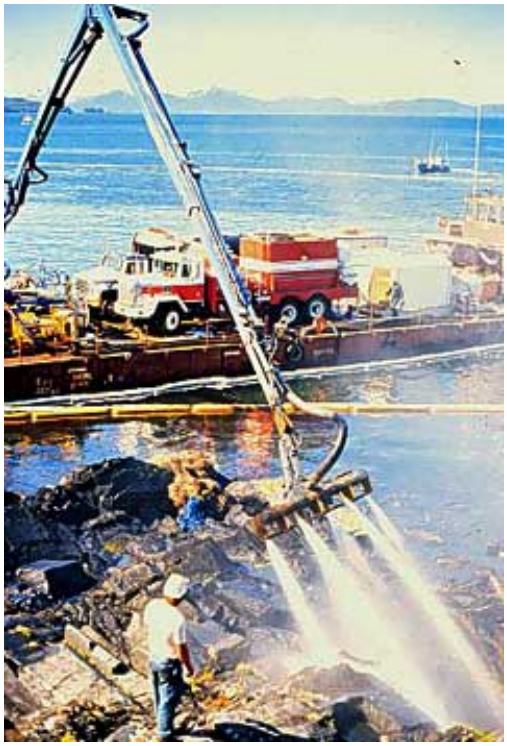
The scientists who monitored the oiled parts of Prince William Sound wanted to study the shoreline's ecological recovery after an environmental disaster like the *Exxon Valdez* spill, and then use those lessons to better respond to future oil spills. Right now, their task is still incomplete. However, some of their findings have changed the way they think about cleaning up oil spills. Following are some examples of what they have learned:

- More limited and measured use of aggressive cleanup methods, such as hot-water washing, would help to minimize the severe effects scientists have observed in plant and animal communities.

- Using water to flush an oil-contaminated beach may also wash away fine-grained sediments, such as sand and nutrients, which small organisms need to successfully colonize. Sometimes, it takes years for the fine sediment to return.

- Adult animals such as clams may survive in oil-contaminated beaches, but juveniles don't do as well.

- Oil that penetrates



An omni-boom blasts oil-coated rocks in an attempt to clean gross oil contamination from a beach on LaTouche Island. NOAA biologists have concluded that such techniques may do more harm than good. (Photo credit: *Exxon Valdez* Oil Spill Trustee Council)

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deeply into beaches can remain relatively fresh for years and can later come back to the surface and affect nearby animals.

- After the *Exxon Valdez* spill, beaches were reworked by heavy machinery to move heavily oiled upper intertidal sediments into the middle intertidal zone, where they could be washed by the surf and where the oil could be collected in booms. After such large-scale excavations, it can take many years for the beach sediments to recover.

- Rocky rubble shores should be of high priority for protection and cleanup because oil tends to penetrate deep and weather very slowly in these habitats, prolonging the harmful effects of the oil when it leaches out.

A NOAA biologist examines freshly excavated live adult clams from heavily oiled beach sediments on Block Island, Prince William Sound, Alaska. Juvenile clams generally do not survive as well as adults on oiled beaches. (Photo credit: OR&R, NOAA)

A brown sediment plume and sheens of refloated oil drift away from this oiled beach as it is cleaned by a team applying high-pressure, hot-water washing. Refloating of oil and the release of sediments are often unavoidable consequences of shoreline cleanup that can cause additional environmental harm. (Photo credit: OR&R, NOAA)

(top)

Prince William's Oily Mess: A Tale of Recovery

Has Prince William Sound Recovered?

We all have some idea of just what "recovery" is—we've all recovered from a cold or the flu—yet to ecologists studying natural systems, it is a very difficult term to define and measure. If you ask a fisherman from Kodiak Island, a villager from the town of Valdez, an Exxon engineer—or, yes, a NOAA biologist—you are likely to receive such different answers that you may wonder if they heard the same question!

Despite the remaining impacts of the largest oil spill in U.S. history, Prince William Sound remains a relatively pristine, productive and biologically rich ecosystem. (Photo credit: OR&R, NOAA)

An ecosystem like Prince William Sound constantly adjusts itself to react to, or compensate for, changes in the environment, such as:

- daily temperature variations;
- changing of the seasons;
- long-term drought;
- rare natural events, like hurricanes and earthquakes; and
- oil spills.

When the *Exxon Valdez* spill occurred in March 1989, the Prince William Sound ecosystem was also responding to at least three notable events in its past:

- an unusually cold winter in 1988-89;
- growing populations of reintroduced sea otters; and
- a 1964 earthquake.

Scientists studying the effects of the spill must evaluate their results against this background of other insults, or stressors, that have affected the sound.

Scientists do not define recovery as a return to the precise conditions that existed before the oil spill. They know that this is unlikely to happen. Nevertheless, they can observe a range of conditions to measure shoreline recovery from the spill.

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For example, if they find that unoiled sites are changing in the same ways and at similar rates as the oiled sites, then the changes are probably caused by natural events and cannot be linked to the oil spill. If conditions at oiled sites fall outside the range found at control sites, then scientists would suspect that oil contamination is still affecting these systems.

In summer 2001, roughly 10,000 pits were excavated as part of a shoreline survey of Prince William Sound. Oil was found at 58 percent of the 91 sites surveyed, which is approximately equivalent to 5.8 km of contaminated shoreline (Short et al., 2001). (Photo credit: NMFS, NOAA)

Just as people differ in their ability to recover from injury, so do plants and animals. Some animals and plants are resilient and grow back quickly. In Prince William Sound, green algae and certain types of worms grew back the first summer. Rockweed and barnacles had repopulated many areas within 2 to 3 years. Other animals, such as clams, limpets, and some snails, are taking much longer.

Today, two escort vessels accompany each tanker that passes through Prince William Sound. They not only watch over the tankers, but are capable of assisting them in the event of an emergency, such as a loss of power or loss of rudder control. (Photo credit: Argonne National Laboratory)

In short, biologists consider the intertidal communities in Prince William Sound to be still recovering, but not completely recovered.

Scientists will continue to regularly monitor a range of study sites in Prince William Sound at least through the year 2005. In 2001, they began a smaller-

scale, experimental phase of their research, focusing on fewer sites. Scientists will use this information to improve oil spill response and cleanup in the future, with an overall goal of minimizing environmental harm. Because of this, the *Exxon Valdez* will leave at least one positive legacy in its unfortunate wake: knowledge that will benefit all of us and the environment the next time disaster strikes.

(top)

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Dr. Mearns Rock—You Be the Scientist!

Now let's turn to a question that you can explore:

How does marine life recover from a major, one-time stress such as an oil spill?

Mearns Rock is located in the intertidal zone on Knight Island in Snug Harbor, Prince William Sound, Alaska. Here is how it appeared in 2003, 14 years after the *Exxon Valdez* oil spill. (Photo credit: OR&R, NOAA)

As you have learned, the answer is not simple. The Mearns Rock Time Series is a series of photographs of "Mearns Rock," a large boulder (approximately 4 feet high by 7 feet long) located in the intertidal zone at Snug Harbor on Knight Island, Prince William Sound, Alaska.

Find the location of Snug Harbor using the trajectory map.

The boulder is located on a very protected, south-facing rocky shoreline that was oiled during the *Exxon Valdez* spill in March 1989. This section of shoreline was not cleaned after the spill. Scientists believe that the boulder, like the rest of the shoreline, was coated by spilled oil, which was gradually removed by natural processes during the year following the spill. NOAA biologists have photographed this boulder—and the animals and plants growing on it—once each year, in late June or early July, for the past 14 years. Look at the map on the right to see how the oil spread in Prince William Sound for the first eight days after the spill and answer this question: ***How many days after the spill occurred did oil reach Knight Island, the location of Mearns Rock?***

Here is your chance to work with some real data collected by real scientists.

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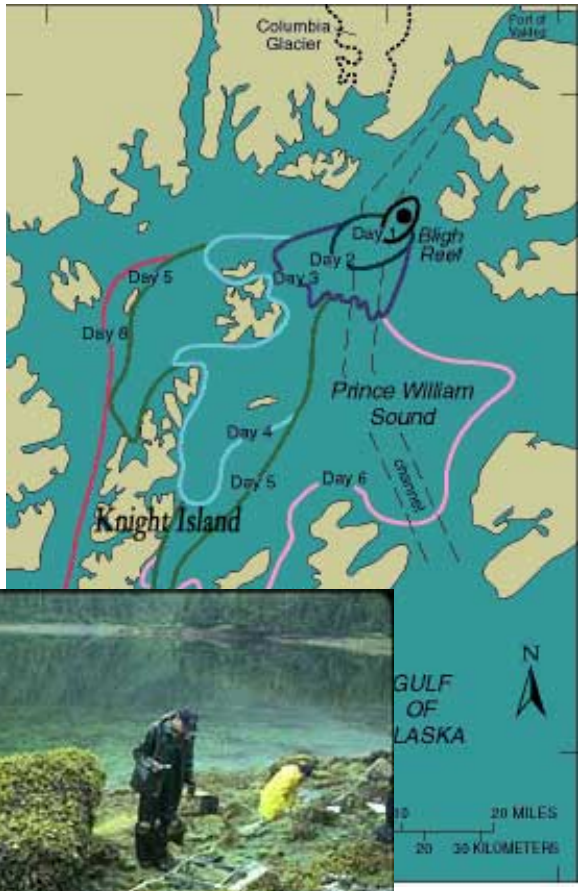
Using photos of Mearns Rock, you can graph changes over time in the percent cover of different organisms that have colonized the rock since the *Exxon Valdez* spilled its oil. You will be working like NOAA scientists, including the scientist for whom the rock is named—Dr. Alan Mearns.

Click on Working With Real Data to get started!



ed out of the normal
nce William Sound,
he map shows the oil
the spill. (Map credit:

NOAA scientists establish a transect line and sample quadrats near Mearns Rock during their 1991 survey expedition. (Photo credit: OR&R, NOAA)

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Prince William's Oily Mess: A Tale of Recovery

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In many locations in Prince William Sound, the action of tides and currents distributed oil throughout the entire intertidal zone. Here, a member of NOAA's Office of Response and Restoration oil spill response team stands on Knight Island in Northwest Bay, Alaska. (Photo credit: OR&R, NOAA)

Glossary of Terms

A | B | C | D | E | F | G |

H | I | J | K | L | M | N |

O | P | Q | R | S | T | U |

V | W | X | Y | Z

A

Abundance—the total number of individuals of a species present in an area. Also see, **Relative Abundance**.

Amphipods—a group of small, laterally compressed crustaceans that includes beach hoppers and others.

Aquatic—growing or living in, or frequenting water. The term "aquatic" is sometimes used to refer specifically to freshwater, as opposed to salt or marine water. See Marine.

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B

Ballast Tanks—special tanks on large ships that are used to provide stability needed when carrying less than a full load of cargo and to keep the ship at the proper depth in the water. When the ship is loaded with cargo, the ballast tanks are emptied and its contents (usually water) are released to surrounding waters; when the ship is empty, the ballast tanks are filled with water (or other substance like soil or sand) to keep it upright.

Barnacles—marine crustaceans with feathery appendages for gathering food that are free-swimming as larvae but permanently fixed (to rocks, boat hulls or whales) as adults.

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Berm—a terrace formed by wave action along the backshore of a beach; a mound or wall of earth, sand or rocks used as a barrier or as insulation.

Biodegradation (or Biodegrade)—the breaking down of substances by microorganisms, like bacteria, which use the substances for food and generally release harmless by-products such as carbon dioxide and water.

Bivalve Mollusk—mollusks with two shells, such as oysters, mussels, and clams. Snails and limpets are gastropod mollusks.

Boom—a temporary floating barrier used to contain an oil spill.

Boulder—a mass of rock greater than 256 millimeters in diameter.

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C

Cobble—a mass of rock greater than 64 millimeters in diameter, but less than 256 millimeters in diameter. Cobblestones are larger than a pebble and smaller than a boulder.

Colonize—to populate or establish a population in an area.

Community—an association of living organisms that have mutual relationships among themselves and with their environment, and thus function, to some degree, as an ecological unit.

Control (or Control Group)—in an experiment, it is the group or subject not exposed to the variable or condition (for example, not exposed to oiling or not exposed to cleanup techniques).

Controlled Experiment—uses an experimental group and a control group to test a hypothesis.

Cover—referring to the amount of plants or other organisms that are occupying the ground, a rock or other surface.

Crude Oil—gooey liquid that contains hundreds of different types of hydrocarbons; raw, unprocessed petroleum (i.e. oil in its natural unprocessed state). It is refined or separated into petroleum gas, kerosene, diesel, fuel oil, bunker oil, etc.

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D

Dispersant—chemical that causes oil to break into small droplets by reducing the surface tension between the water and oil. It is used to cleanup low viscosity oils, yet it impacts the plankton in the upper water layers, because the oil is dispersed within the water.

Diversity (or Biological Diversity)—the variety of species, their genetic makeup, and the natural communities that they compose. All the different kinds of organisms living in an area.

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E

Ecology—the study of the relationship among organisms and between organisms (the biological environment) and their physical environment.

Ecologist—scientist who studies the interactions between species of organisms and their environment (studies the ecosystem).

Ecosystem—a community of living organisms and their interrelated physical and chemical environment.

Environment—the physical and biological conditions that surround an organism or a group of organisms.

Evaporation (or "to evaporate")—the physical change by which any substance is converted from a liquid to a vapor or gas.

Experimental Group—in an experiment, the group exposed to the variable or condition.

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G

GPS (or Global Positioning System)—satellite-based navigation system that permits a user to pinpoint his or her exact location on Earth.

Grazers—organisms that eat grasses or other herbs or, in the case of fish and aquatic invertebrates, scrape or suck plant material from some surface (for example, rocks).

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H

Hydrocarbons—a large class of molecules containing only carbon and hydrogen; common in petroleum products and other oils.

Hypothermia—excessive loss of body heat caused by exposure to very cold water or other conditions.

Hypothesis—an idea or explanation that is based on observations and that can be tested; a suggested explanation for an observation often stated in the form of a question that can be answered by the results of an experiment.

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I

Indicator Species (or Indicator)— a species whose status (i.e., its presence, absence, or abundance) provides information on the overall condition of an ecosystem and of other species in that ecosystem. They reflect the quality and changes in environmental conditions, as well as aspects of community composition.

Insectivore—a heterotrophic organism that eats insects.

Intertidal Zone—on a beach, the area between high tide and low tide.

Invertebrate—an animal lacking a backbone.

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L

Leach—to draw out or remove the oil from the soil or sediments, often a result of the action or percolation of water.

Limpet—marine gastropod mollusk that has a low conical shell broadly open beneath and grazes over rocks or timbers in the littoral area and clings very tightly when disturbed.

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M

Marine—relating to the seas and oceans.

Microorganism—a very small plant, animal or bacterium; some microorganisms, like larger organisms, can be hurt by oil spills; some microorganisms actually break oil down into less harmful substances.

Model—an abstraction or simplification of a natural phenomenon developed to predict a new phenomenon or to provide insight into existing ones.

Mortality—the proportion of deaths in a population.

Mussels—a bivalve mollusk usually having a dark elongated shell.

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N

NOAA—the National Oceanic and Atmospheric Administration (NOAA), an agency of the U.S. government that conducts research and gathers data about the global oceans, atmosphere, space, and sun, and applies this knowledge to science and service that touch the lives of all Americans. NOAA provides these services through five major organizations: the National Weather Service, the National Ocean Service, the National Marine Fisheries Service, the National Environmental Satellite, Data and Information Service, and the Office of Oceanic and Atmospheric Research; and numerous special program units. In addition, NOAA research and operational activities are supported by the nation's seventh uniformed service, the NOAA Corps, a commissioned officer corps of men and women who operate NOAA ships and aircraft, and serve in scientific and administrative posts.

Non-petroleum Oils—oils that are not derived from petroleum; this group of oils includes vegetable oils and animal fats.

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O

Oil—crude oil and refined petroleum products (motor oils, fuels, lubricants, etc.), as well as vegetable oils, animal fats, and other non-petroleum oils.

Oil Slick—a layer of oil floating on the surface of water.

Oleophilic—having a strong affinity for lipids, including petroleum oils and fats. Oleophilic materials absorb or stick to petroleum oils.

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P

Percent Cover—the proportion (in percent) of a certain species or group of species that is occupying a surface such as the ground, a rock, etc.

Petroleum—a mixture of liquid, gaseous, and solid hydrocarbon compounds found naturally underground. The liquid form of petroleum is called crude oil. Crude oil is occasionally found in springs or pools but usually is drilled from wells beneath the Earth's surface. Petroleum can be processed (refined) into a number of useful products including asphalt, diesel fuel, fuel oil, gasoline, jet fuel, lubricating oil, and plastics.

Photolysis (or Photolysed)—chemical decomposition by the action of radiant energy (as light).

Physical Environment (or Abiotic Environment)—nonliving things in the environment, e.g., water and minerals. Also refers to physical processes in the environment such as evaporation, currents, wind, etc.

Polychaetes (class Polychaeta)—segmented worms that have parapodia (i.e. flattened extensions that have stiff and sometimes sharp bristles).

Prediction (or "to predict")—a scientific model to explain what happens, and why it happens; an indication in advance based on observation, experience, or scientific reason.

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Q

Quadrat—a small plot or sample of land that is representative of the particular habitat that is being studied. Often the plot of land is demarcated using a frame made of PVC pipe or other material.

R

Rationale—an underlying reason.

Recolonization—to reestablish a colony or population after being removed from a particular location by a disturbance.

Recovery—the act, process or instance of bringing a habitat or ecosystem back to a normal condition; or to save it from loss and restore it to usefulness.

Reef—a chain of rocks or coral or a ridge of sand at or near the surface of the water, forming a hazardous obstruction.

Relative Abundance—the proportion or numbers of a species compared to the total number of individuals of all the species in the community or sample.

Remedial—intended as a treatment or correction.

Replicate—one of several identical experiments, procedures or samples.

Replication—performance of an experiment or procedure more than once.

Resilience (or Resilient)—the capacity to recover structure and function after disturbance. A highly resilient community or ecosystem may be completely disrupted by disturbance but quickly returns to its former state.

Restoration—bringing back or restoring species and ecosystems after human disturbance.

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S

Sediments—the matter, such as soils, sand and rocks, that settles or is deposited on the bottom of a water body by the action of water, wind or glaciers.

Seine—a large net with sinkers on one edge and floats on the other that hangs vertically in the water and is used to enclose and catch fish when its ends are drawn together or drawn ashore.

Skimmers—devices used to remove oil from the water's surface.

Sorbents—substances that take up and hold water or oil; sorbents used in oil spill cleanup are made of oleophilic materials.

Stressor—the five external forces (i.e. stressors) identified as affecting coastal and marine ecosystems are pollution, invasive species, climate change, extreme events, and land or resource use.

Subtidal—the coastal life zone that remains underwater (below low tide), but above the continental shelf.

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T

Tide Pools—small habitats formed when spaces between rocks retain water at low tide.

Tides—very long-period waves that move through the oceans in response to the forces exerted by the moon and sun. Tides originate in the oceans and progress toward the coastlines where they appear as the regular rise and fall of the sea surface. When the highest part, or crest, of the wave reaches a particular location, high tide occurs; low tide corresponds to the lowest part of the wave, or its trough.

Trajectory—the path taken by something.

Trajectory Model—a prediction about the path of something—like an oil slick.

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V

Viscosity (or Viscous)—amount of resistance to flow by a liquid. Corn syrup is much more *viscous* than water. High molecular weight oils have high viscosity (i.e. do not flow easily).

Volatile—referring to "volatile organic compounds" (VOCs)—a family of chemical compounds found in oils; VOCs evaporate quickly and can cause nerve damage and behavioral abnormalities in mammals when inhaled.

W

Weathering—action of the wind, waves, and water on a substance, such as oil, that leads to disintegration or deterioration of the substance.

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An Oil Spill Trajectory Model

Scientists used computer models to predict how spilled oil from the *Exxon Valdez* would travel across Prince William Sound, Alaska, during the first week after the spill in March 1989. Predicting the direction in which oil will spread from a spill is an important part of the response strategy. Trajectory models help guide recovery efforts by showing which locations are most likely to need resources, such as lengths of boom, to protect the shoreline. (Photo credit: OR&R, NOAA)

(top)

An Oily Mess HOME

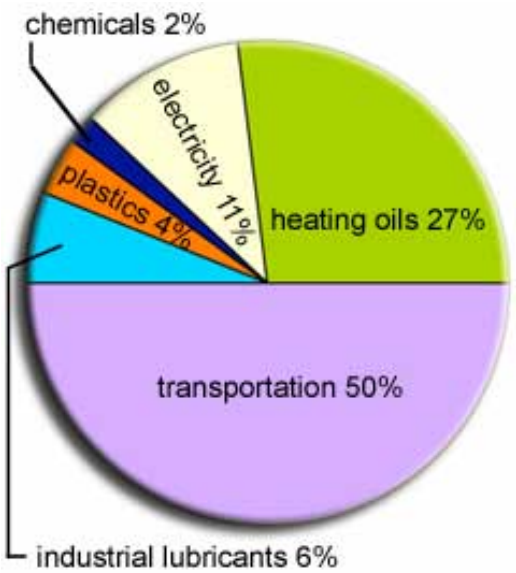
An Oil Spill Primer for Students

How much oil do we use and what do we use it for? | In the *Exxon Valdez* incident, how much oil was spilled? | How do oil spills happen? | What happens after oil hits the water? | Who takes care of the problem? | Who is ultimately responsible?

How much oil do we use and what do we use it for?

The United States uses about 700 million gallons of oil every day. The world uses nearly 3 billion gallons each day. That this much oil must be transported evey day is truly hard to imagine. However, if you think about all the ways we use oil, perhaps these numbers are not so surprising. We use oil:

- to fuel our cars, trucks, and buses, and to heat our houses.
- to lubricate machinery large and small, from bicycles to printing presses.
- to make the asphalt we use to pave our roads.
- to make plastics, such as the toys we play with and the portable radios and CD players we listen to.
- to make medicines, ink, fertilizers, pesticides, paints, varnishes, and electricity.



The worldwide uses of oil resources. (Source: Association of Plastics Manufacturers of Europe)

(top)

In the Exxon Valdez incident, how much oil was spilled?

The largest oil spill to occur in the United States so far was the *Exxon Valdez* spill into Prince William Sound, Alaska, in March 1989. The *Exxon Valdez*, a medium-sized oil tanker, ran aground on a reef to cause this spill of almost 11 million gallons of crude oil. While this was a big spill, it was actually only a small fraction of the oil—less than 2 percent—of what the United States uses in one day!

These big numbers are hard to relate to everyday life, so let's make some comparisons. To better understand how much 11 million gallons of oil is, check the table below. It shows how many familiar rooms or buildings would be filled up by the approximate amount of oil spilled from the *Exxon Valdez*. For example, that much oil would have filled up nine school gyms or 430 classrooms.

Total Volume	Gallons	Gyms	Houses	Classrooms	Living Rooms
Exxon Valdez Oil Spill	10,800,000	>9	108	430	797
School Gymnasium (50' X 50' X 65')	1,274,163	1	13	51	94
Average House (40' X 40' X 8')	100,365	0.1	1	4	7

Average Classroom (20' X 20' X 8')	25,091	0.02	0.25	1	2
Average Living Room (12' X18' X 8')	13,549	0.01	0.125	0.5	1

(top)

How do oil spills happen?

Oil spills are caused by accidents involving tankers, barges, pipelines, refineries, and storage facilities, usually while the oil is being transported to us, its users, via rivers, bays, and the ocean. Spills can result from:

- people making mistakes or being careless.
- equipment breaking down.
- natural disasters such as hurricanes.
- deliberate acts by terrorists, countries at war, vandals, or illegal dumpers.

(top)

Aerial photo of the Valdez Marine Terminal, where crude oil is loaded from the Trans-Alaska pipeline onto tankers for shipment to markets. It was here that oil was loaded onto the *Exxon Valdez* for shipment to Los Angeles. **Click image** for larger view and further details.

What happens after oil hits the water?

Oil floats on salt water (the ocean) and usually floats on fresh water (rivers and lakes). Very heavy oil can sometimes sink in fresh water, but this happens very rarely. Oil usually spreads out rapidly across the water surface to form a thin layer that is called an oil slick. As the spreading process continues, the layer becomes thinner and thinner, finally becoming a very thin layer called a sheen (or a film), which often looks like a rainbow. (You may have seen sheens on roads or parking lots after a rain.)

Depending on the circumstances, oil spills can be very harmful to marine birds and mammals, and can harm fish and shellfish. You may have seen dramatic pictures of oiled birds and sea otters that have been affected by oil spills. Oil destroys the insulating ability of fur-bearing mammals, such as sea otters, and the water-repelling abilities of a bird's feathers, thus exposing these creatures to the harsh elements. Many birds and animals also ingest (swallow) oil when they try to clean themselves, which can poison them. Depending on where and when a spill occurs, the number of injured and dead birds and mammals may range from only a few up to hundreds or even thousands.

(top)

The Amoco *Cadiz*, an oil supertanker, sinking off the coast of France in 1978. (Photo credit: OR&R, NOAA)

Who takes care of the problem?

Once oil has spilled, any of various local, state, and

federal government agencies, as well as volunteer organizations, respond to the incident. They may use any of the following kinds of tools to clean up spilled oil:

- booms, which are floating barriers to oil (for example, a big boom may be placed around a tanker that is leaking oil, to collect the oil).
- skimmers, which are boats that skim spilled oil from the water surface.
- sorbents, which are big sponges used to absorb oil.
- chemical dispersants and biological agents, which break down the oil into its chemical constituents.
- in-situ burning, which is a method of burning freshly spilled oil, usually while it's floating on the water.
- washing oil off beaches with either high-pressure or low-pressure hoses.
- vacuum trucks, which can vacuum spilled oil off beaches or the water surface.
- shovels and road equipment, which are sometimes used to pick up oil or move oiled beach sand and gravel down to where they can be cleaned by being tumbled around in the waves.

Which methods and tools oil spill responders choose depends on the circumstances of each event: the weather, the type and amount of oil spilled, how far away from shore the oil has spilled, whether or not people live in the area, what kinds of bird and animal habitats are in the area, and other factors. No two oil spills are the same. Different cleanup methods work on different types of beaches and with different kinds of oil. For example, road equipment works very well on sand beaches, but can't be used in marshes or on beaches with big boulders or cobble.

Responders also may set up stations where they can clean and rehabilitate wildlife. Sometimes, government agencies or other organizations may decide not to respond at all, because in some cases, responding isn't helpful or even adds to the damage. In the United States, depending on where the spill occurs, either the U.S. Coast Guard or the U.S. Environmental Protection Agency takes charge of the spill response. They, in turn, often call on other agencies, such as NOAA and the U.S. Fish and Wildlife Service, for help and information.

The goal of new federal regulations is to prevent oil spills from happening. People who cause oil spills must pay severe penalties, and the regulations call for safer vessel design in the hopes of avoiding future

During a response, NOAA spill specialists record information about oil slicks in photographs and overflight maps of the area surveyed. This photo, taken during an overflight, shows a streamer, or slick, of brown, emulsified oil, with silver and gray sheen along its edges. **Click image** for larger view and further details.

Workers spray dispersant over spilled oil. Dispersants are chemicals that break oil into small droplets that decompose faster; however, they don't work well if the oil is too viscous. Spill response specialists use on-site observations and model predictions to find out when conditions are best for applying dispersants. (Photo credit: OR&R, NOAA)

Volunteers clean a common murre (*Uria aalge*) that was oiled during the *Exxon Valdez* spill. Birds like this one often do not survive oiling, even when they have been cleaned, so it is important to protect them from oiling whenever possible. (Photo credit: OR&R, NOAA)

spills from ships. In the U.S., agencies that respond to oil spills must practice by conducting training drills, and those who manage vessels and facilities that store or transport oil must develop plans explaining how they would respond to a spill, so that they can respond effectively to one if they ever need to.

(top)

Who is ultimately responsible?

Because oil and oil products in the environment can cause harm, we need to prevent problems when we can. For example, by avoiding dumping oil or oily waste into the sewer or garbage, we avoid polluting the environment we live in. Sometimes, we can find ways to avoid using oil in the first place: we can bicycle, walk, or take the bus rather than taking a car to some of the places we need to go. When we use less oil, less needs to be transported, and there's a lower risk of future oil spills. We should understand that it is because we rely on oil that we run the risk of oil spills. That means that all of us share both the responsibility for creating the problem of oil spills and the responsibility for finding ways to solve the problem.

Workers from the National Ocean Service's Office of Response and Restoration clean an oiled, rocky beach with high-pressure, hot-water hoses. (Photo credit: OR&R, NOAA)

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How Toxic is Oil?

Assessing the toxicity of oil can be a tricky business. The main difficulty is that "oil" is typically a mixture of many different chemicals. Proportions in the mixture vary even within a single category of oil, like crude oil. For example, Arabian crude oil differs in composition from Louisiana crude oil, which differs from Alaska North Slope crude oil.

Most of the oil residue scientists find in Prince William Sound originated with the *Exxon Valdez* spill. Other potential sources scientists have identified include diesel fuel, nonspecific combustion sources that could include anything from wood stoves to vessel exhaust, and spilled oil not linked to the *Exxon Valdez*.

- Oiled wildlife often dies because oil fouls fur and feathers and destroys their insulation value. Birds and mammals die of hypothermia (they get too cold).

- Some animals eat the oil while trying to clean it off their fur or feathers, or while scavenging on dead animals. Oil is toxic when ingested and can cause sickness or death.

- The oil impacts some animals in ways that don't result in a quick death. It may cause liver damage or blindness, for example. A sick or impaired animal cannot compete for food or avoid predators. Oil can also impair reproduction.

- Smaller organisms, such as aquatic invertebrates (barnacles, periwinkle snails, polychaete worms, clams, etc.), can be smothered by a thick layer of oil washing ashore. These organisms are very important food sources for many organisms, especially insectivores such as fish and birds. Aquatic invertebrates are often important indicator species - scientists use their presence and abundance as indicators of the overall health of an ecosystem.

- Oil also changes the physical environment for plants and animals by forming hard,

Various dead, oiled wildlife collected in Prince William Sound, Alaska, in March 1989. (Photo credit: *Exxon Valdez* Oil Spill Trustee Council)

Oiled sea otter on shore in Prince William Sound. (Photo credit: *Exxon Valdez* Oil Spill Trustee Council)

An example of asphalt "pavement" is seen here as a thick, black deposit on a beach face in Prince William Sound. Such pavements consist of cohesive, heavily oiled surface sediments. (Photo credit: OR&R, NOAA)

asphalt-like pavements, which cover and smother the vegetation and other living things that organisms depend on for food, water, and shelter. Sometimes, the environment has been so extensively altered that the organisms can no longer survive in their old habitat. Imagine a sea otter or a shorebird trying to live on a paved parking lot!

The oil from the *Exxon Valdez* killed or injured many marine organisms in these ways, but no one knows exactly how many died as a direct or indirect result of the spill. Scientists do know that the carcasses of more than 35,000 birds and 1,000 sea otters were found after the spill. These numbers do not include the carcasses that quickly sank into deep waters following the spill, which are thought to be the majority. So, these numbers probably represent only a small fraction of the actual death toll. The scientists' best estimates are that 250,000 seabirds, 2,800 sea otters, 300 harbor seals, 250 bald eagles, up to 22 killer (orca) whales, and billions of salmon and herring eggs died immediately following the spill (source: *Exxon Valdez* Oil Spill Trustee Council).

Scientists studying the effects of the *Exxon Valdez* oil spill on survival and reproduction in Alaskan sea otters carefully take a blood sample from an anesthetized otter. (Photo credit: Paul Snyder, Purdue School of Veterinary Medicine)

It is even more difficult to estimate the number of organisms that may have died from the indirect or long-term effects of oil in the environment. Since that fateful day in 1989, some species have fully recovered from the effects of the spill, but others are still recovering. However, it is difficult to know when a population has "recovered" because it is difficult to distinguish natural changes from the impacts of the oil.

Cleanup workers hose down a rocky shore with hot water under high pressure. Do their presence and the cleanup activities cause more harm than good? (Photo credit: *Exxon Valdez* Oil Spill Trustee Council)

You may ask, ***didn't the cleanup efforts improve the situation following the spill?*** This complicated question is also difficult to answer. Because of the *Exxon Valdez* oil spill, scientists now know that their attempts to clean up an oil spill can also indirectly cause harm to some of the resources they are trying to protect. For example, using hot water or chemicals to remove oil can harm plants and animals. In addition, simply sending a team of cleanup workers into an oiled area can trample sensitive organisms and mix oil more deeply into a beach. The experts who respond to oil spills consider all of these potential problems when evaluating the trade-offs of how far to go in removing spilled oil.

Can you think of other human activities meant to help threatened wildlife that might, in fact, cause more harm than good?

Return To How Much Oil Remains

Fingerprinting Oil

This photograph shows a heavily impacted rocky beach in Prince William Sound showing pools of unweathered surface oil just days after the spill. (Photo credit: OR&R, NOAA)

The chemical composition of oil found in the environment yields important clues about where it came from. The process of determining where an oil residue originated is what scientists call "fingerprinting" or "source fingerprinting." Source fingerprinting is a complex procedure that is part art and part science, relying both on the experience of the analytical chemist and on the results of ratios between certain components in a mix. Similar to the literal uses of fingerprinting, experienced chemists can analyze the evidence left at a "crime scene" (spill site) to make a reasonable determination of "whodunit"—that is, if a residue is, in fact, oil, where it might have originated, and, possibly, who spilled it. For example, the U.S. Coast Guard uses such forensic methods to determine whom the "responsible party" is when an oil spill with no known source washes up on a shoreline.

Most of the oil residue scientists find in Prince William Sound originated with the *Exxon Valdez* spill. Other potential sources that scientists have identified include diesel fuel, nonspecific combustion sources that could include anything from wood stoves to vessel exhaust, and spilled oil not linked to the *Exxon Valdez*.

Weathering

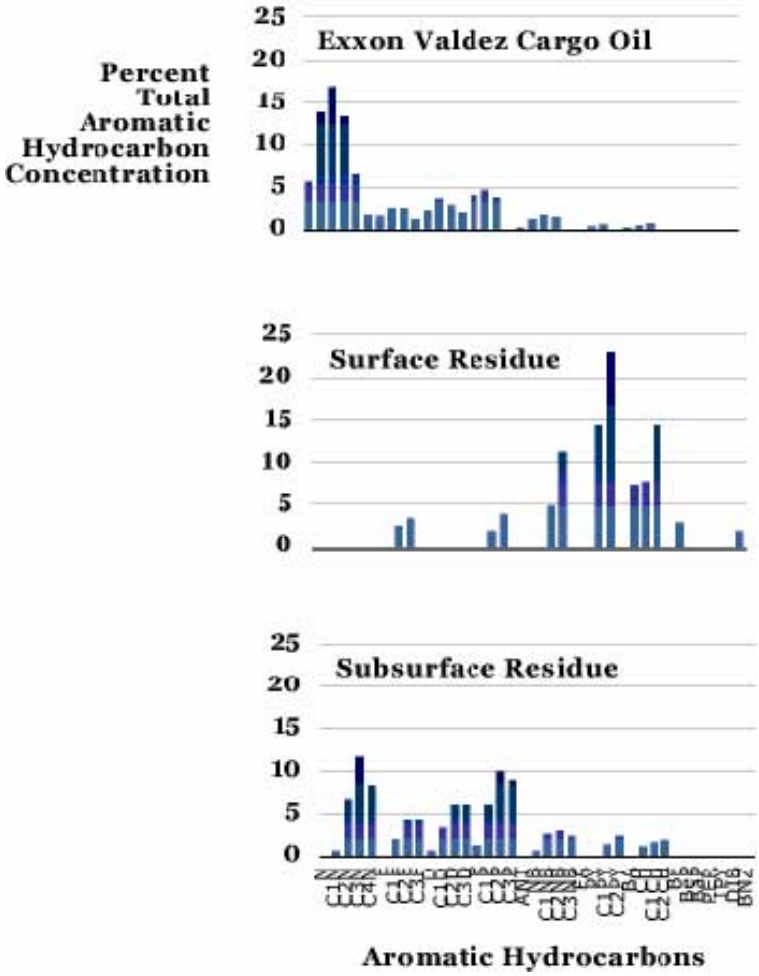
Oil is a mixture of many different chemicals. Not only does each chemical have its own toxicity, but each also behaves differently in the environment.

- Some components are much more volatile than others, and so they tend to evaporate more rapidly when oil is spilled.
- Some components of oil are more easily broken down by microorganisms on the beaches.
- Sunlight can also degrade oil components (called photolysis).

The sum of these physical and

biological processes results in what scientists call "weathering" of the oil, which is reflected in the changes in chemical composition of oil residues over time. The more closely the chemical composition of a residue resembles that of the unspilled oil, the "fresher" it is. In Prince William Sound, chemists tell us that the remaining *Exxon Valdez* oil ranges from very weathered to relatively fresh. What does this mean? In general, scientists have found that the more exposed to the elements the oil is, the more rapidly it weathers. Accordingly, the least weathered oil can still be found under the surface, or as buried residues of the original oil.

(top)



Differences in composition of oil from the *Exxon Valdez* tanker, and surface and below surface (subsurface) residues found in 1994. Notice that the subsurface oil, buried and thus protected from many weathering processes, resembles the original oil much more than the surface residue. Also notice that oil is composed of a mixture of chemicals (each bar is a different hydrocarbon).

Prince William's Oily Mess: A Tale of Recovery

Working With Real Data:
Graphing Changes in Marine Life Abundance

Welcome to *Working with Real Data!* In this hands-on activity, students work with real data collected by scientists at NOAA's National Ocean Service, who are studying the ecological **recovery** of Prince William Sound following the *Exxon Valdez* oil spill. From photos of sampling **quadrats** at Mearns Rock, an oiled shoreline **boulder**, students record the **abundance** of marine **intertidal** organisms, graph the data and interpret their results. (All bolded terms are defined in the **Glossary Express** at the end of this document.)

Start with **STEP 1a** below…

STEP 1a: Read the Introduction

Want to try your hand at some marine biology? Then grab your raingear and follow steps 1, 2, 3 & 4 to make a study of the **marine** life occupying a **quadrat** of Mearns Rock. A quadrat is a small sampling plot or area that is designed to represent a larger area that is being studied. Mearns Rock is a boulder in Prince William Sound, Alaska, that was oiled in 1989 by the *Exxon Valdez* oil spill. For your study, you'll use a series of close-up photos of the quadrat, each showing a different year from 1990 to 2004. Your goal will be to see how the **percent cover** of **mussels**, **barnacles**, and *Fucus gardneri* (a kind of seaweed, also called rockweed) in this study area has changed during those 15 years.

As you complete this project, you'll be using the same method used by real marine biologists. To study how marine life **abundance** changes from one year to the next, marine biologists sometimes section off a small plot of land that's representative of the particular habitat they're studying (for example, a rocky shoreline or a beach). They use a frame (generally a 0.25 or 0.5 square meter of PVC pipe), known as a quadrat, which they place on the ground to mark an area to study in depth. Each year, the biologists return to count the organisms or plants that occupy the area inside the quadrat. In most studies, many quadrat samples are necessary to adequately represent the whole area. In the photo at the left, a NOAA marine biologist is using a quadrat in his studies of the Mearns Rock site. He's trying to find out how the abundance of *Fucus*, barnacles, mussels, and other organisms has changed since the year before.

STEP 1b: Learn the Organisms

Use the field guide on PAGES 3-5 to learn more about the organisms that you will later observe in the Mearns Rock quadrats. The photo on PAGE 3 of the field guide shows representative patches of three common marine, **intertidal** organisms that live on Mearns Rock: *Fucus* (a type of algae), barnacles and mussels.

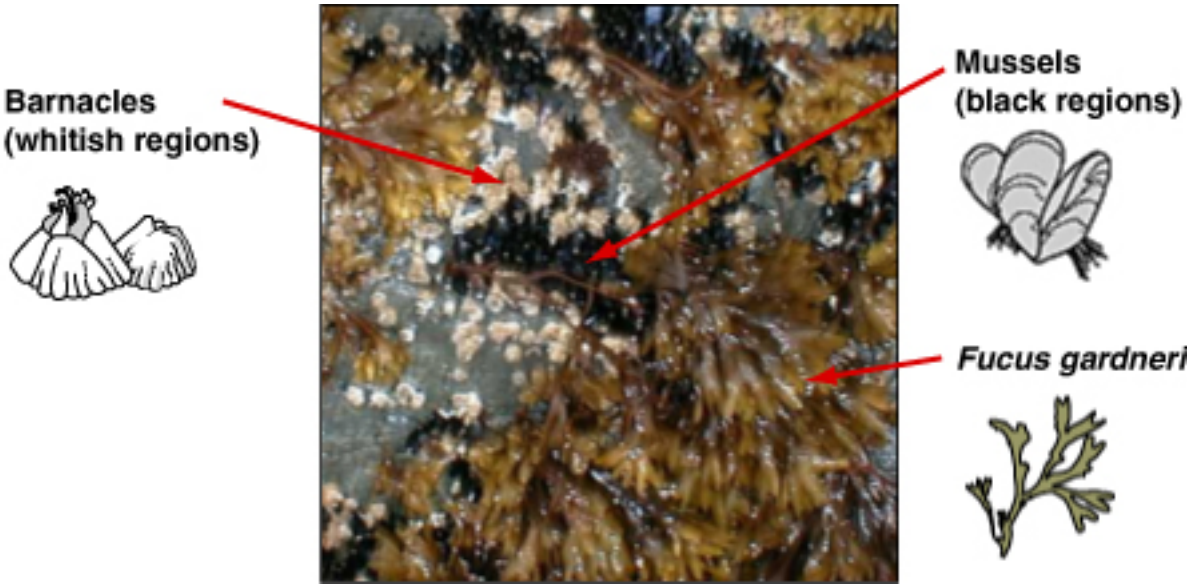
Then, scroll down to PAGES 4 and 5 to read more about the biology of these three life forms. Later, you'll observe these organisms in the photos of the Mearns Rock **quadrats**, estimate their **percent cover**, and establish the criteria you'll use to make your observations.

Mearns Rock Field Guide

Rockweed (Fucus)

Mussels

Barnacles



Rockweed *(Fucus gardneri)*

Fucus (pronounced like mucus) is a type of brown algae that grows in the middle- to upper-intertidal zone (the higher part of the tidal flat) of cold ocean waters. The body of the alga is composed of flattened "branches," some of which end in swollen receptacles that house reproductive parts (eggs and sperm). *(Fucus* is sometimes called "popweed." Can you guess why?) The holdfast, at the base of the alga, attaches it to the rocks on which it lives. Because *Fucus* is sometimes out of water for hours at a time when the tide is low, it has a thick "skin" that helps it keep its moisture, and it makes a sticky substance to keep from losing water. In late spring and summer, in locations where *Fucus* grows well, it may nearly cover all other intertidal organisms!

Mussels *(Mytilus trossulus*, the Pacific Blue mussel)

Mussels are bivalves (their bodies are enclosed by two shells, or valves) that can be found firmly attached to rocks, floats, and pilings. A mussel stays attached to the substrate by its byssus, a collection of tough, leathery threads of organic material secreted by the mussel. Adult *M. trossulus* range from 3 to 10 cm in length and can vary considerably in color. Generally, the shell is dark blue-black or brownish black, but the shell of young mussels is often brown. Like many other bivalves, mussels are filter feeders, pulling water into their body chambers with their inhalent, or intake, siphon (the larger, frayed-edge gape on the upper edge of the mussel), and then forcing it out the exhalant, or exhaust, siphon (which is smaller and has a smooth edge). Dense masses formed by mussels provide protection and other biological necessities for many organisms, such as small shrimp, amphipods, and polychaete worms. Mussel beds also serve as a substrate to which barnacles may become attached.

Barnacles *(Balanus glandula)*

Barnacles are tiny crustaceans (animals related to crabs, lobsters, and shrimps) that occupy volcano-like shells. They colonize rocks, pilings, and even boats, by attaching masses of their whitish-colored shells to the substrate. The shell of *B. glandula* consists of a number of overlapping plates. The barnacle controls the opening at the top of the shell by moving these plates. A large *B. glandula* is about 1.5 cm across, with its diameter about the same as its height. In large masses, you may notice that the barnacle shell is more cylinder-shaped than volcano-shaped. (Why do you think that is?) The barnacle feeds by using six feather-like appendages, called cirri. As the cirri rapidly extend and retract through the opening at the top of the barnacle, they comb the water for microscopic food.

Reference

Kozloff, Eugene N. 1973. Seashore Life of Puget Sound, the Strait of Georgia, and the San Juan Archipelago. Seattle, WA: University of Washington Press. 282 pp.

STEP 1c: State Your Predictions!

The next step is to state and write down your **prediction(s)** about the results you expect once you collect the data.

Predictions are always stated BEFORE seeing your data. Making predictions is usually the first step in a scientific investigation (perhaps your teacher will explain why this is the case). Before you even look at the photos of the quadrats, you should write down at least one prediction. For example, you could make a prediction about the percent cover for each species. Here is an example:

> **I predict that as time goes on, mussels will come to dominate the percent cover (it will be >50%) because...**
>
> After the "because..." you should state WHY you think this predication will be true (this is called the rationale for the prediction).

Don't worry whether your predictions are "true" or "false." You are simply making a statement of expectation based on your **hypothesis**, which scientists always assume is true (and so should you).

> *By the way...**What is your hypothesis here?***

STEP 2a: Observe Mearns Rock Photos and Quadrats

The goal in this step is to familiarize yourself with the two types of photo data you will see in this exercise.

First, photos of the Mearns Rock quadrat from 1990 to 2004 are located on **PAGES 18-26**. Second, photos of Mearns Rock (in its entirety) from 1990 to 2004 are located on **PAGES 27-44.** Quickly look through some of these photos and learn to navigate on these pages. Don't worry about reading all the accompanying text for now—you will return to this section later to do that.

Later, you will go back to the quadrat photos to estimate the **percent cover** (i.e. abundance) of each organism. You will refer back the Mearns Rock photos at the very end of this activity to help you interpret your data.

But first, you will need to collect a few resources in order to record your data. **Proceed to Step 2b** to gather these resources and begin recording your data.

STEP 2b: Record Your Data

Before you begin collecting data, you need to gather the resources necessary to record your data from the quadrat photos. You should do the following:

Data Table - **Print out the Data Table on PAGE 14, if you have not done so already**.

You'll use it to record your estimates of percent cover of *Fucus*, mussels, and barnacles in the Mearns Rock quadrats from 1990 to 2004.

Charts - **Print out the Percent Cover and Color Charts on PAGE 15, if you have not done so already.**

You'll use these charts as an aid for estimating the percent cover of a particular form of marine life in the quadrat you are observing.

Tips for Collecting Data

Because the Mearns Rock quadrat photos were taken at different times of day and under different weather and light conditions, they vary in their color and clarity.

Watch for four color ranges to identify the marine life:

Gray areas tend to be bare rock.

Black areas are often mussels.

Areas that range from green to gold to brown are often *Fucus gardneri* (rockweed or popweed). Young *Fucus* plants are greener in color; mature plants are browner.

White or light gray regions tend to be barnacles.

Establish Observation Criteria

As you look through the photos, you will note that algae or seaweed sometimes covers much of the rock, possibly hiding barnacles and mussels from view. Before making your estimates, first establish the criteria that you'll follow. For example, consider basing your observations on "what's visible" rather than on your best guess of what might be living underneath something else. Also, consider the intense competition for space that exists among marine life forms in the intertidal region. For example, if sea otters clear mussels off a section of the rock, that opens space for barnacles, *Fucus*, or other organisms to "move in" to that space. You'll see several examples in these photos.

Time to Get Started!

You are now ready to open the series of high-resolution photos of the same quadrat of Mearns Rock, taken each year from 1990 to 2004. As you examine each quadrat photo, you will estimate how much of the quadrat *Fucus* occupies (as a percent of the total area), how much of the quadrat mussels occupy, and how much of it barnacles occupy. Record your estimates in the data table you printed out earlier.

Use your printout of the **Percent Cover Chart** and the **Color Chart** as an aid in estimating the percent cover of each organism on the quadrat you are observing. Think of the black areas in the Percent Cover Chart as representing one of three life forms you learned about earlier in the field guide.

Now, go to the quadrat photos located on PAGES 18-26 to start recording your data!

STEP 3a: Plot Your Data

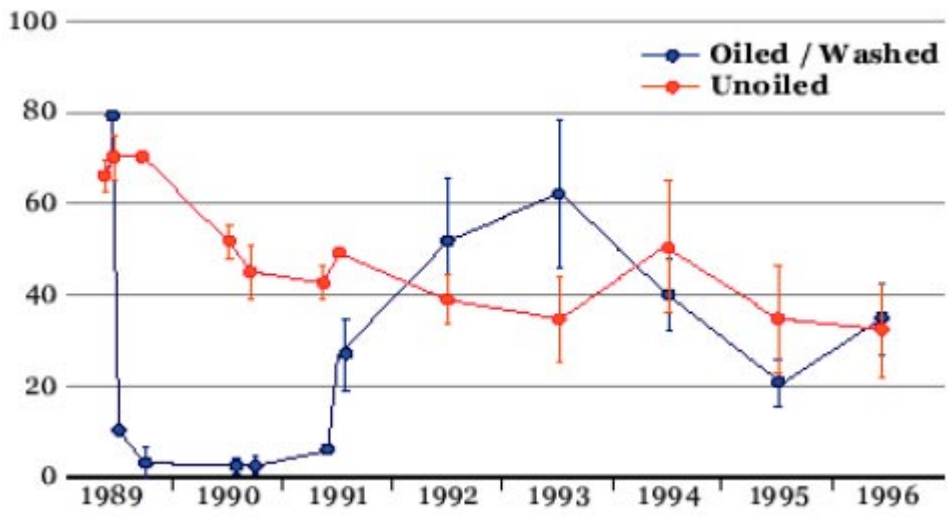
Your next step is to graph your data so that you can see trends over time in the **relative abundance** of the three organisms in the quadrat. **Relative abundance** is the number of individuals of a species compared to the abundance of all the other species. Your graphs will look similar to those that marine **ecologists** make after actually measuring the amount of **cover**.

▶**Graphs for Plotting** - **Print out the timeline graphs on PAGES 16-17.** You'll plot your data from the data table on these graphs.

STEP 3b: View An Example Graph

The graph below was prepared by a marine biologist, and looks much like the graphs you'll prepare as you complete this project. Below is the comparison of rockweed cover at middle elevation unoiled sites and oiled/washed rocky sites, 1989-1996. Washed sites were cleaned by hot-water washing during the months after the spill.

Mean Percent Cover of a 0.25 Square meter Quadrat



Summary of *Fucus gardneri* Abundance

This graph shows mean percent *Fucus gardneri* cover of 0.25 square meter quadrat from 1989 to 1996. Abundance is plotted for these categories: oiled/washed and unoiled. The data for oiled/washed sites show a steep decline in cover in 1989 after treatment. Mean abundance of oiled/washed *Fucus* dropped from a high of 80% cover per quadrat in 1989 to a low of less than 5% in 1990. Abundance then steadily increased to a high of over 60% in 1993. Cover again declined, reaching a low of about 20% in 1995, then increasing to about 35% in 1996.

The abundance of unoiled *Fucus* fluctuated somewhat during the same period, but gradually decreased from about 70% cover per quadrat in 1989 to just over 30% in 1996. Although the steep decline in *Fucus* cover in 1989 at oiled/washed sites almost certainly reflects the impact of oil and treatment, the other fluctuations are more difficult to explain. This is true for oiled/washed sites, as well as control sites.

Step 4a: Interpret Your Data and Write a Scientific Report

Interpret Your Data

Now, look at the trends that your graph reveals.

What can you conclude about the relative abundance of different organisms in your study area?

To help you interpret your data, **go to the Mearns Rock photos on PAGES 27-44** and read the NOAA biologists' explanations of the year-to-year changes they have observed on Mearns Rock. This will help you in interpreting your data.

Write a Scientific Report

Your teacher may have you, or your team, write a scientific report. It should have the following sections:

	What is this report about? Why are you, or your team, writing this report? What should readers expect to learn from this report? What is your hypothesis? What is (are) your prediction(s) and the **rationale** behind them. Research on Background Information: • What is the **intertidal zone**? • Where are intertidal zones located? • What type of plants and animals live there? • What are some interesting facts about these species? • And so on... Purpose/Problem • What is the question that scientists are asking about Mearns Rock? • Why are scientists conducting a study of Mearns Rock? • How long has this study been occurring? • Why are scientists studying these species? • Why do scientists sample at the same time each year? • And so on...
Procedure	Explain how you or your team recorded data from the

	photographs of quadrats of Mearns Rock (use a step-by-step format).
	Keep accurate records using the data table provided. You will want to include your graphs of these data in your report.
	• Put your table of data, your graphs, and the photos of the quadrats on Mearns Rock side-by-side on the tabletop. Review each and ask yourself: As time passes, what do you observe about the percent cover of each organism living on Mearns Rock • Considering your data and graphs, answer the following questions: Did the prediction(s) you made before you began this study turn out to be true or false? How does this reflect on your hypothesis? Did your data support or refute your hypothesis? • What can the results of the Mearns Rock study tell us about other locations in Prince William Sound? • How can studying Mearns Rock help us to learn about oil spills in other locations in the world? • Explain how Prince William Sound has or has not recovered from the *Exxon Valdez* oil spill. • What questions do you still have that you would like to explore yourself or discuss with a scientist?

Step 4b: Share What You Have Learned

Scientists share their results with each other at scientific conferences. Your teacher may have you, or your team, share your findings with your classmates at your very own scientific conference. Each team member will present a section of your scientific report at the conference.

For example, Dr. Mearns has shared the results and conclusions of his studies in Prince William Sound at several conferences, including the *Exxon Valdez Oil Spill Symposium*, which was hosted by the American Fisheries Society in Anchorage, Alaska in 1993. He was an author on three chapters in the proceedings published on the symposium. Here is the citation for one of his chapters:

Mearns, A.J. 1996. *Exxon Valdez* Shoreline Treatment and Operations: Implications for Response, Assessment, Monitoring, and Research. Pages 309-328 *in* S.D. Rice, R.B. Spies, D.A. Wolfe, and B.A. Wright (editors). Proceedings of the *Exxon Valdez* Oil Spill Symposium. American Fisheries Society Symposium 18. An abstract for this chapter and all the chapters published in the Proceeding

Mearns Rock as it appeared in 2003—fourteen years after the *Exxon Valdez* oil spill. (Photo credit: OR&R, NOAA)

Glossary Express

(Glossary terms in the text are bolded)

Abundance—*the total number of individuals of a species present in an area.*

Barnacles—*marine crustaceans with feathery appendages for gathering food that are free-swimming as larvae but permanently fixed (to rocks, boat hulls or whales) as adults.*

Boulder—*a mass of rock greater than 256 millimeters in diameter.*

Cover—*referring to the amount of plants or other organisms that are occupying the ground, a rock or other surface.*

Ecology—*the study of the relationship among organisms and between organisms (the biological environment) and their physical environment.*

Hypothesis—*an idea or explanation that is based on observations and that can be tested; a suggested explanation for an observation often stated in the form of a question that can be answered by the results of an experiment.*

Intertidal—*on a beach, the area between high tide and low tide.*

Marine—*relating to the seas and oceans.*

Model—*an abstraction or simplification of a natural phenomenon developed to predict a new phenomenon or to provide insight into existing ones.*

Mussels—*a bivalve mollusk usually having a dark elongated shell.*

Percent Cover—*the proportion (in percent) of a certain species or group of species that is occupying a surface such as the ground, a rock, etc.*

Prediction *(or "to predict")— A scientific model to explain what happens, and why it happens; an indication in advance based on observation, experience, or scientific reason.*

Quadrat—*a small plot or sample of land that is representative of the particular habitat that is being studied. Often the plot of land is demarcated using a frame made of PVC pipe or other material.*

Rationale—*an underlying reason.*

Relative Abundance—*the proportion or numbers of a species compared to the total number of individuals of all the species in the community or sample.*

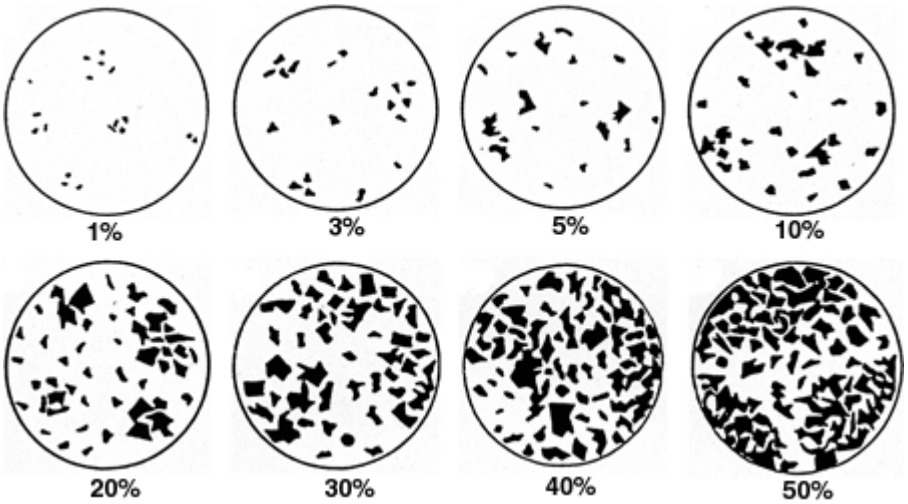
Data Table

Print this table, then use it to record your best estimate of the percent cover of *Fucus gardneri*, mussels, and barnacles from 1990 to 2004. We assume that the percent cover of each species was 0 in 1989. To help you "calibrate" your estimates, we've included our estimates of percent cover in 1990.

Year	*Fucus gardneri* (percent cover)	Mussels (percent cover)	Barnacles (percent cover)
1989	0	0	0
1990	50	5	5
1991			
1992			
1993			
1994			
1995			
1996			
1997			
1998			
1999			
2000			
2001			
2002			
2003			
2004			

Percent Cover Chart

Use this chart as an aid for estimating the percent cover of a particular form of marine life in the quadrat you are observing. Think of the black areas in the chart as representing one of the three marine life forms you're studying.



Color Chart

Because the Mearns Rock quadrat photos were taken at different times of day and under different weather and light conditions, they vary in their color and clarity.

Watch for four color ranges to identify the marine life:

Gray areas tend to be bare rock.

Black areas are often mussels.

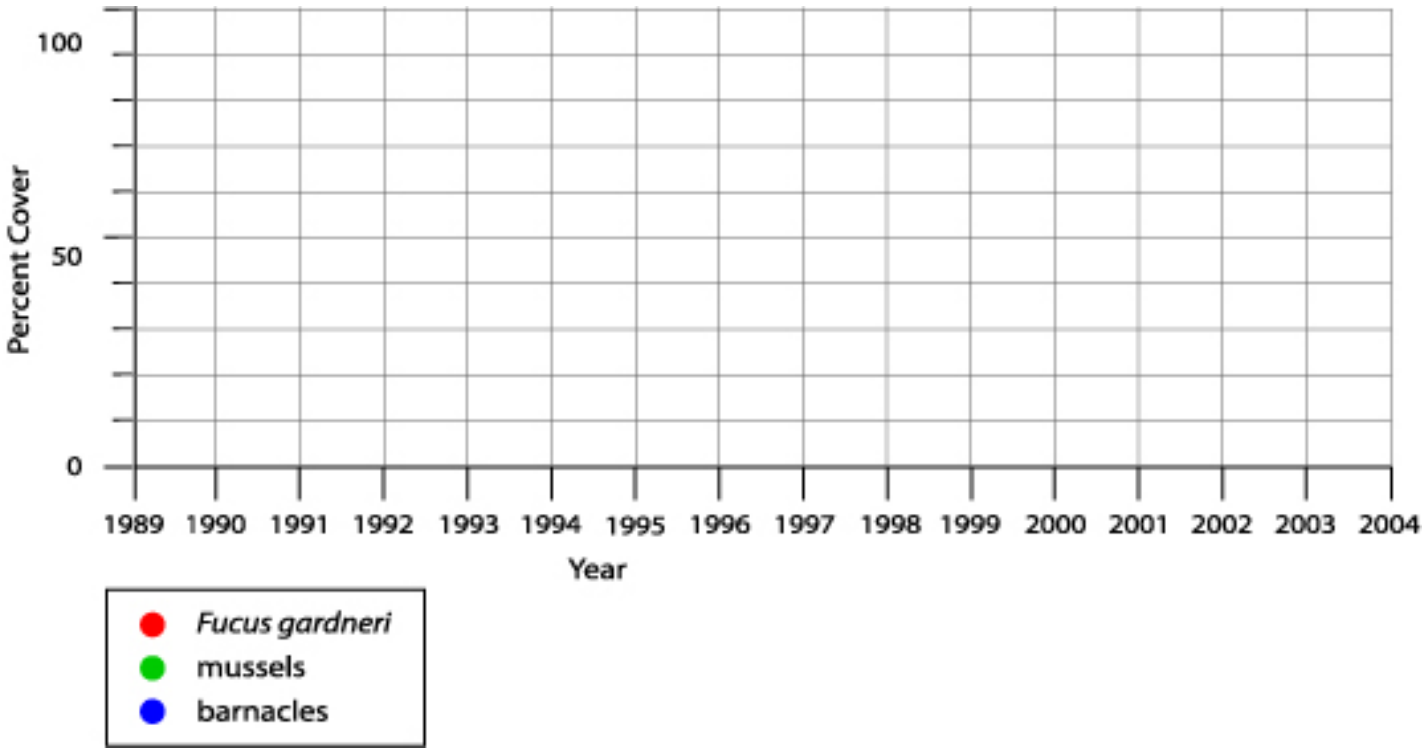
Areas that range from green to gold to brown are often *Fucus gardneri* (rockweed or popweed). Young *Fucus* plants are greener in color, mature plants are browner.

White or light gray regions tend to be barnacles.

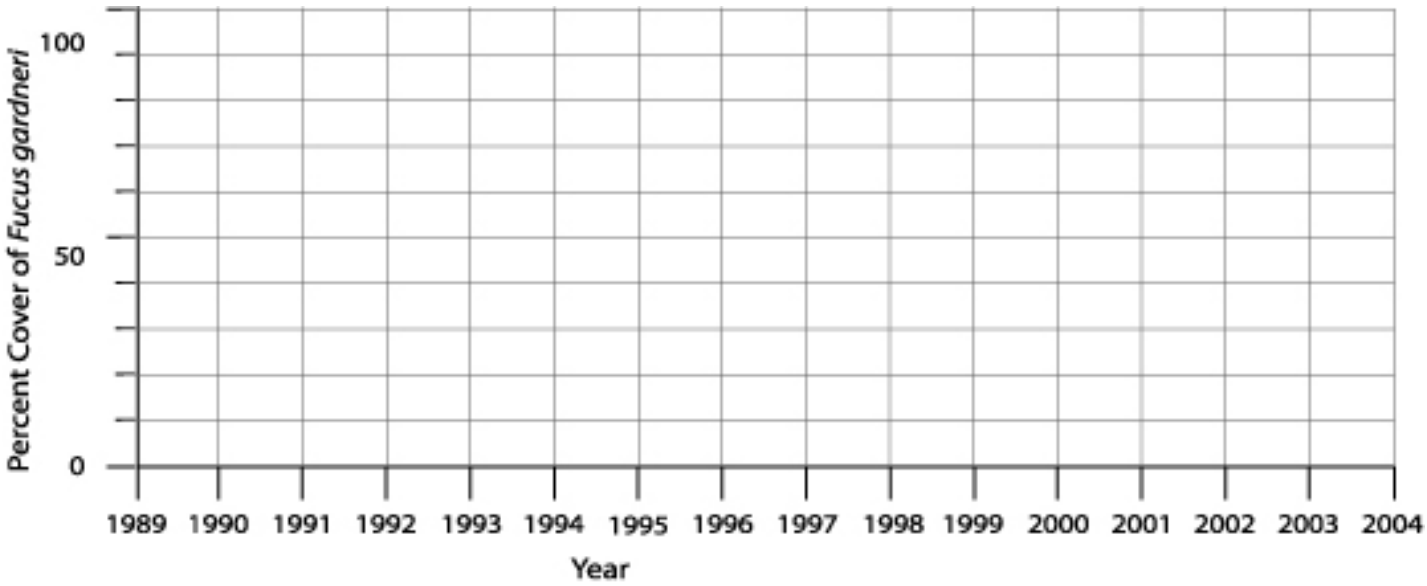
Plotting Your Data

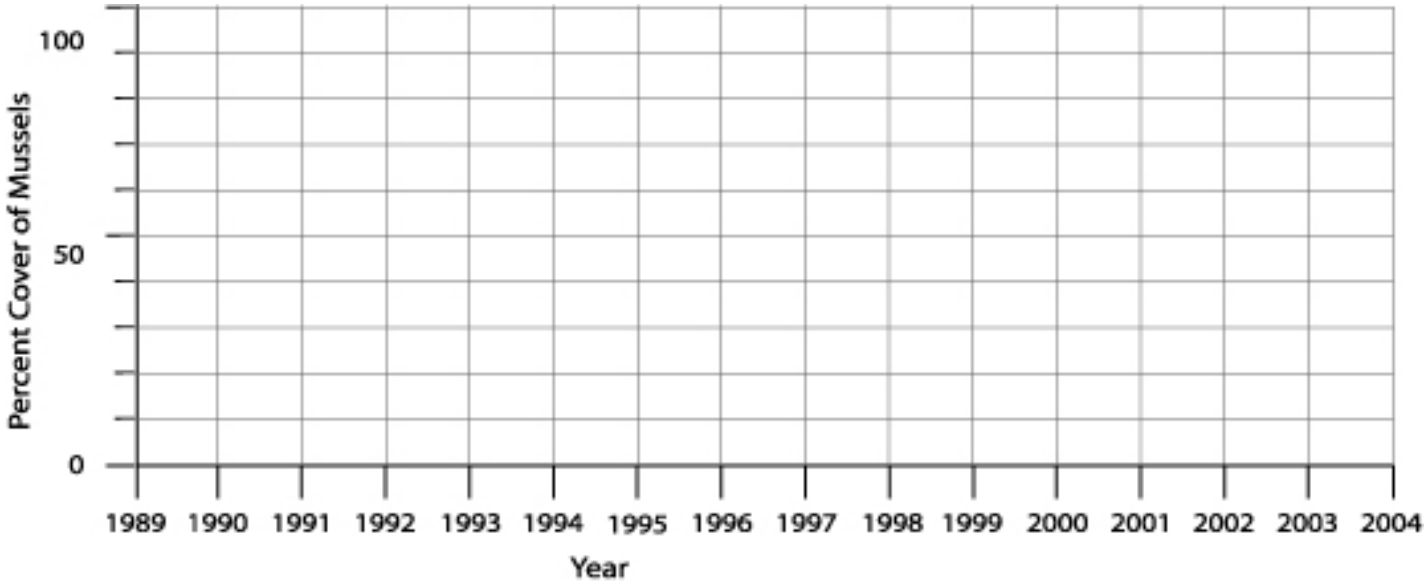
Print this page, then choose either **graph set (a)** to plot the percent cover of *Fucus*, mussels, and barnacles on one graph, or **graph set (b)** to plot the percent covers on separate graphs.

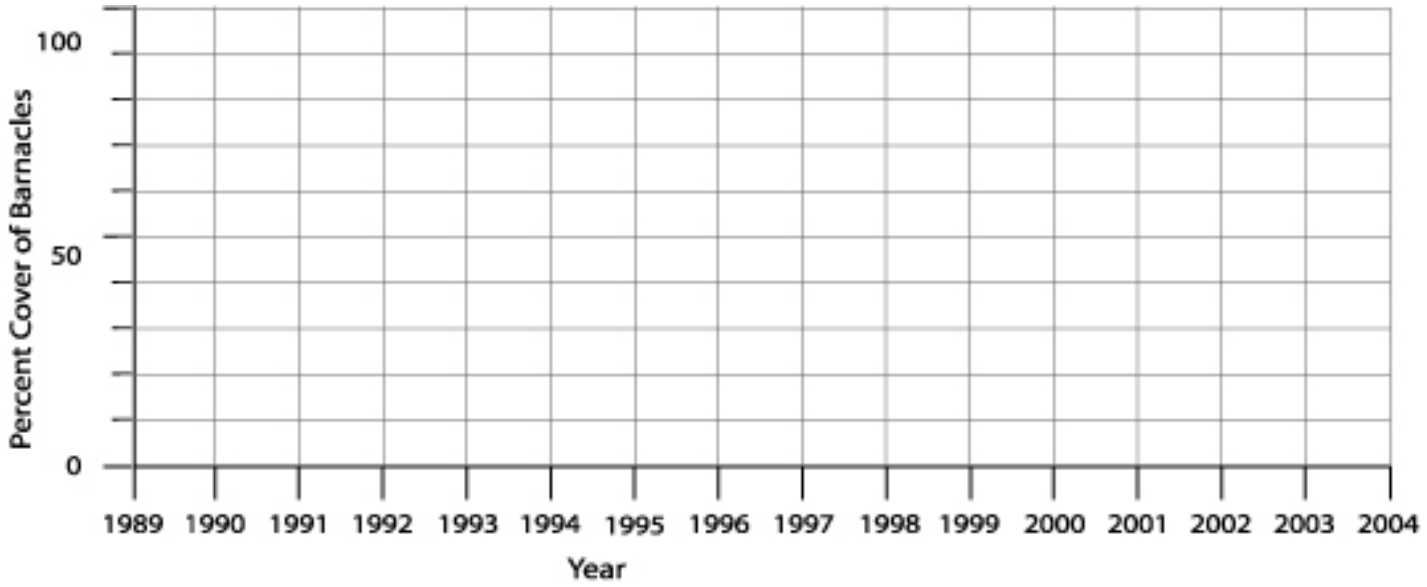
(a)



(b)




100
50
0
Percent Cover of Mussels
1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
Year


100
50
0
Percent Cover of Barnacles
1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
Year

Mearns Rock Quadrat Photos

1990

1991

1992

1993

1994

1995

1996

1997

1998

1999

2000

2001

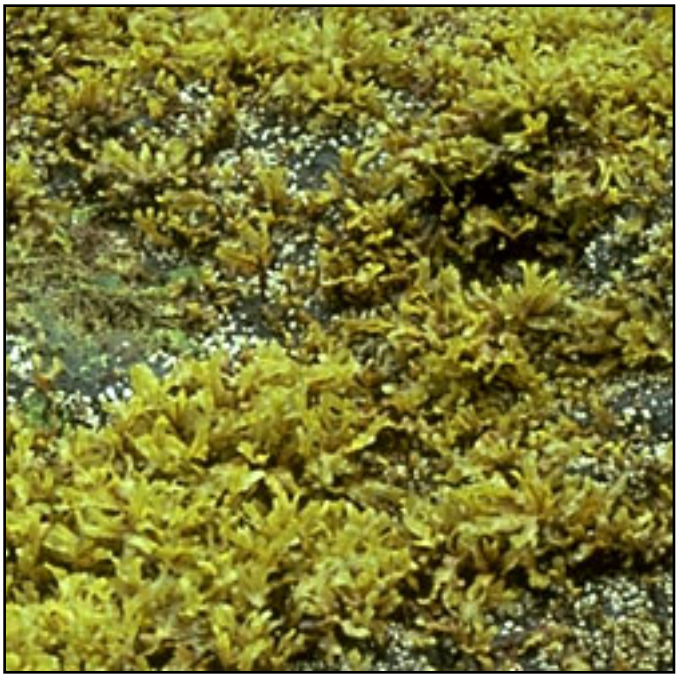
2002

2003

2004

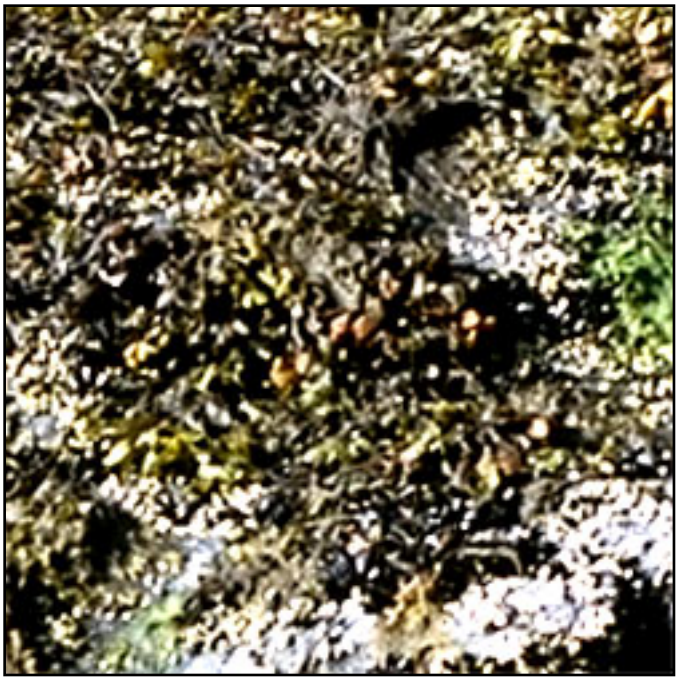
Introduction
We chose a representative section of Mearns Rock to show you at high resolution. Each of the photos in this series is a closeup of the region approximated by the quadrat shown in red below.

To view the photos, click the link to any year, at left.



1990: In this photograph, you can see the young *Fucus* plants that almost covered the boulder in 1990, as well as young barnacles, which appear as tiny, white spots. We think the dark region in the upper right section of the quadrat may be young mussels.

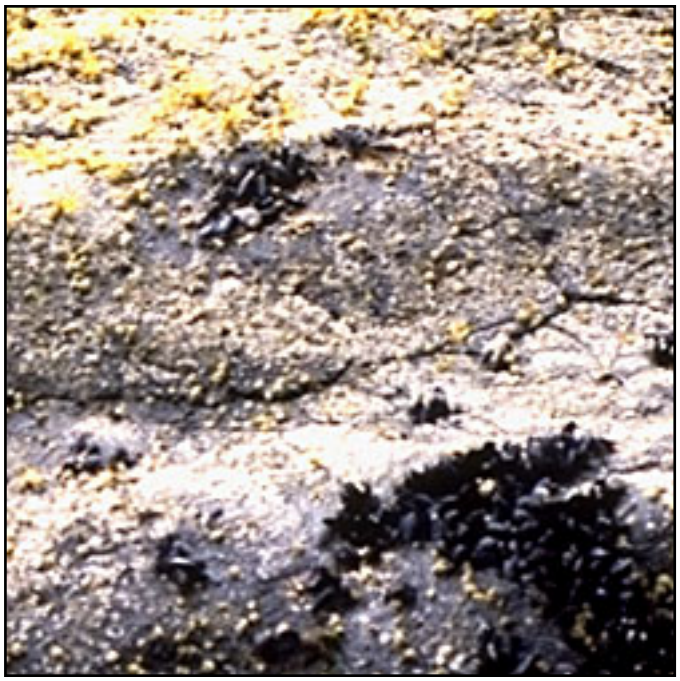
1991: Although this photo is unclear, we can see more mature, gold-brown *Fucus* and dark-colored juvenile mussels in this photo. Some of the small, very light, circular patches may be barnacles.



1992: Larger, older seaweed (mainly *Fucus*) is dying off. Light-colored barnacles are filling in spaces left by dying seaweed. The mussels appear larger now.

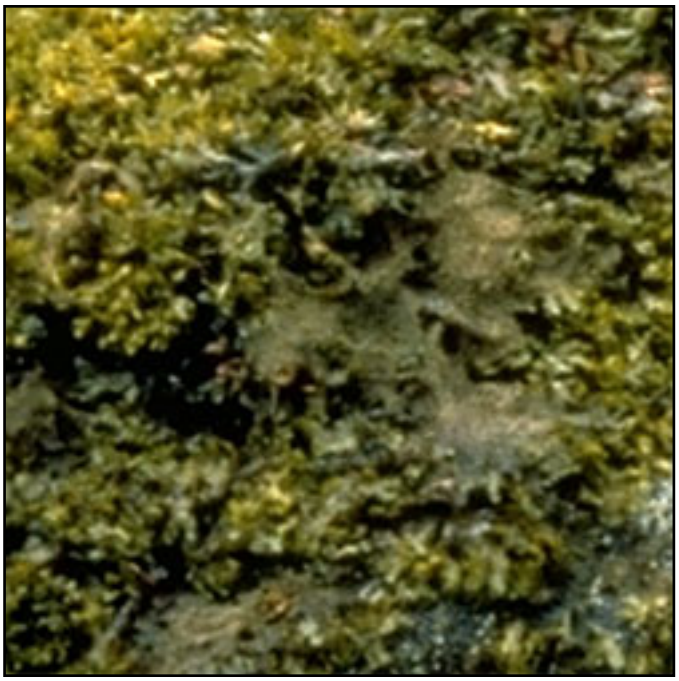
1993: In this photograph, dark patches of mussels have taken hold on the boulder. Also visible are whitish patches of barnacles and, in the upper section of the photo, young, gold-brown *Fucus* plants.

1994: The quadrat is dominated by mature mussels. A few barnacles are visible, but no *Fucus*!

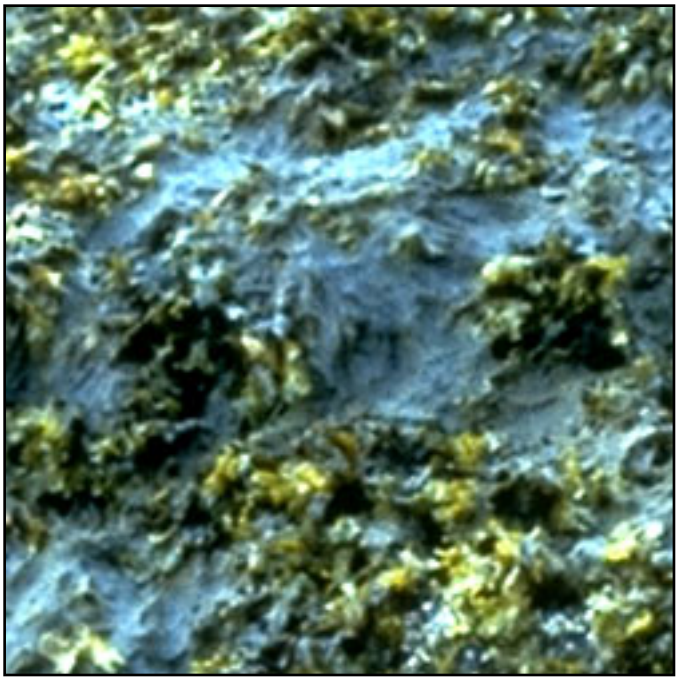


1995: Many of the mussels in the quadrat have disappeared. In contrast to earlier photos, much of the light-colored regions of the boulder is bare rock! Some barnacles are visible (you can distinguish them from the bare rock by their bumpy texture), and in the upper section of the quadrat, you can see some young *Fucus* plants.

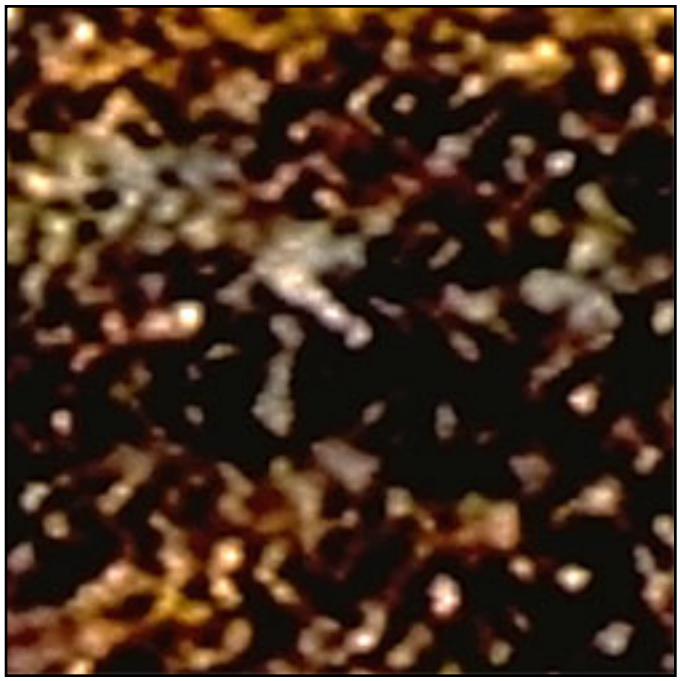
1996: In the quadrat in 1996, the *Fucus* cover has increased. Here, the bare rock appears as darker gray. Most of what was bare rock last year is covered by barnacle spat (young barnacles) this year. It's difficult to tell if young mussels occupy the dark regions of the quadrat.



1997: This year, the quadrat is occupied by *Fucus*, some dark sections of mussels, and a slimy, filamentous algae.



1998: It's difficult to know what quantity of *Fucus* is present under this filamentous algae that has grown on top of it (which we think is *Pilayella littoralis*). We think that the dark areas of mussels have grown larger since the last photo.



1999: Like all scientists, our biologists sometimes experience problems in the field. When this photo was taken in 1999, low tide occurred at sunrise, which didn't provide enough light for conventional photography. Our biologist was able to provide a photograph taken from a videotape; however, this quadrat photo is very unclear.

This is our interpretation of the photo: Mature *Fucus* and possibly mussels are the only marine life forms visible in the quadrat.

2000: Mature *Fucus* and a large filamentous algae are the only marine life forms visible. The mussels seem to have disappeared.

2001: In this photo, the slimy algae appears to be dying back. We can see older (brownish) *Fucus* plants, younger (greenish) *Fucus*, as well as white regions of barnacles. The small dark areas are either mussels or shadows.

2002: Only a few mature Fucus plants remain in 2002. More barnacles (white bumps) are visible, but no mussels are present.

2003: In this photograph, we can see a few patches of mature, gold-brown *Fucus*, the largest appearing in the lower left section of the quadrat. Some very young (greenish) *Fucus* plants have also sprouted on the quad. A sprinkling of new barnacles (young of the year, which appear as small whitish bumps) are visible, but much of the boulder is bare rock (dark gray). The barnacles that covered the rock in 2002 have largely disappeared and have been replaced by new baby barnacles in 2003.

2004: Much of the quadrat is covered by young Fucus plants in 2004. No mussels are visible. The tiny barnacles that set in 2003 have grown, creating a white crust under the Fucus. This year, there is little or no bare rock. Note the new species of seaweed (resembling a spider) in the upper right section.

Mearns Rock Time Series

Here is a series of photographs of "Mearns Rock," a large boulder (approximately 4 feet [1.2 meters] high by 7 feet [2.1 meters] long) located in the intertidal zone at Snug Harbor on Knight Island, Prince William Sound, Alaska. The boulder is located on a very protected, south-facing rocky shoreline that was oiled during the Exxon Valdez spill in March, 1989. This section of shoreline was not cleaned after the spill. We presume that the boulder, like the rest of this shoreline, was coated by spilled oil, which was gradually removed from it by natural processes during the first year after the oil spill. (Note that we have not yet provided photos of a "control" site, a boulder on a similar shoreline that was not oiled.)

NOAA biologists have photographed this boulder--and the animals and plants growing on it--once each year (in late June or early July) during the past 15 years. Click on any photo below to see a larger image and our biologist's interpretation of what you're seeing.

1990

1991

1992

1993

1994

1995

1996

1997

1998

1999

2000

2001

2002

2003

2004

Mearns Rock in 1990

What You See

In this photograph, taken 15 months after the spill, you see only the top portion of the boulder because the tide was in at the time that the photo was taken. The boulder's surface is almost entirely covered by young plants of the algae *Fucus gardneri* (commonly called "rockweed" or "popweed"), which is abundant on the shorelines of Prince William Sound. On the right section of the boulder (the area of white color) is a settlement of young barnacles. The dark patch (on the right section) is a colony of small mussels.

What's Happening

No oil appears on the boulder because biological processes have cleared it away. NOAA biologists assume that adult *Fucus* plants that were present at the time of the spill were damaged by the oil and/or the particularly cold temperatures of the previous winter. Young *Fucus* have grown since that time.

Mearns Rock in 1991

What You See

In mid-1991, the entire boulder is covered with gold-brown *Fucus*. You can see darker species of seaweed forming an apron around the base of the boulder; the beach area surrounding the boulder (the "beach face") is also completely covered with other seaweed species. In the water behind the boulder, you can see a healthy eelgrass (*Zostera marina*) bed.

What's Happening

The boulder's condition appears to be improving, shown by the heavier covering of seaweed. One might conclude that this shoreline had recovered from the oil spill.

Mearns Rock in 1992

What You See

The boulder is now about 50% covered with larger, older seaweed (mainly *Fucus*). Barnacles are filling in spaces left by dying seaweed. The beach face is heavily covered with seaweed.

What's Happening

The *Fucus* that was young in the 1990 photo has aged and is now dying off. Why is it dying off?

Mearns Rock in 1993

What You See

Fucus now covers about 20% of the boulder's surface. Large, older plants are gone; they seem to have been replaced by young plants. Mussels are growing on the front face of the boulder (black regions). Although the barnacle areas are difficult to see in the photo, the barnacles have died back considerably.

What's Happening

The young seaweed from the 1990 photo has matured, died back, and has almost entirely left the boulder. The patches of mussels probably began as young animals in 1992, but were too small to be seen in the 1992 photo. Now that they are larger, they are more visible. NOAA biologists aren't sure why the barnacles have died back. Have you any ideas why?

Mearns Rock in 1994

What You See

Fucus has completely left the boulder, leaving it dominated by approximately 2-year-old mussels (black areas on the boulder) and scattered barnacles. Very little seaweed is growing on the beach face. Where did the plants go? Why aren't they growing here anymore?

What's Happening

In 1993 and 1994, something happened that caused a great reduction in the abundant marine life on this shoreline. NOAA biologists believe that the loss of seaweed, mussels, and barnacles is part of the growth cycle of the marine life, rather than due to oiling per se.

Mearns Rock in 1995

What You See

In mid-1995, about half of the mussels have disappeared, leaving smaller dark regions on the right side of the boulder. *Fucus* is making a comeback on the left side and top surface of the boulder. You can also see a resurgence of algal growth on the beach face.

What's Happening

The disappearance of the mussels may be the result of predation (perhaps by sea otters) or natural mortality. Regardless of whatever caused the boulder's plant life to die back in 1993-94, the boulder now seems to be supporting new plant and animal life.

Mearns Rock in 1996

What You See

This year, the boulder looks somewhat like it did in 1990. Young *Fucus* plants cover much of the boulder, young barnacles appear in the open spaces, and the mussels have disappeared.

What's Happening

A second "wave" of recovery has clearly taken hold.

1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004

Mearns Rock in 1997

What You See

The boulder is once again covered (about 80%) with the seaweed *Fucus*. There are several age groups of *Fucus* on the boulder. Young *Fucus* is growing over the top section of the boulder and adult *Fucus* is growing around the mid-portion. The beach face is again rich with seaweed. No mussels are visible and the areas occupied by the barnacles have shrunk. (Which other photo does the boulder resemble now?)

What's Happening

Starfish and sea otters may have been preying on the mussels, and a predatory snail, *Nucella*, has likely been eating the barnacles. (Although you can't tell from the photo, the *Nucella* population has been slowly growing on the boulder.)

1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004

Mearns Rock in 1998

What You See

The boulder is now covered with patches of adult *Fucus* and a filamentous algae, which we think is *Pilayella littoralis*. We can't see what quantity of mussels and barnacles are present because they are covered by the *Pilayella*. What other year does this scene remind you of?

What's Happening

Young plants that took hold in 1995 are now maturing.

Mearns Rock in 1999

What You See

You can see that a second crop of *Fucus* seaweed, which began to grow in about 1995-96, has matured and now nearly covers the boulder. The larger seaweed that was prominent in 1998 has disappeared.

What's Happening

The mature *Fucus* plants visible in this photo may be starting to die back. Our observations over the years suggest to us that individual *Fucus* plants survive for about 4 to 5 years.

Mearns Rock in 2000

What You See

Mature *Fucus* now covers about 10% of the boulder's surface. In addition, there is a heavy cover of a grayish, slimy seaweed (this could be any of three or four seaweed species that can look like this). As in other years, these plants may be hiding barnacles, mussels, or young *Fucus* plants from our view. The white areas on the beach face look to be large barnacle sets. Eelgrass is barely visible in the water.

What's Happening

As in the 1993 photo, the mature *Fucus* plants are again dying back. However, at this time, there is no sign of a third new crop of young *Fucus*.

1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004

Mearns Rock in 2001

What You See

This year, the boulder has a 20%-30% cover of *Fucus*. Older (brownish) plants are visible on the left section of the boulder and younger (greenish-brown) plants on the right. A whitish "bald" patch on the upper left is actually a patch of barnacles. Another bare-looking patch on the lower right corner contains barnacles (white) and small mussels (dark spots). A bright green algae, possibly "sea lettuce" *(Ulva)* droops down along the lower third of the rock face. Algae and barnacles also cover most of the cobble on the beach face.

What's Happening

During the early 1990s, marine plants and animals covered most of the boulder. Then, almost everything other than mussels disappeared by 1994. Later, the cycle of new life started up again in 1995 and 1996. We thought this might be part of a four to five year-long cycle of colonization, growth, and death. However, in 2001, six years later, the cover of marine life has not disappeared nearly as completely as it did in 1994.

So what's going on? Perhaps, over the past 12 years, intertidal marine life here has experienced variability that is decreasing with time. We may never see the boulder (and the shoreline) go bare again as it did in 1993-94. On the other hand, other things happened in the late1990s that had not occured in the early 1990s, including the pronounced 1997-98 El Niño.

Perhaps the El Niño led to local conditions that prevented plants and animals from dying off in the late 1990s, as they did in 1993-94. How would an El Niño do this?

1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004

Mearns Rock in 2002

What You See

In 2002, the boulder is dominated by barnacles, creating a 50% cover. A few large, old *Fucus* plants on the upper section of the rock make up a 10%-15% cover. None of the green algae that was present along the mid section of the rock in 2001 is present this year. A small amount of green "sea lettuce" *(Ulva)* (much less than in 2001) is visible in the lower left section of the boulder. In 1993/94, when the rock last appeared quite bare, many mussels covered the boulder; however, none are present now. Overall, the boulder location is a somewhat desolate landscape this year, with more bare rocks exposed than in previous years.

What's Happening

The die off we anticipated in 2001 is now occurring in 2002. Like in 1994/95, there is an absence of juvenile *Fucus* plants, but unlike 1994/95, the mussels are not returning. Perhaps they will in 2003?

Mearns Rock in 2003

What You See

This year, the barnacles have died back somewhat, and no new *Fucus* plants have been established. The *Fucus* plants that remain appear slightly larger this year. Sea lettuce continues to grow in the lower left corner of the boulder.

What's Happening

Conditions are very similar to 2002, with perhaps somewhat less cover of barnacles. We expected both young *Fucus* and mussels to colonize the rock by now, as they had in 1994/95, but they have not. This could be due to a lack of reproduction in both species or heavy grazing by animals such as limpets and snails. Neither are apparent.

Mearns Rock in 2004

What You See

In 2004, the boulder has a heavy covering of young (greenish-brown) *Fucus* plants. Barnacle density remains high on the right side of the boulder. Again this year, no mussels are visible. In the lower left corner of the boulder, the patch of sea lettuce seems to be dying back. On the beach face, the density of *Fucus* is similar to that on the boulder. In the background, an eelgrass bed (*Zostera marina*) is visible in the water.

What's Happening

Conditions in 2004 are very similar to 1996. At that time, we wrote that it appeared that a second "wave" of recovery was occurring. Now it looks like a third wave of regrowth is occurring. During the first years of recovery, there was a heavy growth of mussels; however, that doesn't appear to be the case for the second and third waves of regrowth.

We had originally thought that there was a 5-6 year period from new growth to die-off. If that was true, we should have seen a new recruitment of *Fucus* by 2001. Obviously, the new growth didn't happen for about 8 years (until 2003/2004). Thus, the time between significant recruitment events is many years, but also variable.

Questions: What do you think this Snug Harbor site will look like in June 2005, and why? Do you think the mussels will ever return?

1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004

Prince William's Oily Mess: A Tale of Recovery

Thinking Like a Scientist: Summary

Have you ever wondered how marine life fares following an oil spill? How many die? How many survive to die later? How long does it take for an ecosystem to recover? What about the site of the *Exxon Valdez* oil spill—has the marine life along the shore recovered after 15 years? As a NOAA scientist, Dr. Alan Mearns has been asking and answering these types of questions since the spill occurred in March of 1989.

More with Dr. Mearns

Learn More About Dr. Mearns's Research: Read the Full Interview

Profile of a NOAA Scientist: Learn More About Dr. Mearns's Early Influences and Career

Dr. Mearns is a marine ecologist at NOAA's Hazardous Materials Response Division in the Office of Response and Restoration, part of the National Ocean Service. His office is in Seattle, Washington. His job is to provide scientific information during the cleanup of oil and hazardous substance spills in coastal and marine waters.

His investigations in Prince William Sound began with two questions:

"Would cleanup methods, such as high-pressure, hot-water washing, speed up the recovery of the shoreline marine life, or would they actually delay the recovery?"

and

"How did the oil affect the populations of marine life and wildlife of Prince William Sound?"

He didn't know then that he and his team would spend the next 10 years trying to

Meet Dr. Alan Mearns, a NOAA scientist who has studied and tracked the biological consequences of the *Exxon Valdez* oil spill that occurred in Prince William Sound in 1989. Read here about the research conducted at his namesake—Mearns Rock! (Photo credit: OR&R, NOAA)

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1. Welcome
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3. Remaining Impacts of the Spill
4. How Much Oil Remains?
5. An Ecosystem in Transition
6. Lessons Learned From the *Exxon Valdez*
7. Has Prince William Sound Recovered?
8. Dr. Mearns' Rock - You Be the Scientist!
9. References

Oil Spill Trajectory Model

An Oil Spill Primer for Students

How Toxic is Oil?

Ask an Expert

Report a Spill

answer these two basic questions.

Dr. Mearns began by breaking down these two questions into numerous smaller, more answerable questions, which is typical of how most scientific investigations begin. Then, to try to answer these questions, Dr. Mearns and his team used the same approach that most scientists use. First, they read all the relevant published literature about the effects of both oil spills and shoreline cleanup activities on marine life. They found that not much was published on these topics. The information in the literature was not good enough to predict whether the hot-water cleanup method would be effective (in removing oil) or if it would really speed up "recovery." To find out for sure, they decided that they needed a long-term field-monitoring study.

(top)

The study they designed called for monitoring approximately 24 sites in three categories:

- **Oiled** (but not cleaned)
- **Oiled and cleaned** (with high-pressure, hot-water washing)
- **Unoiled and not cleaned** (called a "control")

Hundreds of workers used high-pressure hoses to clean the worst of the oiled beaches in the weeks after the spill. (Photo credit: *Exxon Valdez* Oil Spill Trustee Council)

This grand experiment had the attributes required of good science: exposed and control sites (for both oiled and cleaned); replication (more than one site in each category); and repeated sampling over a long period. In the spring of 1990, the research team made its first "reconnaissance" trip to Prince William Sound to confirm that the sites were adequate and simply to "learn the territory." With two boats and a crew of nearly a dozen scientists and technicians, they went out every summer from 1990 to 2000, surveying these sites during the "spring tide" period (a time of very low, low-tides).

To survey marine life on these shorelines, the scientists used methods that gave them quantitative data like the kinds of species present, and their numbers or percent cover in each sampling area. As the tide flowed out, they randomly selected five or 10 points along a 100-foot line parallel to the water line (called a transect or survey line). They did this at three elevations: upper, middle and low tide elevations. At each point on a rocky shore transect, they laid down a one-quarter-square-meter quadrat (0.25 m on a side). You can see one of these quadrats on the ground in the photo to the right; the transect line is vaguely visible near the left center portion of the photo. Then they identified and counted every plant and animal inside the boundary of the quadrat. In areas of "soft" sediment (sand, gravel, or mud) they took a core sample and then, back at the lab,

they carefully sorted through the sample and counted and identified all the clams, amphipods, polychaetes, and other marine organisms.

(top)

s a quadrat to sample the organisms of the
n Snug Harbor on Knight Island, Prince
Alaska. (Photo credit: OR&R, NOAA)

A NOAA researcher examines his sampling quadrat on a cobbled beach in Prince William Sound, Alaska. (Photo credit: OR&R, NOAA)

They found that during the first months after the spill, the oil had killed about half of the marine life on the *oiled* shores. Washing the shore with high-pressure hot water killed most of what survived the initial oiling. This washing removed a lot of oil, but not all of it. By the second summer (1990), seaweeds, barnacles, snails, limpets and other organisms were coming back, but a lot of oil remained in gravel under the shoreline surface. By the third and fourth summers (1991 and 1992) there was, with notable exceptions, a prolific growth of seaweeds, including rockweed, and intertidal animals at *all* of the shoreline sites. The cleaned sites actually took *a year longer* to recover than the oiled but uncleaned sites.

To make sure of their results, they continued the study for another six years. When they reviewed the newer data with the old data, they discovered that there were actually no real differences in the recovery times of the oiled and cleaned sites versus the oiled (but not cleaned) sites. Thus, they had to modify their conclusions and recommendations: heavy cleaning *did* kill off marine life that otherwise survived the oiling, *but* the recovery time was about the same. Heavy cleanup made little difference in the end. It certainly did not remove all the oil, nor did it speed up recovery time of the shoreline marine life.

After 10 years, the team was ready to end its long-term study. However,

Dr. Mearns noticed from the data, and from 10 years of shoreline photos, that something else was going on with the intertidal marine life in Prince William Sound. It looked like mussels, seaweeds, clams, barnacles and other organisms were going through a series of cycles. In some years, the shores were covered with mussels. Yet, in other years, mussels were nearly absent and the sites were thick with seaweed. The photos from one site, which featured a large boulder, clearly showed this long-term variation. Another NOAA biologist gave this boulder a name: **Mearns Rock!** Since 2000, Dr. Mearns and several colleagues have continued to return and re-photograph a dozen oiled sites in Prince William Sound, including his namesake rock.

More with Dr. Mearns

Learn More About Dr. Mearns's Research: Read the Full Interview

Profile of a NOAA Scientist: Learn More About Dr. Mearns's Early Influences and Career

(top)

Back to Thinking Like a Scientist: Summary

Full Interview: Dr. Alan Mearns

Have you ever wondered how marine life fares following an oil spill? How many die? How many survive to die later? How long does it take for an ecosystem to recover? What about the site of the *Exxon Valdez* oil spill—has the marine life along the coast recovered after 15 years? As a NOAA scientist, Dr. Alan Mearns has been asking and answering these types of questions since the spill occurred in March of 1989.

A NOAA research team, including Alan Mearns (in yellow pants), examines its sampling quadrat on a cobbled beach in Prince William Sound, Alaska. (Photo credit: OR&R, NOAA)

Dr. Mearns is a marine ecologist at NOAA's Hazardous Materials Response Division in the Office of Response and Restoration, a part of the National Ocean Service. His office is in Seattle, Washington. His job is to provide scientific information during the cleanup of oil and hazardous substance spills in coastal and marine waters. We spoke to Dr. Mearns about his work with oiled ecosystems and particularly his work in Prince William Sound, and his namesake—Mearns Rock. Here is what he had to say:

Interviewer: When did you first start asking scientific questions about the aftermath of the *Exxon Valdez* oil spill?

Alan Mearns: Actually, I was involved in the spill from the very first day. I was in the NOAA HazMat (meaning Hazardous Materials) "war room" in Seattle on the morning of March 25, eight hours after the *Exxon Valdez* struck Bligh Reef. The HazMat Director was briefing the NOAA Administrator, telling him "This is the big one," and seeking support from NOAA. By that time, several NOAA HazMat staff members were already on flights to Alaska.

On that first day, my thoughts centered around how this very large oil spill was going to affect the marine life and wildlife of this productive and remote area. I also wondered how the arrival and activities of thousands of cleanup workers, hundreds of boats, news crews, and dignitaries were going to impact the area. I feared that these human activities might impact Prince William Sound as much as the oil spill itself!

Just a month after the spill occurred, I was asked to participate in a NOAA summer research cruise to survey shorelines and marine life in the spill area. The NOAA Research Vessel *Fairweather* was retrofitted to conduct biological studies for this purpose, and it began surveying the oiled coast of Prince William Sound in May. I joined the cruise in July. My task was to collect and process samples of sediments from several dozen sites along the Kenai Peninsula, Cook Inlet and Kodiak Island (**See a Map of the *Exxon Valdez* oil spill**). This was my first exposure to a major oil spill. During that cruise, I saw many sites, oiled and unoiled, and lots of wildlife. I have visited many of the oiled sites nearly every year since.

Interviewer: In your research with oiled marine life at the site of the *Exxon Valdez* oil spill, what was the first question you wanted to answer?

Alan Mearns: The first question was: ***Would the cleanup methods speed up the recovery of the shoreline marine life, or would they actually delay the recovery?*** Little did I know, then, that my colleagues and I would spend the next 10 years trying to answer this question.

In the spring of 1989, the government approved the use of high-pressure, hot-water washing to remove oil from the seaweed-covered, rocky, boulder, cobble and gravelly shorelines. Floating barges were built that were fitted with large pumps and water heaters to deliver this high-pressure hot water to the shoreline cleanup crews. The crews were using large fire hoses to blast oil out of the rocks and cobble, causing it to float on top of the water (called "refloating") and washing it back out into the water, where it could be picked up by skimmers fitted on boats.

(top)

In the end, we returned to that first, very basic question I had asked on the first day: ***To what extent would this type of cleanup enhance or delay recovery of shoreline marine life?*** We quickly broke down this simple question into numerous smaller, more answerable questions, and our long-term monitoring project was born. This is a typical scenario in a scientific investigation—scientists often take a very general question or an overwhelmingly large question and break it down into a series of smaller questions that they can answer through experimentation or observation.

Interviewer: Explain to us how you went about deciding how you would answer that first question.

Alan Mearns: We used the same approach that most scientists use when they first tackle a question. First, we read all the relevant published literature about the effects of both oil spills and shoreline cleanup activities on marine life. We found out, however, that not much was published on these topics. There had been some studies about the cleanup of oil spills, but we did not think the information was good enough to predict whether the hot-water cleanup method would be effective (in removing oil) or if it would really speed up "recovery." To find out for sure, we decided that we needed a field-monitoring study at the site of the *Exxon Valdez* oil spill at both oiled and hot-water cleaned sites.

Fortunately, another research team had already started sampling and surveying the sites we needed. These included sites that were:

- **Oiled** (but not cleaned)
- **Oiled and cleaned** (with high-pressure, hot-water washing)
- **Unoiled and not cleaned** (called a "control")

Alan Mearns and colleague establish a transect at Mearns Rock, a large boulder located in Snug Harbor on Knight Island in Prince William Sound, Alaska. (Photo credit: OR&R, NOAA)

It was a grand experiment, with almost all the attributes required of good science, including exposed and control sites (for both oiled and cleaned), replication (more than one site in each category) and repeated sampling over a long period of time, provided we could argue for long-term funding.

We also had some data from parts of Prince William Sound that another research team happened to be studying before the *Exxon Valdez* oil spill took place—which was very lucky for us. We wanted to study all of these sites for several years using this "sampling design," as scientists call it. One of the first questions my research team posed was:

Would the sampling design be sufficient to allow us to clearly conclude when the marine life of oiled versus oiled and cleaned shoreline sites had actually recovered?

In other words, we needed assurance that the control sites were indeed comparable, so that over several years, we could fairly compare recovery at the oiled sites with the natural variation that we expected to occur in the absence of oiling and cleanup.

Additional sampling design questions we asked were:

- How many study sites or sampling areas needed to be monitored in each category (oiled; oiled and cleaned; and control sites)?
- How frequently must we monitor these sites?
- How many replicate samples must we take at each location?
- How often must we sample, to make sure we can claim that "recovery" has occurred?

(top)

First, we made sure that the control sites were indeed unoiled by checking detailed Coast Guard 1989 cleanup records. We needed to know if the unoiled control sites were similar to the oiled sites in terms of wave exposure and other forces of nature. We looked at detailed maps to see where each shoreline site was located, what kind of substrate it was (rocky, boulder, cobble, mud flat) and how it was exposed to wind and waves.

Next, we evaluated how many sites would be needed in each category. We knew one each would not do because marine life and shoreline habitats, whether oiled or not, are extremely patchy. You could easily come to the wrong conclusion by chance alone. We sought three, four or five sites in each of the three categories.

Next, we considered how many replicate samples we needed at each site, at each time period, and at each of several tidal elevations (upper, mid and low intertidal). Again, one sample each would not do. Basic statistical analysis told us that we should have at least five replicate samples of each of the categories (oiled, oiled and cleaned, control). Fortunately, in most places, 5 to 10 samples had been taken at each site and each elevation in 1989.

Finally, we made our first "reconnaissance" trip to Prince William Sound in the spring of 1990, confirming that most sites were adequate, adding or adjusting sites and sampling locations, and just learning the "territory." With two boats and a crew of nearly a dozen scientists and technicians, we went out every summer from 1990 to 2000, surveying these sites during the "spring tide" period (a time of very low, low-tides). After 2000, I led a small research team of three to continue photographing a dozen sites, including Mearns Rock.

Interviewer: What are the some of the field methods you use to study oiled marine life, especially along the coast? What technologies have you used? How have they assisted you in gaining a better understanding of oiled marine life?

Alan Mearns: Any shoreline field investigation requires the following:

- a tide table to plan how much low-tide time we had at each site;
- a statistically based monitoring plan (as described above);
- the logistics for training staff and getting to and operating in the field locations (everything from boats and food to rain gear);
- tools (such as GPS) for precisely locating stations and samples;
- a team of people who are experts in identifying hundreds of species of marine plants and animals (called taxonomists);
- people who are not taxonomists, but who can record the data;
- taxonomic reference books;
- photography equipment;
- dozens of field notebooks and data forms;

- biological survey tools (quadrats, core tubes, shovels, labels, jars, and preservatives); and
- thick steel stakes (i.e., rebar) or marine putty to use as permanent markers at each site.

(top)

To survey the marine life on the shorelines, we used methods that gave us quantitative data like the kinds of species present, and their numbers or percent cover in each sampling area. On our first visit to each site, we randomly selected five or 10 points along a 100-foot line parallel to the water line (called a transect or transect line), using a “random numbers table.” At each point on a rocky shore transect, we laid down a one-quarter-square-meter quadrat (0.25 m on a side: you can see quadrats and a transect line in some of the photos on this page) and then identified and counted every plant and animal inside the boundary of the quadrat. Lastly, we used steel rebar or marine putty to permanently mark each quadrat location, so that we could relocate these exact points in subsequent years of our study and resample the same locations. This is known as a “fixed random” experimental design. The sample locations (quadrats) were randomly selected only the first time. In subsequent samples, the same locations are sampled again—so the locations were “fixed” in the remainder of the study.

In areas of "soft" sediment (sand, gravel, or mud) we took a core sample and then, back at the lab, we carefully sorted through the sample and counted and identified all the clams, amphipods, polychaetes, and other marine organisms. Samples were also taken of the sediment to determine grain size distribution, organic content, and oil concentration (more specifically, polycyclic aromatic hydrocarbons or PAHs). Mussels were also collected from each sample location to test their tissues for PAH levels. We could also use the PAH information to “fingerprint” the oil to determine its origin. We did this at three elevations: upper, middle and low tide elevations.

This beach, near Knight Island, was heavily oiled and then cleaned in 1989. (Photo credit: OR&R, NOAA)

Our fieldwork had to be done accurately but quickly, because we had a finite amount of time before the tide turned. If we stayed too long as the tide began to come in, we were flooded off the site! Surveying a dozen sites often took a week or more of especially low spring tides. We repeated this process for many sites, resulting in hundreds of quadrat samples, and thousands of numbers for each survey. One or two weeks of such fieldwork resulted in nearly a year of laboratory work, statistical analysis and report writing!

After three or four years, we thought we had our answer: The cleaned sites actually took a year longer to recover than the oiled, but uncleaned, sites. To make sure, we continued the study, eventually working with a second group of researchers. When we reviewed the new data and all the old data using newer statistical methods, we discovered that there were no real differences in recovery times! Thus, we had to modify our conclusions and recommendations: heavy cleaning did kill off marine life that otherwise survived the oiling, but the recovery time was about the same. Heavy cleanup made little difference in the end; it certainly did not remove all the oil, nor did it speed up recovery time of the shoreline marine life.

After 10 years we were ready to end the program. However, I noticed from our data, and from 10 years of shoreline photos, that something else was going on with the intertidal marine life in Prince William Sound. It looked like mussels, seaweeds, clams, barnacles and other organisms were going through a series of cycles. In some years, the shores were covered with mussels. Yet, in other years, mussels were nearly absent and the places were thick with seaweed. And, in other years, hardly anything at all grew on or inhabited some sites. This variation had no impact on our scientific study, however, because we were always comparing oiled and cleaned sites to unoiled sites.

The photos from one site, which featured a large boulder, clearly showed this long-term variation. My

colleague and fellow biologist Gary Shigenaka gave this boulder a name: Mearns Rock! We used the Mearns Rock photos to capture the imagination of the boating public. Since 2000, I and several colleagues have continued to return and rephotograph our oiled sites, including Mearns Rock, in the company of local citizens.

Interviewer: How will you use the data you collected at Mearns Rock and other locations in Prince William Sound?

Alan Mearns: As you may have noticed, the Mearns Rock photo series is only "the tip of the iceberg"; a small piece in a much larger puzzle. Mearns Rock was one of our study sites that was oiled but not cleaned. One purpose of the Mearns Rock photos is to see if we can use these landscape-scale photos to replace some of the very intensive and expensive quantitative biology methods (described above) at future oil spills. We have the photos and the data we collected for the past 10 years, but have not yet begun to compare them.

Another purpose of conducting our annual trips to Prince William Sound was to train local citizens in hopes that they would continue long-term monitoring and photography once we were gone. Each year, we invited members of the Whittier Coast Guard Auxiliary to join us as we traveled around Knight Island. Often, two or more vessels operated by citizens and their families accompanied us. We took them ashore, showed them the photo sites, and dug pits to look for signs of oil.

Showing the photos of Mearns Rock is only the first step in the scientific process. To begin to answer the "so what?" questions, we need to look at similar photos over the same period from other locations, especially locations that were not oiled. About half the people that look at these photos ask, "*Do you have pictures of an unoiled site*?" If you want to begin understanding why marine life has been changing, that is exactly the right question to ask! We hope to make photos from all the sites available in the coming year.

Interviewer: What is the present (2005) situation in regards to rockweed (*Fucus*) and mussel populations and other marine life in Prince William Sound, especially at Mearns Rock?

Alan Mearns: This past summer (June 2004) three of us, accompanied by local citizens, visited about 10 of our oiled, oiled and cleaned, and control sites, including Mearns Rock, which is on Knight Island. From 2001 to 2003, the percent cover of marine life at most sites was very low. This summer it looked like the rockweed was starting a new period of exuberant growth. Mussels were not particularly abundant. Overall, the abundance of conspicuous intertidal marine life has varied greatly at all sites, regardless of whether they were oiled, oiled and cleaned, or unoiled.

Interviewer: Overall, what changes have occurred in Prince William Sound and Mearns Rock since 1989?

Alan Mearns: During 1989, the oil killed off about half of the marine life on the oiled shores. Washing the shore with high-pressure hot water killed off most of what survived oiling. This washing removed a lot of oil, but not all of it. By the second summer (1990), seaweeds, barnacles, snails, limpets and other organisms were coming back, but a lot of oil remained in gravel under the shoreline surface. By the third and fourth summers (1991 and 1992) there was, with notable exceptions, a prolific growth of seaweeds, including rockweed, and intertidal animals at all of our shoreline sites. After that, the abundance of algae and animals at oiled sites (both cleaned and not cleaned) varied considerably from year to year, just as similar variations occurred at the unoiled sites.

(top)

Interviewer: Has Prince William Sound “recovered” from the 1989 *Exxon Valdez* oil spill? What is the evidence to support your answer?

Alan Mearns: As a scientist, I find it difficult to answer the general question, “Has Prince William Sound recovered?” Imagine if a storm completely trashed your garden and then it started to "recover." When would you say that it had completely "recovered"? After a year, you would have some plants and birds come back, looking like they did before, but other plants would be much slower to regrow, and some would have died, perhaps to be replaced by weeds for a season or two. You would have a change in the amount of shade and sunlight coming into various portions of the garden, changing the rates at which various plants grow and flower. And, you would have year-to-year variations in rainfall and soil moisture, which would also change the course of your garden’s "recovery."

So let me try to answer the question about specific groups of organisms affected by the oil spill rather than all of Prince William Sound. In terms of the abundance and diversity of shoreline marine life in oiled areas, meaning the seaweeds, barnacles, mussels and other invertebrates, they have recovered. In fact, that kind of recovery took place within three to four years after the spill, but we didn't know we could say that with specified scientific certainty until we "oversampled" for a period of 10 years. A different answer might be this: all of that shoreline marine life was going to return, no matter what we did. But oil still exists in the shoreline sediments. Of the 10 sites we visited this year (2004), we dug small trenches in soft sediment and found oil sheen at six of the sites. One site has what looks like an asphalt pavement in the upper intertidal zone. The oil had mixed with gravel, then dried out.

Other researchers from government and industry have studied other groups of wildlife affected by the oil spill in Prince William Sound. The answers are mixed. Bald eagles recovered to their former abundance many years ago. Sea otters, however, may still be suffering at several locations, because they continue to feed on contaminated clams and mussels.

Some years ago, an article by writer Marguerite Holloway appeared in *Scientific American*. She used the French term, *mis en mis*—"window in a window"—to describe how people look at recovery. It depends on how close or how distantly you look at Prince William Sound and all the data compiled since March 25, 1989.

Interviewer:What were some of the challenges you faced in conducting your research at Mearns Rock?

Alan Mearns: One was simply getting there! Mearns Rock and the other 12 study sites are located on Knight Island, over 50 miles southeast of the nearest port in Whittier, Alaska. We have been very fortunate to get to the Mearns Rock site each year despite weather delays and engine troubles. May and June are often pleasant months in Prince William Sound, but storms can pop up anytime, especially in July. An engine failure nearly terminated our 2002 survey, but we completed it with the help of a citizen who volunteered his time and vessel.

Another is the timing of the tides. We need a good "minus" tide during daylight hours to photograph our sites. One year, the low tide was at dawn on a very dark and cloudy morning. Our film speed was not fast enough to get quality pictures and I had to rely on the low-light capability of a video camera to get passable photos. We always had to have a contingency plan, had to be ready to go when the tides and weather were right, and to hold back when they weren't.

Also, there was the challenge of funding and support. We have been very fortunate that NOAA and other agencies have funded this work for over 10 years. But it has not been easy. Funding cycles go up and down, and in some years we had to argue and argue that the program should continue for at least one more year. Part of the "art" of being a scientist is being a good proposal writer and giving good speeches and presentations. Fortunately, the trips to Mearns Rock and other sites were relatively low in cost, and it was easier to justify a brief annual photo-survey than it was to justify a major annual biological survey.

Interviewer: Do you or other NOAA scientists continue to study the marine organisms on Mearns Rock? What about other locations in Prince William Sound?

Alan Mearns: Yes, our NOAA HazMat team continues to monitor sites in Prince William Sound. In addition, the *Exxon Valdez* Trustee Council and the Oil Spill Recovery Institute continue to make measurements in the sound.

In the spring of 2001, we had a surprising opportunity to try another approach to answering our question. A large earthquake in Prince William Sound caused a landslide on northern Knight Island, only a few miles from one of our study sites. The landslide buried about 400 meters of old shoreline, creating a new one composed of dozens of house-sized boulders. We used this new shoreline to monitor how marine life colonizes bare rock from the very beginning, and in the absence of mortality from an oil spill. Scientists call this a "natural experiment"—in other words, an experiment created by Mother Nature's manipulation of a situation, rather than a planned manipulation by scientists.

We predicted that recovery of marine life at this new site would be identical to what we saw in 1989-1993 at the oiled and pressure-washed sites. Indeed, our three years of photos clearly show the same sorts of recolonization patterns that we saw elsewhere in the early 1990s, including an explosion of mussels in 2003, three years after the landslide.

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Profile of a NOAA Scientist: Dr. Alan Mearns

A Marine Scientist's Publications

"In my first year of college, I learned that...there is a big difference between having an "interest in nature" and "studying nature."

–Dr. Alan Mearns

Dr. Alan Mearns (far right) and colleagues on a research expedition in Prince William Sound, Alaska. Dr. Mearns is a marine ecologist at NOAA's Hazardous Materials Response Division in the Office of Response and Restoration, a part of the National Ocean Service. (Photo credit: OR&R, NOAA)

Alan Mearns is a marine ecologist at NOAA's Hazardous Materials Response Division in the Office of Response and Restoration, a part of the National Ocean Service. His office is in Seattle, Washington. We talked to Dr. Mearns about how he came to be a scientist, his career as a scientist at NOAA, and how he came to study the effects of oil spills and other hazardous materials. Here is what he had to say:

Interviewer: Can you tell us how you became interested in a career in science? Can you trace your interest in science back to a childhood experience, a favorite teacher or a favorite course?

Alan Mearns: I became interested in nature early in my childhood. I grew up in Long Beach, California, in the 1950s. When I was 10, we moved out into the "country," where I played among the orange groves with my buddies. There were snakes and lizards everywhere. We noticed that every fence lizard or skink we caught had lost its tail, and I wondered why. I didn't know it then, but I had posed my first scientific question! I kept some horned lizards (called "horny toads") in a box in the garage to see if there was any truth in the story that they spit blood out of their eyes. I am afraid to say what I did to try to get them to squirt blood, but they never did.

A pet shop opened nearby, and I began spending time there. I bought several aquaria and started raising tropical fish in the garage. My high school buddy, who also raised tropical fish, told me about the tropical fish he heard about that lived in the low desert. With our brand new driver's licenses and his 1936 Packard Coupe, we made our first big "fishing" expedition. In the desert, near Palm Springs, we used a seine and dip nets to catch sailfin mollies, swordtails and platies, which we sold to fish stores in Long Beach.

During that trip, a fish not found in pet stores—the desert pupfish (*Cyprinodon macularius*)—piqued my interest. I quickly forgot about the non-native tropical fish I had been so fascinated with since childhood, and tried to learn everything I could about this strange "tropical" fish that had lived in desert springs for thousands of years. I even wrote an article for the Garden Grove Aquarium Society's magazine called "Fish in the Desert?"

Despite all my wonderful childhood experiences with living things, I had not yet learned that there was a big difference between having an *interest in nature*, and *studying nature*. I found out that science is more than enjoying nature. It involves using logical thinking and experimental methods to ask and answer questions about the world around us. Until I learned this, I was using only part of the scientific

method: I asked questions about tailless lizards, blood-squirting horny toads and desert pupfish, but I had not rigorously answered my questions. During my college and graduate school years, I was exposed to “scientific thinking”—in other words, thinking through questions and problems using logic and experimental design. It was not until then that I truly used the scientific method to ask and answer questions about nature.

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Interviewer: Tell us about your educational background, and your first job in your field.

Alan Mearns: I was a smart kid, so my folks wanted me to be a doctor or dentist. I began college as a pre-dental major at California State College in Long Beach. It took only two semesters of zoology classes and a class field trip to the Sea of Cortez, in Mexico, to make me realize that I was destined to be a field biologist. During the next three years, I took all the "-ology" classes that my college offered—invertebrate zoology, entomology, botany, and so on. My professors took us on many exciting field trips and gave me my fill of painful lab practical exams—but I am grateful to them for all of it.

After I graduated from college, I decided to go to graduate school. I earned a master's degree at Long Beach, and then a doctorate (PhD) in fisheries at the University of Washington. I had the good fortune of having some wonderful and highly motivated professors, and others, guiding my academic and early professional development.

After earning my PhD, my first job was as a biologist with the Southern California Coastal Water Research Project (http://www.sccwrp.org/) in Los Angeles. I was hired to investigate why fish living around sewage outfalls appeared to have skin tumors. The famous filmmaker and naturalist Jacques Cousteau, and other environmental advocates, had claimed that sewage was causing the tumors. They demanded that the California State Legislature pass laws requiring a higher level of sewage treatment. Their claims seemed “fishy” to me; I suspected the tumors might have another cause. My scientific training caused me to ask questions that challenged the assumptions made by Cousteau and the others.

Dr. Alan Mearns collecting data on a boulder-strewn shoreline in Prince William Sound (Photo credit: OR&R, NOAA)

I discovered that the only places where people looked for the tumor-bearing fish were around the ocean sewage discharges. No one had sampled away from the discharge area. My team and I quickly mounted a survey of remote areas to test the hypothesis that the tumors were unique to fish around the sewage discharges. We discovered that the same fish species away from the discharges also had skin tumors, and that tumors were just as common in these fish as those around the sewage discharges. Further, it had just been discovered that the tumors in fish in the Northwest were caused by a marine parasite. The sewage discharges were not the problem, as people had assumed; the tumors were caused by a parasite! Jacques Cousteau was a wonderful naturalist, adventurer and politician, and brought much-needed attention to the oceans, but he was not a scientist.

Interviewer: Tell us about your career at NOAA. What is your job title? What are your duties?

Alan Mearns: After 10 years at the Water Research Project, and leading the Biology Division there, I came to work for the National Oceanic and Atmospheric Administration (NOAA). Officially, my job title is “ecologist.” My first assignment at NOAA was to help with a program investigating pollution in Puget Sound and the New York Bight. We were challenged with rigorously testing hypotheses about some common popular assumptions about pollution. The Puget Sound research evolved into a nationwide evaluation of marine pollution. Several years later, I led a national team of scientists in an effort called "Historical Trends Assessment." We collected pollutant data from dozens of laboratories all around the U.

S. coastline and wrote several reports showing that marine pollution was increasing during the 1950s and 1960s, and then started to decline in the 1970s.

Then, on March 24, 1989, the *Exxon Valdez* ran aground on Bligh Reef in Prince William Sound, Alaska. Every able-bodied scientist at NOAA in Seattle was called upon to help the NOAA HazMat team, including myself. That summer, I joined the effort and helped design and undertake field surveys to determine the extent and magnitude of effects of the oil on marine life. The next year (1990), I officially joined the HazMat team and was given responsibility for conducting a long-term monitoring survey to document the recovery of injured shoreline marine life.

Currently, I work at NOAA's Hazardous Materials Response Division in Seattle, Washington. During my career at NOAA, I have been assigned as leader of the HazMat Biological Assessment Team and, more recently, as senior staff scientist. My duties include supporting national coordinators and the U.S. Coast Guard during spills of oil and other materials, conducting research on the best ways to clean up oil spills, representing my office at national and international conferences, recommending policy to my managers, and providing training to the Coast Guard and state agencies, industries, and others involved in spill response.

(top)

Interviewer: What advice would you give to a high school student who would like to pursue a career similar to yours—in the marine sciences such as marine biology, marine ecology, marine chemistry, or marine environmental policy?

Alan Mearns: I advise taking as much science as you can in high school, especially earth science, biology, chemistry, physics and math. In addition, read everything you can get your hands on, and practice writing whenever possible.

It is critical for you to surround yourself with smart people, and realize that your education never stops. I am still learning to this day!

Dr. Mearns digs for residual oil on a cobbled beach in Prince William Sound. (Photo credit: OR&R, NOAA)

Every science course I took in college has helped me in my career at NOAA, but I think some of the non-science courses were the most valuable to my future as a scientist. What I learned in courses in philosophy, speech, statistics and writing has been helpful on a daily basis. Of all the courses I took, writing and speech have been among the most useful.

In addition, practical experience outside the federal government was critical in my later work at NOAA. I learned how others approached problems and I brought those skills with me to NOAA. If possible, I recommend that students "try it out" as a volunteer or intern with several types of organizations—in government, nongovernmental organizations, environmental organizations, corporations or schools. Many science-based and policy-based organizations, including NOAA, offer internship opportunities for students.

Interviewer: What are some alternative career options for young people with backgrounds in the marine sciences?

Alan Mearns: There is a great need for well-trained marine environmental scientists in industry, consulting firms, and nongovernmental environmental organizations, as well as at all levels of government. I think there is a critical need for well-trained marine scientists to work for nongovernmental environmental advocacy organizations. These organizations are often in the public limelight and need to make sure that their facts are correct and accurate—in other words, they need to back up their advocacy with science.

(top)

A Marine Scientist's Publications

One of the jobs of scientists is to publish their work in scientific journals. Written papers and reports represent the scientists' "portfolio," the ultimate summary of their work. By submitting papers to journals, scientists subject their work to "peer review," which is a careful review by other scientists selected by the journal's editors. This process insures that mistakes are minimized, that the work represents good science, and that the results and conclusions are understandable. Information that is not subject to peer review, such as most Web sites, should be considered with caution.

Below is a select list of the 150 papers and technical reports that Dr. Mearns' has published. They demonstrate the great variety of subjects that marine scientists may work on during their careers. All but the 1993 article in *Sea Technology* were peer-reviewed.

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Mearns, A.J. 1981. *Effects of municipal discharges on open coastal ecosystems*. Pages 25-66 *In* R.A. Geyer (editor). Marine Environmental Pollution 2. Dumping and Mining. Elsevier Scientific Publishing Co., New York. 574 pp.

Mearns, A.J., D.R. Young, R.J. Olson and H.A. Schafer. 1981. *Trophic structure and the cesium-potassium ratio in pelagic ecosystems.* CalCOFI Reports 22:99-110.

Mearns, A.J. and M.J. Sherwood. 1977. *Distribution of neoplasms and other diseases of marine fishes relative to the discharge of wastewater.* Annuals of the New York Academy of Science 128:210-224.

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