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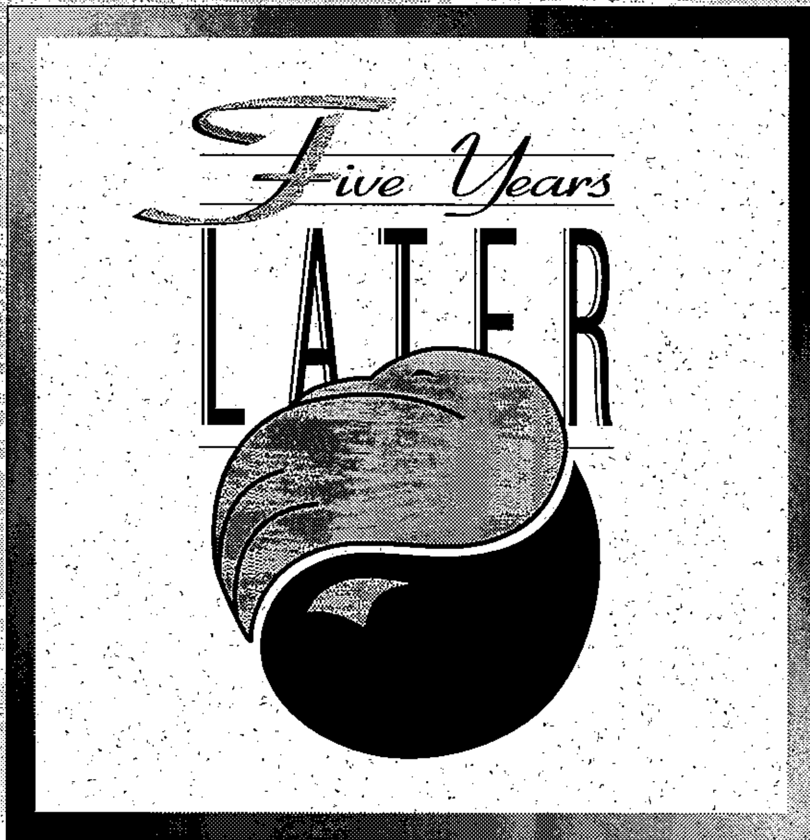

1994 WHAT HAVE WE LEARNED ?

EXXON VALDEZ OIL SPILL FORUM

EXXON VALDEZ TRUSTEE COUNCIL

Proceedings

March 1994

This document contains summaries of presentations delivered at a public forum on March 22, 1994 in Anchorage, Alaska, sponsored by the *Exxon Valdez* Oil Spill Trustee Council. To obtain additional copies, contact:

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Five Years Later: What Have We Learned?

Proceedings of a Public Forum

Anchorage, Alaska

March 22, 1994

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TRUSTEE COUNCIL
ADMINISTRATIVE RECORD

October 1994

Dear Interested Citizen:

This document summarizes presentations made by scientists on March 22, 1994, two days before the fifth anniversary of the March 1989 *Exxon Valdez* oil spill. The occasion was a public forum in Anchorage, Alaska, entitled *"Five Years Later: What have we learned?"* The forum was sponsored by the *Exxon Valdez* Oil Spill Trustee Council and attended by over 200 scientists, members of the public and representatives of Trustee Council agencies.

Each scientist making a presentation was asked to provide the most up-to-date information in their discipline regarding these questions:

> How was the environment injured because of the spill?... What is the status of recovery?... What has the Trustee Council done to aid recovery?... What do we still not know?... Where are we going next?

Representatives also presented comments on behalf of Alaska Governor Walter J. Hickel and Secretary of the Interior Bruce Babbitt, reflecting the cooperation between state and federal agencies. This cooperation is a defining characteristic of restoration activities undertaken by the Trustee Council.

We hope that you find these presentations informative and useful.

Sincerely yours,

James R. Ayers
Executive Director

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Statement from Governor Hickel

Craig Tillery
State Trustee Representative
Assistant Attorney General
Alaska Department of Law

As many of you are aware, Governor Hickel played a central role in bringing about the settlement of the *Exxon Valdez* litigation for the governments. Since that time, he has maintained a keen interest in ongoing restoration efforts. The Governor very much regrets not being able to be here today, but he has prepared a statement which I have been asked to read to you:

"My fellow Alaskans, five years ago the *Exxon Valdez* oil spill resulted in a tragic environmental disaster right in the heart of one of the world's richest marine ecosystems. Alaskans pitched in to mitigate the damages. In the months following the spill, literally thousands of people washed beaches, rescued and cleaned birds and otters, and conducted scientific research so we could better understand what was happening.

"I am proud to have been the catalyst behind the record court settlement in 1991, which resulted in the formation of the *Exxon Valdez* Oil Spill Trust Fund and which provides the basis for our efforts at restoring and enhancing the environment of the spill-affected area. I am also proud of the progress we have made towards restoration.

"The state Trustees have joined hands with their federal counterparts to move forward with a comprehensive approach to restoration and enhancement. This balanced approach includes direct restoration activities, monitoring and research, and habitat protection.

"The Trustees have also taken steps to ensure that a long-term monitoring and research program is established. This program includes developing a first-rate research institute in Seward, a Woods Hole of the North Pacific. It also includes establishing a restoration reserve account so that important research programs can be maintained well into the future.

"I support the recent purchases of inholdings in Kachemak Bay State Park and the land at Seal Bay on Afognak Island to protect habitat critical to the recovery of many of the species injured by the spill.

"We have made great strides in cleaning up the spill and in restoring the ecosystem. However, we must develop a comprehensive understanding of the complex effects this disaster has had and may continue to have on the resources and services that depend upon the health of our resources and the ecosystem that supports them. Many questions still remain unanswered.

"The scientific endeavors initiated by the Trustee Council to restore the damaged elements of the ecosystem will answer many of these questions and help people in the spill region return to the lifestyles and security they enjoyed before the spill. The increased understanding of the marine ecosystem in the Northern Gulf of Alaska that we will gain through our scientific research will be one of the most important and lasting positive legacies of this environmental tragedy.

"Providing opportunities for members of the public to hear reports from leading scientists about effects of the oil spill, such as today's public forum, is a very important part of the Trustee Council's mission. I welcome forum attendees and participants and urge you to use what we have learned to better the lives of all Alaskans and all Americans.

"Sincerely, Walter J. Hickel, Governor."

Statement from the Clinton Administration

Deborah L. Williams
Special Assistant to the Secretary
of the Interior for Alaska
U.S. Department of the Interior

It is my honor to present the following statement from U.S. Secretary of the Interior Bruce Babbitt:

"This week marks the fifth anniversary of the *Exxon Valdez* oil spill, one of the most devastating environmental disasters in our nation's history. Five years ago, the tanker vessel *Exxon Valdez* ran aground and spilled over 11,000,000 of crude oil into the pristine waters of Prince William Sound of the Northern Gulf of Alaska.

"Without question, the spill was a major ecological disaster for the natural resources of Prince William Sound and the other areas impacted by the spill, for seabird populations, fisheries stocks, marine mammals and other species. Five years later, many populations of injured species have yet to fully recover. The people also suffered. The spill was also a social and economic disaster for the people of the fishing communities and Native villages which depend upon a clean and healthy ecosystem for their livelihoods and spiritual sustenance. For the people who live in the spill area, the social and economic impact of the spill continue to be felt to this day.

"But as we have seen so often in our nation's history in times of adversity, the people of Alaska rallied together to combat the advancing tide of oil and continue to work to help clean up and restore Prince William Sound to the condition God meant it to be. The Clinton Administration recognizes that Prince William Sound, the Northern Gulf of Alaska, and the Kodiak Archipelago are truly special places for Alaskans and all Americans.

"And just as we have found in other parts of our country, a clean and healthy environment in coastal Alaska is a pre-condition for strong and local economies. In Cordova, Kodiak, and villages throughout the region, hard-working men and women, their families and small businesses depend on a healthy, productive environment for recreation and tourism and for sport, commercial and subsistence fishing.

"That is why the Clinton administration has made the restoration of Prince William Sound and the entire spill area a top national and natural resource priority. As stewards of our nation's natural resources, Secretary Espy, Secretary Ron Brown and I have worked closely with Governor Hickel and the Trustees for the State of Alaska to develop a balanced, comprehensive approach to guide the restoration of natural resources that were damaged by the oil spill. Through our common efforts and cooperative relationship with the State of Alaska, we hope to seize the opportunity this year to improve our understanding of the biological workings of the spill area through research and monitoring while we protect critical habitat for fish and wildlife as part of a balanced effort to restore this unique and productive ecosystem."

Keynote Speaker:

Placing the *Exxon Valdez* oil spill in a matrix of world ecosystems

Dr. George Rose
Research Scientist, Fisheries & Oceans Canada
Scientific Program Leader, Ocean Production Enhancement Network
NW Atlantic Fisheries Centre, Newfoundland

My task this afternoon is to try to put this *Exxon Valdez* oil spill and its impact on coastal Alaska into some sort of a broader perspective. I claim no great expertise about oil spills or about the particulars of the affected area, so if you're looking for your $200 expert from far away, don't look at me. I prefer to leave the details of this to the real experts who live and work in Alaska.

Where I'll try to make my contribution is in addressing the spill in a much more general way, as a gross environmental perturbation. Though the spill was very severe, as has been pointed out already by previous speakers, it certainly was not unique in the world. It shared common properties and perhaps common solutions with many other perturbed ecosystems.

On a more personal level, to me it was amazing that though I live thousands of miles away from here, the *Exxon Valdez* oil spill was front page news. To everyone interested in the environment, especially in the marine environment as Newfoundlanders are, this spill was a major thing. It was felt literally around the world. To me it symbolizes the difficulties we have in sustaining the quality not only of ecosystems but also of people's lives, especially people who live closest to the land and to the sea, and as a Newfoundlander this strikes very close to my heart.

The image of this broken tanker, leaking oil into such a beautiful, pristine wilderness, not only lingers in the mind but it sort of crystallizes this contrast we have between economic development and trying to preserve not only ecosystems, but people whose very lives depend on them. But there is a lot more to this, of course, than symbolism — there's reality.

When a spill like this occurs, it forces all of us, especially the people most closely involved, to ask some very difficult questions, and there are no simple or universally accepted answers. Some of the questions are difficult because we simply don't know very much about these ecosystems. Ecosystem degradation occurs worldwide. Some people seem quite content to let it happen. But the number one question we have to ask ourselves is what level of restoration action is warranted or what type is really wanted — and how to assess when restoration has taken place. In many cases, this will turn out to be some sort of a value judgment because we have no actual baseline data to say, "okay, now it's restored," or, "we need to do more." In reality there are certain species that are going to get preferential status. This may be for a lot of different reasons. It may be for cultural reasons, it may be for economic reasons, it may be for social reasons and those things then may take priority in restoration.

There are some general things we should keep in mind here. One is that whether it is species or habitats or whatever, if we lack historic information to judge recovery, then it's going to be very difficult to assess when restoration or recovery has taken place. Another thing is that species may have to be selected as the prime targets for restoration for the reasons I mentioned earlier, or because they may be species which help to indicate a healthy environment. These indicator species are difficult to find, but nevertheless the search must go on.

There is a lot of muddy water here, but one thing I think is clear. It is right at this point that science should earn its keep, and there seems to be some opinion that in this particular case it hasn't. This wouldn't be unique, certainly, and it's not an over-criticism of this particular situation. There are many situations in my own part of the world where the same thing is happening, and I'll refer to those a little bit later on. But it is the job of science not only to determine how to monitor these systems, but also to figure out how they work. With that knowledge, if we had it, it would be much easier to judge just what happened in the case of this particular oil spill or in many other environmental areas.

I don't want to make this sound too simple, because it's not. Making any prognoses or predictions about ecosystems is difficult, some would argue impossible. We must go well beyond a correlative approach, where we know one thing has gone up and the other thing has gone up, and so on and so forth. We must get well beyond that and develop some kind of a functional understanding of what really is making these ecosystems work.

Science learns in several ways: through observation, through experience and experimentation. In most cases regarding ecosystems we just haven't learned enough to say much in terms of predicting outcomes of actions. I was at a meeting a couple of weeks ago in my own country, and we were talking about this. Some obvious point came up, and I said something flippant, like you don't have to be a rocket scientist to figure that out. Afterwards someone came up and challenged me, saying that rocket science is real easy compared to marine biology. The idea was maybe we should turn that around. There's a strong point to be made there — this is very difficult scientific work.

So what should we do? We can't throw our hands up in despair. I would suggest that we have to do two things. First of all we have to learn to the best of our abilities how these ecosystems function, and then we have to learn how to monitor in a very cost-effective and hopefully simple way the status of those ecosystems through time.

How do we do that? I'm going to probably ask a lot more questions today than give you answers. The first question I have is – so what is an ecosystem? People talk all the time about compartmentalizing ecosystems very neatly. But you must consider that meteorological and oceanographic forcing occurs at world scales, and that the effects may cascade down to smaller scales with often chaotic effects.

For example, if we take a small plant, its whole world may be small indeed, but it is influenced by weather conditions that may occur half a world away. On the other hand, if we look at a large migrator, such as a migrating seal, they play in a much larger sandbox. This is from my part of the world. These seals breed in the Newfoundland area, and travel all the way up to Greenland. We track their paths through radio telemetry and satellite linking. You can see that this animal and the population that it represents plays in a very large world which includes over half of the northwest Atlantic. Some birds and fishes, of course, migrate much, much further. So how do we define that ecosystem?

It is even more complicated because cascading effects may not be linear but chaotic. If we take all of the species under consideration together and try to block it out in a very simple way, large-scale migrators may use the whole world or half of it, therefore the system that they impact and are impacted by may operate at very large scales.

Immobile animals and plants are the exact opposite. Between these extremes, there is a very, very complex system. In all of the world's oceans there is large-scale oceanographic forcing which controls cold water currents. This affects the plankton populations, the forage fish populations, the distributions of predators, the parasite loads that occur in fish and seals and so on down the line.

These things can get very complicated, and what occurs at a large scale may not translate simply into a similar effect at the smaller scale of a region, for example, Prince William Sound or Newfoundland Island Bay.

Now, in your part of the world — the northern Pacific — the same thing is true. The ecosystem that we're talking about today in Prince William Sound does not operate in isolation from the large-scale processes. There are effects in the southern Pacific and northern Pacific which highly impact what happens at the local scale. There are animals which migrate in and out of Prince William Sound large distances and are an important part of the local system, yet they operate on a much larger scale.

What do we do with this? If we look at the life histories of most species, and in particular marine species, there are usually sensitive times in certain places in the life cycle. Simply put, not all times and places are of equal importance to survival. There exist bottlenecks. So, for restoration and for monitoring, we should concentrate our efforts on those sensitive components of the system.

This approach may have many offshoots, including how we conserve these systems. We may learn, for example, if we can map out in a very schematic way the spatial life cycle of a population, that there are areas which are very sensitive to survival which should be totally protected. There may be other areas that are not as important, and environmental impacts in these areas may not hurt that species all that much, whereas even a small perturbation in another part of the life cycle may have a great impact on what happens to that species.

These are the things, I believe, that we have to learn. At this level and on down the line, habitat protection becomes important, but at the present time in most cases we don't really know enough to identify the critical habitat to protect. In some cases we do know, when there are fixed breeding areas, migration routes, and so on.

One interesting thing that has come out of the major research program in which I am involved in the northwest Atlantic is the actual closure in certain areas to most human activity because the areas are sensitive nursery grounds. These are open ocean areas, by the way. This is common practice on land, but to actually do this in the open ocean is something new. I set up this simple conservation paradigm, but it is one that has seldom been followed, and particularly not with marine ecosystems.

I said before that science learns in one sense primarily from experience. I'm going to go through a couple of examples here that I am very familiar with which will perhaps help illustrate what we should do and what we shouldn't do.

Newfoundland is a long ways south of Alaska, but we also enjoy a terribly cold climate because of the influence of oceanographic conditions. You don't have to convince Newfoundlanders that oceanographic conditions are important to the overall ecology. I want to give you an example from Newfoundland that should give heart even to the most pessimistic among us. This is a terrestrial example — the Avalon caribou herd. This is the most southerly herd of woodland caribou in the world, a herd that was decimated by habitat degradation and thoughtless slaughter until the early '50s. It was nearly extinct and down to about 50 animals.

But something happened in the early '50s to turn this whole situation around, and really it came to a human level. I think it really started with one person, then others. These people just decided that their ecosystem had to include a large and well managed herd of woodland caribou, and restoration began. It took the form of restoring the habitat, which had been degraded by water and power development, and it took the form later on of actual land protection.

At first, no one knew what the target restoration was. It was guided by common sense and a bit of intuition. Research started, however, to try to determine what were the most sensitive areas, and ask: how do you actually conserve this? How do you restore this ecosystem? The calving grounds in the sensitive areas were identified, they were then gazetted (mapped) and protected from further degradation. This has turned out to be a tremendous success story. Starting from less than 50 animals, the herd has continued to grow to the present time so that the herd is now some 6,000 strong.

How did this happen? How come these people accomplished this, and in other cases you can't? I maintain that it comes down to a couple of simple things. I'm going to oversimplify this because I have to for this presentation, but I'd like to point out at least three main things that were essential in this case.

One was user involvement. I mentioned that this started with the people. It didn't start with science and it didn't start with politicians. It started with people who cared and who wanted to live in an ecosystem that they wanted to define. So, user involvement was important. After about a decade of restoration, actual harvest was started, and local hunters became involved in the actual management process in terms of censusing animals and also in providing biological information. You can see that a return to hunting had no effect on the growth of the herd at all. In fact, it may, if anything, have increased it. But another thing that was done was to control the technology of hunting. It was realized that you can't go in there with machine guns and destroy the herd.

I'm using this in an analogous sense to compare to all sources of degradation. The key is that some form of control of harvest technology was used. And the other principle here is to protect the sensitive habitat areas for that particular species. With those sorts of simple actions undertaken, we see that the outcome was a success story.

There are other examples that I could use of success, but there are probably more of non-success. For that I'm going to turn to our major stock, the northern cod. We have been trying to restore the northern cod for 30 years. This wasn't so much a case of habitat degradation; this was just blatant lack of control of harvest starting back in the '60s when the European fishing fleet discovered the offshore spawning grounds of this stock. There was no protection at that time and the stock was decimated. The stocks dropped down and we have never really recovered. In the early 1980's, we started to make some recovery, but then our own fishing fleets moved in — we couldn't control those either — and now we find ourselves at the lowest point for stocks of northern cod ever in our history. In fact we now have complete closure of our fishery.

How come? I ask just a simple question: Why is it that here we have the same location — Newfoundland. We have desirable species — both the codfish and the caribou are species that people want to be there. How come we have two very different outcomes?

I want to go back to these characteristics. What we see if we examine the northern cod fishery is that we had almost no user involvement at all in any way. In fact, there was only user hostility and total lack of any user involvement in the conservation of the resource. We had no or little technology control. We didn't understand what the advances in commercial fishing technology could do to us.

Technology is a double-edged sword. It can help you or it can cut you, and in this case we got cut very badly by it. The other thing is that no protection of spatial or seasonal areas could be implemented until very recently when it was too late to stop the precipitous decline. I maintain that these things are symptomatic of our ability not to be able to restore damaged resources.

Perhaps some of you may be wondering what this has to do with an oil spill? Some may think that an oil spill is fundamentally different from these other human-caused perturbations, and, of course, in its details it is. But in our responses and abilities to restore damaged resources, I'm not sure that it differs all that much.

The immediate responses of course are very different. We have some technologies which can be brought to bear to clean up the oil. But I think the longer term effects are probably far more important than that. We have had oil spills happen on our coast as well. We have a growing oil industry at the present time, and, touch wood, we have not had a bad disaster such as you have experienced. However we have had some small ones.

Several years ago there was an accident which resulted in a burning tanker off the Grand Banks. Fortunately, it was well offshore and did not cause us much damage. If we were really on top of things, we would know ahead of time where the sensitive areas were and protect these from traffic or take other steps. But as often as not, we don't know. We don't have that kind of information, and all we can really do is follow some sort of common sense.

For example, if we look at the critical elements of a spill zone — I'm just going to come back to these same old things — what we really must know are the sensitive areas for a species and its productivity cycles, which is really just a temporal aspect of the same thing. We are not going to be able turn the clock back completely to the point where we don't have industrial development. Few people would vote for that solution anyway.

What we want to do is use our intelligence to try to conserve ecosystems and restore them and still allow some sustainable level of economic development. If you take these things just in a very simplistic way, we know that a spill like this one off the Grand Banks didn't really do any damage. It didn't occur in a sensitive area. The oil dissipated and burned, and so the overall net result in terms of restoration was probably minimal.

But consider a capelin spawning beach on the north shore of the Gulf of St. Lawrence. Capelin is a small pelagic fish, and the most important forage species in the northwest Atlantic. One can imagine in an area like this — many fish spawn on the same beaches and in the intertidal zone — a spill in this area would be devastating to this species, which is the most important forage species for almost everything that eats fish in the northwest Atlantic. This is the sort of thing that I'm talking about in a very general and common-sensical way, without having a lot of hard data and knowing exactly what the effects would be.

What I'm getting at is that our longer–term approach to this has to be at the ecosystem level. There may be some particular effects associated with an oil spill — I'm not an expert at this and I don't want to go into detail. We talked a little bit about the difference between populations and habitat, but maybe I can just spend a minute talking about acute and chronic, cumulative effects. The immediate impacts of oil are obvious: things are covered in oil and get slimed up and they die. We all know that. That's not a pretty sight, but it may not be the most serious result. We simply don't know what the most serious results are.

This is where more research into not the acute effects but the chronic effects of this type of spill may be needed than has currently been brought to bear on the problem. This could result in mortality down the line. We have the outstanding problem right now of the salmon and herring in Prince William Sound. They aren't there. People want to know why.

There are so many natural fluctuations in these populations, it's difficult just off the top of your head to point the finger and say, yes, it's because of the oil. We need more information, but certainly mortality does not have to occur in an acute sense right now. Mortality can be down the line as the result of a cumulative effect . Genetic damage is even worse. It's much less harmful to a population to destroy a number of its individuals than to harm its genetic structure, and this is something that we don't know very much about. I would suggest that these are areas that we have to find out more about.

So the major question is, how do we go about actually studying ecosystems? I have a fair amount of experience with this, but I don't have much time to talk about it now. I'll just mention some key points that I believe are important. The first one is the team approach. Individual people, individual scientists, have been funded to try to understand marine ecosystems since the turn of the century. I think it basically started in Norway, with Hjort who basically came up with a number of hypotheses on how marine ecosystems, particularly fisheries, fluctuate. None of this has done any good. If there is one thing we should have learned from all of this it is that the only way we are ever going to make progress is to use a team approach to problem solving.

This team should include scientists, but it also should include people who are not scientists. It should include users and representatives of the resource-using industry and so on. Anyone who has played any team sports knows that a good team will beat a group of dysfunctional superstars every time. You also need a solid research plan based on hypotheses so that the team can work together as a unit to address the particular problem. I won't go into any details here — you can use your imaginations. The problem you want to grapple with could be anything, but you need to develop that approach.

Another thing that we found to be very helpful is using simulation models to pre-test hypotheses and point directions. An example from some of my own work is a cod simulation model for the northeast shelf where there is a lot of physical, oceanographic, in-depth information which you can manipulate and say, okay, cod, do this, and let the model run and see what happens. Basically, based on some fairly simple assumptions, we can get the cod to follow a migration track which simulates reality very, very closely, and we have been able to validate this based on cooperative work with our commercial fishing people. I am highly supportive of the use of modeling before and also during data collection. There also should be some kind of a feedback loop in the process.

Another thing that I support a great deal is to try to make technology work for conservation and restoration and not against it. For so long, technology developments, especially in the ocean, have been used just to kill things. It's about time that we started to use the technology, which isn't bad in itself, to try to improve the quality of life and not just to destroy it. We have been using a lot of remote sensing and acoustic work in our area. We have been able to map out and track acoustic images of a cod school for months at a time over their range. We have developed a very high resolution spatial map of its distributions. We also tried to put this data together with physical information so that we can get a better understanding of what it is that's actually driving this ecosystem — whether it's physical forcing or biological forcing or other factors.

Putting the data together is a very difficult thing. It has to be done in a systematic way, but I believe that the results will more than justify the effort involved. In looking at predator-prey interactions, which seems to be an important thing in Prince William Sound, you could actually use acoustic technology to examine single fish in 400 meters of water in deep, open ocean at very high resolution. The high resolution data gained on the interaction between predators and prey may lead to insights into the very important effects that those interactions have on the population dynamics of the whole species.

I'll just leave you with a final thought. Science can certainly help solve these problems, but science cannot solve them alone. In the long term, I believe it is the involvement of the people, particularly of the users, that will solve this problem, and without that all the science in the world is not going to get you very far. I would go so far as to say that the future will bring more experimental management involving people who are users of the system. These are lessons that we have learned hard in some of the older fisheries of the world, such as in Newfoundland. Newfoundland fishermen are people who live on the water. We are trying to work very closely with them. Our older fisheries in the Atlantic have learned the lesson that failing to do this will usually lead to disaster. We've learned it the hard way. You — the way I see it anyway — have everything going for you. Let's not repeat those mistakes here.

Perspectives on the *Exxon Valdez* Oil Spill — Five years later

Charles P. Meacham
Deputy Commissioner
Alaska Department of Fish and Game

Alaska passed a milestone this month, pumping the 10 billionth barrel of north slope crude oil through the trans-Alaska pipeline. Presently, over 25 percent of domestically produced crude oil passes through this pipeline and into tankers which ply the waters of Prince William Sound. In the 17 years that tankers have been transiting the sound, over 12,800 trips have been safely executed.

Unfortunately, one serious accident occurred. Five years ago, on March 24, 1989, the 1,000 foot long supertanker *Exxon Valdez* ran hard aground on Bligh Reef in Prince William Sound. An estimated 250 thousand barrels (11.2 million gallons) of crude oil was spilled into the pristine waters of Alaska. Over the ensuing weeks, I watched oil spread with wind and ocean currents to impact about 1,300 miles of shoreline. This was the worst tanker oil spill in United States history.

Response efforts were initiated shortly after the spill with considerable attention directed at containment, protection of critical areas, and cleanup. Efforts by Exxon Corporation were extraordinary — 7,000 people, 1,400 vessels, and nearly 100 aircraft joined the assault against the spilled oil. By the end of the 1992 cleanup season, Exxon had spent about $2.5 billion to remove spilled oil. Today the casual observer is hard pressed to find any physical signs of oil contamination.

My personal involvement was in the damage assessment arena. Many studies that were initiated immediately after the spill documented resource injuries that, surprising to many of us, continue today. For some pink salmon stocks, it appears that there may be genetic damage which inhibits reproductive success. Harlequin ducks appear to be experiencing limited recruitment. Unexplained disease problems seem to be afflicting herring. In the case of Cook Inlet sockeye salmon, the consequence of oil–related fisheries closures was extremely large escapement levels that may have resulted in overgrazing of lake rearing areas. The summer of 1994 will be our first opportunity to actually quantify the number of adult sockeye salmon produced from those fish that spawned during the year of the spill.

Even though it was five years ago, I clearly remember my flight into Cordova shortly after the spill occurred as calm and uneventful — in stark contrast to events that would soon follow. A multi-agency team had been mobilized to develop injury assessment projects. The ensuing ten days and nights were largely sleepless for many people as the spill continued and the crisis assumed gargantuan proportions. This unprecedented event extracted the best each person had to offer with individual and state/federal agency efforts being meshed into an extremely powerful injury assessment program.

More than 100 studies were developed to determine the extent of injury or loss of natural resources that resulted from the spill. Studies were conducted in accordance with Natural Resource Damage Assessment regulations which outlined a process to determine appropriate compensation to the public for injuries to natural resources. Unfortunately, nearly all our activities were hidden under the veil of litigative secrecy.

At this point I must express my admiration of Alaska's Governor Hickel, the U.S. Department of Justice, and Exxon Corporation for pursuing an early settlement which provided over one billion dollars, largely for restoration and enhancement activities, rather than legal fees.

Our process is no longer litigious and secret. The public needs to understand what the trustees are doing and why. More important, we need meaningful public involvement up front — not just in review. In this regard I really appreciate the formation of the Public Advisory Group and especially look forward to their continuing contribution to this process.

Throughout history catastrophic events have often caused rapid, beneficial, changes in our philosophy. This is also true of ecological disasters, both real and perceived. About 100 years ago we had deforested an area of our country the size of Europe. The future of our forests looked bleak. Congress responded by creating federal forest reserves. In 1905 President Theodore Roosevelt converted forest reserves into the National Forest System, creating the U.S. Forest Service with Gifford Pinchot at the helm. The Chugach National Forest in Prince William Sound was created through this process.

A drastic reduction in the nation's wildlife during the 1930's coupled with the ecological horror of the "dust bowl" years inspired the nation, let by Aldo Leopold, to develop and support the new field of scientific wildlife management. And, in 1962 Rachel Carson's book *Silent Spring*, which dealt with the disastrous ecological effects of some pesticides, aided in mobilizing our nation toward an environmental consciousness that continues today.

As the largest oil spill in the history of the United States, the 1989 *Exxon Valdez* oil spill may also precipitate beneficial change. Already, this catastrophe in one of the nation's most pristine environments has rewritten the book on the effects of oil in temperate marine ecosystems, as you will hear this afternoon.

As you learn of our continuing concern for some species and the recovery of others, keep in mind this was more than a natural resource problem. Please keep in mind the effects on the residents of the oil affected area. While those of us who reside elsewhere are legitimately concerned, in my view our challenge is to do right by those folks who were more directly impacted than me and many of you.

At this point, five years after the spill, we have expended or obligated only about one-third of the settlement funds. As we set about developing projects on which the remaining six hundred million dollars are to be expended, we need to proceed with a balanced approach that includes (1) continued research on affected species, (2) restoration and enhancement of damaged resources and service, and (3), acquisition of some critical habitat.

Overview of Research & Monitoring

Dr. Robert Spies
Trustee Council Chief Scientist

Today I will provide you with an overview of the Trustee Council's scientific program: where it's been, where it is going, and the reasons why we're doing what we're doing.

I think the single most important point about the Trustee Council's scientific program is that it is an applied science program. That has implications because we're really dealing with the intersection of two different cultures: the scientific culture with the political and social dimensions of pollution problems, especially the *Exxon Valdez* oil spill. Although I understood that the intersection of these cultures—where the applied science was brought to bear on social questions—was very important, the spill has driven this idea home in my personal experience in a way that's quite real.

The excitement and discovery that we are trained for, the reason we became scientists, really is not the sole reason for our existence and not the sole reason for what we're doing under this applied science program.

The scientific program since the spill has consisted of several different phases: the response phase, the damage assessment phase, and finally the restoration phase. Right now we are really starting to shift paradigms from the damage assessment—following resources and counting them and seeing how they recover in kind of a simplistic way, to shifting over to try to understand what we can do for damaged resources and the resources we wish to enhance in the spill area.

Under the response phase certainly the management objectives were quite different than we see under the other phases. During response you find and track the oil, rehabilitate stressed animals, recover carcasses, and identify and protect sensitive areas. The characteristics of the science that is applied during these periods involve a very short time frame for planning, there may not necessarily be a lot of scientific rigor possible in the work, you may apply existing technologies to a new situation or a new problem, and the science can be fairly qualitative.

At the same time that the response was going on, and in this case it went on for several years, the program almost immediately went into a damage assessment phase. The researchers were attempting to ascertain the effect of the spill — what was the bottom line effect that the spill had on this environment? The management objectives were again quite different during this phase. We really needed to develop the legal evidence to establish the degree of liability and finally to establish what are the bases for restoration, what can we learn about the degree of injury and/or how we can restore the resource, or at least track its recovery.

During the damage assessment phase the science needs to enumerate the damaged resources and deal with cause and effect. Sorting out cause and effect in the environment after a large oil spill is not a simple matter. Nature is extremely complex, and assigning cause and effect in nature, with pollution separating natural from anthropogenic changes, is a very, very challenging undertaking. As George Rose said, it's not rocket science.

In this case we had to deal with a tremendous lack of baseline data that we could have used to get a better understanding of the state of the resources before the spill compared to what happened just after the spill. There was intense peer review required of all the work because of the rigorous nature of the scientific inquiries, and the scientific effort was fairly quantitative.

If we move on to the recovery and restoration phase, the management objectives switch again. This is where we are right now. We want to determine the rates of recovery for injured species and develop a restoration strategy. Those things have been laid out in the Restoration Plan that the Trustees recently adopted.

One of the characteristics of the science during this restoration period is that we continue to monitor populations. That's a necessary baseline ingredient of the program.

At the same time, we start to switch paradigms with these injured species. It's no longer enough to understand how badly they were hurt or whether they are recovering. If we want to do something about restoration, we have to understand what the bottlenecks are, what factor limits reproduction of this species, what the sensitive areas are, is the species dependent on food, how does it interact with natural factors, competition, predation. All of these processes suddenly become extremely important.

It requires a new paradigm, and we are in the process right now of shifting paradigms. We must also work within a long time frame to understand those resources that are slow to recover and to test ideas about how natural variability interacts with anthropogenic effects.

Those questions have to be asked within the ecosystem context, and the science is really driven by the management objectives that derive from that approach. This includes a strong, strong need to prioritize. There isn't enough money in ten settlements to answer all the good questions that people could ask about the marine environment and how it works. So we have to really think very carefully and rigorously about what we do and why we do it, and how it relates to restoration.

Nearshore Ecosystem

Dr. Charles H. Peterson
Institute of Marine Sciences
University of North Carolina

Because the oil initially floats and therefore gets transported in and deposited on the intertidal and nearshore ecosystem, it is this environment where the spill is most evident to the public and, as it turns out, where the damages are most intense. What I am going to tell you about today is that the damages to the nearshore ecosystem were widespread, that they were pervasive and penetrated deep into the ecosystem, that recovery is incomplete, and that damages still continue to occur from the spill in those ecosystems.

My talk is divided into three parts. First, I will talk about the oiling of the habitat itself, then about the intertidal ecosystem and biota, and then about the subtidal ecosystem and biota. In each case I will be telling you what we know, in summary form, about the damages that occurred initially, early on, what we know about the processes that have occurred since the spill, and I will give you some of the problems that remain to be addressed by the restoration and recovery and Trustee groups.

First, please note that the pure and simple mileage that was oiled in the three geographic areas — Prince William Sound; the Kenai Peninsula; Kodiak and the Alaska Peninsula — was extensive and unprecedented. The most intense oiling, the heaviest oiling, occurred in Prince William Sound, but the greatest extent of oiled mileage was in the Kodiak-Alaska Peninsula region.

The surface contamination after that initial oiling has been greatly reduced to considerably below the 1989 levels in all three regions. On the other hand, there is persistent and widespread asphalt and staining present in the high intertidal zone, there are oil patties still present and obvious on sediment surface among boulders in some heavily oiled shores, such as Sleepy Bay, and the subsurface oil has degraded more slowly than the surface oil. In fact, there are reservoirs of subsurface oil persisting in many sorts of locations: in fine sediment marshes such as the Bay of Isles, under oiled mussel beds where they are protected by the dynamic action of waves, by the mussels and their byssal threads, and in other protected sites, such as around boulders and in sheltered localities.

There are restoration challenges that remain vis-a-vis these contaminations of intertidal habitats. One — and it's a serious one — is how and if to clean oiled mussel beds to prevent injury of important mussel consumers. I'll mention that again later when I speak of the ecosystem. There's a question of whether asphalt should be targeted for cleanup, especially on national parks and in wilderness areas or in culturally sacred shorelines. There's a question of whether any cleanup should be targeted on oiled estuarine sites or fine sediments, where spill histories elsewhere show extremely long persistence. And further, there is a question of whether additional technologies should be explored, such as the Tesoro citrus oil technique, to try to clean surface and subsurface oil in particularly nasty places, like Sleepy Bay. Oiled mussel beds are one of the major concerns in the nearshore ecosystem.

We should note that there was also oil contamination of the subtidal habitat. Oil reached the shallow subtidal sea floor by transport on particles, rather than by the direct oiling that occurred in the intertidal. Various techniques, such as core sampling, sediment trap collections and assays of oil-degrading bacteria, revealed a time lag in contamination levels, with peak contamination occurring later than that in the intertidal zone, as cleanup in the intertidal helped move the oil down the slope and out of sight into the subtidal. Levels of PAHs and petroleum hydrocarbons in the shallow subtidal sediments have since declined, but there are relatively refractory petroleum hydrocarbons widespread, and those materials and their influence in these sediments are likely to be long-lived.

Now, I'll review the damages to intertidal biological resources. The initial damages were substantial and large. They resulted in widespread alterations of abundances of both plants and animals. The injuries were great in all three geographic regions. Furthermore, the before/after tests by NOAA demonstrated that the pressurized hot water cleanup itself was a major contributor to mortality of intertidal organisms. The specific impacts of the *Exxon Valdez* oil spill on the intertidal ecosystem varied with geographic region, elevation on the shore, and habitat type. However, in general, one can say that rockweed, *Fucus*, blue mussels, limpets *(Tectura)*,a periwinkle, some barnacles, littleneck clams and butter clams declined greatly in abundance, while oil-degrading bacteria, oligochaete worms, and an opportunistic barnacle increased. The abundance of intertidal fishes was greatly reduced by 50 to 70 percent, even when assessed in 1990.

What has subsequently happened in this environment? There was greening of the shoreline, as opportunistic algae colonized the space that was freed by the death and removal of *Fucus*. There has been subsequent slow recovery of *Fucus*, upwards on the shore, to a degree that only the high intertidal zone finds *Fucus* still depressed in abundance today.

In fact the high intertidal zone and its ecosystem — its community, if you will — has been the slowest to recover. Mid and upper elevations were colonized by an overabundance of an opportunistic barnacle, *Chthamalus*, and that, by preemption of space, helps retard recovery of the barnacles and limpets with longer life cycles that are normally abundant at that level on the shore.

There is an analogous pattern lower on shore in this system, which is characterized by scientists as one dominated by strong interactions among the species. There is analogous preemption of space low on the shoreline by *Fucus*, where it has spread over areas and prevents the natural assemblage of red algae from returning. There are several species with non-dispersing, non-planktonic larvae that have been documented to be slow to recover, notably one periwinkle and predatory drills. The slow recovery of these drills means that the opportunistic barnacles that have come to colonize the high level of the shore are not being removed by their predator at rapid rates and continue to preempt space.

Recruitment of clams remains depressed on oiled shores, postponing their recovery as a population. The community composition is slowest to recover and still grossly altered in estuarine habitat and in coarse textured shorelines. Intertidal fishes were substantially recovered in abundance by 1991, but I have an additional comment on that in a moment. Reliable reports from subsistence users reveal continuing depression in abundance of octopus and chitons, which are important species and long-lived invertebrates in this system.

There are restoration challenges facing us in the intertidal community. Given the importance of *Fucus* (rockweed) as a habitat provider for invertebrate animals and its inability to spread rapidly upwards on the shore, should restoration action be attempted to speed that return in the high intertidal zone? Should we transplant of predatory drills to speed their recovery and overcome their slow recruitment because of their reliance upon a non-planktonic form of reproduction and colonization?

Furthermore, it's quite clear that in this system, where damages are so pervasive and have not yet recovered, that ongoing monitoring of recovery is important so that we can inform the public about the continuing damages and changes in the system. But how often should that monitoring occur, where should it be, and of what sort? There's a question of whether we should attempt sediment restoration to promote clam recovery on the shores they normally occupy. Legitimate questions arise about whether a shellfish hatchery should be constructed to provide seed clams and other shellfish to facilitate recovery.

One of the most serious of problems in the intertidal zone is concern over the continuing ecosystem effects of oiled mussels and other prey in inducing reproductive impairments of important vertebrate consumers in the nearshore ecosystem. These are most notably black oystercatchers, harlequin ducks (perhaps also goldeneyes, scoters, turnstones, surf birds), river otters, and sea otters.

The subtidal communities also suffered initial ecological damages from the spill. There were major changes in the size and frequency of habitat-providing large algae, the small kelps, *Laminaria Agarum*, and the larger kelp –*Nereocystis* – where the oil apparently killed large numbers of old plants, but there was colonization by large numbers of new kelps by 1990. The oiling reduced the number of flowering stocks and blade densities of eelgrass, an important habitat-providing plant in the shallow subtidal. Amphipods, shown elsewhere to be a very oil-sensitive taxon, decreased greatly in abundance. Certain large invertebrates, notably the helmet crab and the leather star, were reduced in abundance, and the benthic infaunal community composition — this means the abundance of invertebrates that live in the sediments — was greatly altered by oiling at areas at shallow depths below the seagrass beds.

The subsequent changes in this shallow subtidal ecosystem are as follows: eelgrass parameters reveal essentially complete recovery; amphipods too appear to have recovered rapidly, even perhaps by 1991. However, the community composition of the benthic infaunal invertebrates remains altered and will probably recover only slowly, as judging from the history of other oil spills such as the *Amoco Cadiz*. During last year, the work of the scientists in the shallow subtidal zone has demonstrated an explosion of green sea urchins in the algae beds of Prince William Sound. This is exactly what one would have predicted from a large reduction in sea otters, which are their major predator. Shallow water fishes collected last year from oiled sites in Prince William Sound showed hemosiderosis, a liver malfunction indicative of ongoing exposure to some sort of pollutant or stress, with oil the most likely because this exposure occurred in oiled areas but not in unoiled areas.

There are restoration challenges, needless to say, that face us in the shallow subtidal systems. The first, and this follows from my comments moments ago, is to what degree the explosion in sea urchins will lead to a subsequent cascading of impacts on the shallow subtidal ecosystem. Urchins, when freed from their predators, are known to create urchin barrens, where they overgraze the small algae and kelps, thereby destroying an important habitat for recruitment of invertebrates and fishes, changing the abundance of those fish and grossly altering the coastal ecosystem. It seems appropriate that we document what effects occur here and how that cascading occurs and to what degree.

There are questions about what the time frame and trajectory of ultimate recovery will be for those benthic infaunal invertebrates in the soft sediments that have not yet recovered, and there are important questions about how long fishes will continue to be exposed and injured by oil in this environment.

I leave you merely with this question: At what point will this coastal nearshore ecosystem resemble what it would have looked like in the absence of the spill? And I can only tell you that we are not yet there.

Toxicology & Distribution of Oil

Dr. Stanley Rice
Program Manager
National Oceanic and Atmospheric Administration

Chuck Meacham earlier said that if you're a casual observer, you'll probably be a little hard pressed to find oil in Prince William Sound today. Well, I haven't been a casual observer and nor have several state and federal colleagues of mine who have been looking at the oil since it was spilled and then tracking it with time. We know quite a bit about the present distribution, and it is persisting in some environments. Because it is persisting it is suspected in some cases that it may still be doing damage to some of the injured species and causing new injuries. We will examine that information as we go through this talk.

Beginning in 1989, a lot of that oil inevitably ended up on the beach. There was a very visible cleaning effort — nothing we didn't already know. The real question was — how much really got down to where the animals live in the water column and below the surface in the sediments?

NOAA sent a crew into the spill region to track the oil. They found that not a lot of oil got into the water. A lot of it was floating on the water surface and ended up on the beaches because oil is lighter than water and it floats. Nevertheless, some did get below the surface. The highest concentration measured was about 6.2 parts per billion. That's a part per billion, not part per million, so that's not a really highly toxic dose at all. A fraction of the oil was polynuclear aromatics, and they are toxic, but not acutely toxic, at least at that concentration.

We expected that there would have been a bit higher concentrations. The highest concentrations were measured starting at about Day 7 after the spill. By two months later it was very difficult to detect any of the *Exxon Valdez* oil in the water column. This means that we did not have toxic conditions, and they certainly did not persist.

Divers collected sediments from the intertidal zone, down through the shallow subtidal and into the deeper zones. I will be summarizing about a thousand analyses, or maybe even a little more, in a second here, but first I'd like to discuss the processes that get the oil down into the sediments.

The mechanisms can be natural wave action or the mechanical action that occurred in year one and then to a lesser extent in year two. When the fine grain sediments were contaminated with oil and then sank, the oil particles went down into the depths. When we did measurements — literally maybe a thousand or more — we came up with several generalizations, which is really all we have time for today.

In the intertidal zone, oil pooled below the surface of the sediments. We found huge concentrations, concentrations much greater than one part per thousand. Some concentrations were in the parts per hundred. In some places we can find those concentrations in the intertidal zone five years later.

Once you move into the lower intertidal or the shallow subtidal zones, the concentrations go down substantially. It's only in what was termed "the bathtub ring" where the gross amounts of oil were found. The amounts below the bathtub ring are still quite detectable. However, once you move down slope especially below 20 meters, we seldom find *Exxon Valdez* oil. The majority of samples taken do not show *Exxon Valdez* oil below those depths, and what is there is very difficult to detect. We can detect polynuclear aromatic hydrocarbons at those depths but they have natural origins, such as oil seeping out into the sediments over geologic time. So, there is a background matrix of petroleum there, but it isn't *Exxon Valdez* oil.

In terms of mass balance — basically where the oil went — there's good news and there's bad news. The good news is that much of the oil has left the scene for one reason or another through processes such as biodegradation, photolysis or evaporation, for example. A number of animals have the capability to break down oil through biodegradation processes. The vertebrates certainly can break down oil, and many microbes do too, and there's a lot of microbes in the marine environment. If anybody did well with the oil spill, it would have been the microbes; they benefited pretty heavily from this free energy that was put into the system, free energy from their point of view at least.

Atmospheric photolysis also counted for some losses of the oil from the system, certainly some oil was dispersed and removed. Clearly, the two billion dollar clean-up effort helped to recover and dispose of a fair chunk of the oil pie.

We are really left with two pieces of the oil pie that we have to be concerned with after, say, 1991 or so: that oil which was beached and that which was put down into the subtidal sediments. If we look at the comparisons, they are kind of striking.

The majority of the oil remaining is down in the subtidal sediments, but when we look at the data, the concentrations are really low. Even though the majority of the oil went to the subtidal sediments, it is spread out over a large geographic area. We're talking about the contamination in a three-dimensional sense as we look at the topography of the bottom. There is a lot of subsurface subtidal sediments there, both inside Prince William Sound and outside. This is where the majority of the oil is, but it's in low concentrations.

In contrast, a much smaller amount of oil was beached, and some still remains there. It was the most visible, of course, and so we have a lot of pictures of it, in terms of measurements as well as photographs. Also, in contrast to the subtidal zone, the concentrations on the beaches were very high, and the majority of that beached oil was in Prince William Sound — in that bathtub ring.

What about the persistence? How much is still there, and what's the big deal about it? When we look at the subtidal sediments, the concentrations are low. Oil in subtidal sediments does have a long persistence, but it contrasts significantly to the intertidal sediments, where concentrations are much higher. The oil now exists in two parts in that beach environment. We find oil, not only below the surface but also in the intertidal sediments and in the mussels. This is a significant fact, because mussels can be a food source or prey for a long list of higher consumers. That's something we need to track into the future.

In 1993, when the Alaska Department of Environmental Conservation did their standard shoreline survey, they found quite a few sites where significant quantities of oil remained in the intertidal zone. When we looked at the mussel beds, we also found a lot of oil there. During the NOAA surveys, we found 52 sites where concentrations were greater than one part per million. This is where the problems appear to be continuing and where we may need to take a greater, in-depth look.

Just to give you a little science along with this overview, let's look at the levels of oil that we found. The concentrations located at the very northern tip of Chenega Isle in terms of total petroleum hydrocarbons in the sediments was around 26 parts per million or so. Some sites, such as Foul Bay, the levels go up to about 62 parts per million. These aren't the highest or most contaminated sites, but we do have some comparable data.

The amount of polynuclear aromatic hydrocarbons — we concentrate on these compounds because they are a very toxic fraction — is a little over 4 parts per million in the mussels that were resident above those sediments. We found about one percent polynuclear aromatic hydrocarbons in those petroleum hydrocarbon measurements. This is significant because mussels are the biological tissue where you'll find the most hydrocarbons in Prince William Sound, and they are a significant prey item in the marine food chain. We need to track the recovery of the oiled mussel beds. With time, we can see what happens in nature.

When we added the 1993 data, there wasn't much change in the levels of hydrocarbons in the mussel tissues. It seemed like there might be some decrease, but the range of possible error shows a certain amount of variability. The point is, this is a rather stable environment, and if we're going to wait for nature to clean up these particular soft sediments, it's going to take quite a while — like more than my lifetime, maybe, who knows. For that reason, there's some mussel bed cleanup activity being contemplated for the upcoming year.

How do we know this is *Exxon Valdez* oil we're finding in the mussel tissues? We can make "fingerprints" of the different types of aromatic compounds and their patterns. When we look at the mussels overlying those sediments, we find a pattern that we can match to *Exxon Valdez* crude oil. It is getting a little bit weathered with time, so it's not exactly a perfect match, but it's good enough — certainly good enough to say that in 1993 we had both mussels and sediments that were still contaminated with *Exxon Valdez* crude oil, and we're very confident with that statement.

The oil is still there. It's in isolated pockets maybe, but some of the concentrations in those pockets are quite high. So what? What should we do about that? Well, one question is, is it still toxic, and is it a problem? Whether it is a problem depends on the species being examined.

When we look at some of the injured species, such as pink salmon, herring, harlequin ducks, juvenile otters — there are others but these are just some examples — these species live and/or feed in the intertidal zone. Pink salmon, for example, spawn in the intertidal zone, so the eggs and alevins develop in the intertidal zone. Herring spawn in the intertidal zone, pink salmon larvae feed in the intertidal zone, harlequin ducks feed in the intertidal zone, and juvenile otters feed there.

These are animals that have some level of injury and are going to continue to have some level of risk as they continue to live in the intertidal zone. However, if they are still injured, when were they injured? Were they injured in 1989, when there was orders of magnitude more oil in that intertidal zone, literally ten, a hundred thousand times more oil, and consequently they are having a slow recovery period? Or are they continuing to be injured by the amount of oil that's still there?

We have evidence on a couple of species which implies this is certainly the case. Harlequin ducks are still feeding on oiled mussel beds, for example. There is some evidence that the survival rate of pink salmon in oiled streams is still not equivalent to salmon from non-oiled streams, for example. And lastly, you'd have to ask the question regarding some of these species, is the injury that we're observing now the result of the spill? The herring might be an example, rather. The herring crash in '93 — researchers found a lot of diseases in those fish, or they appeared to be diseased. Was that disease natural? Was it caused indirectly through exposure to oil? It's really tough in that case to demonstrate probable cause and effect — Bob Spies mentioned that earlier — and it's even more difficult to prove. For example, consider the harlequin duck. This animal is a vertebrate and a very good metabolizer of oil, if the bird feeds in an oiled mussel bed. We probably have about 12 hours to sample that bird and still be able to detect oiled mussels or oiled food in its crop and stomach. After that time period, the oil is going to be digested well enough and the oil metabolized so that you're not going to be able to track it in that animal. That doesn't give us a very good window over a 365-day year to pin it down and to really confirm that linkage.

That's just one example of where it's a real problem. It is really tough to prove that injury is due to the presence of the oil. And yet, because we are still able to measure a significant amount of oil, in 1994 I'm sure we're going to go out there and find oil again. It is a concern and a worry.

Going back to the two pieces of pie we were looking at earlier, the subtidal oil also continues to be a concern, I think. It's not acutely toxic, certainly, and yet we still have lots of unknowns. The subtidal areas are a lot more difficult to study than the intertidal zones, so we have a lot less information, and yet things are not quite normal there. Is that because of the oil or not? It's really tough to say.

What should we be doing about the subtidal environment? We probably still need to monitor it, although we can reduce the effort that we have been using to monitor recovery. We still need to understand and track the oil, particularly as it relates to the other animals that still live there and that are still showing some level of injury or recovery. I don't think we need to do it with the intensity that we have for the last couple of years. It's a place where we probably should reduce our effort a little bit.

In contrast, the intertidal oil is not a concern, it's more of a worry. We see a fair amount of oil there, and if you live there or harvest there, whether you're an animal or a human, you've got not a concern but a worry about some of those spots in Prince William Sound. The concentrations of the oil that we can find there is still too high, too high in both mussels and the intertidal sediments. The species are still showing signs of injury even though we are really hard pressed to show the direct linkage, the real proof. Nevertheless, we need to be following that.

As far as the intertidal oil, though, what can we do? There are some restoration plans for this year. We are planning on going out there, along with ADEC, and digging up some of the oiled mussel beds, removing the oiled mussels temporarily, replacing the underlying oiled sediments with clean sediments, and then putting the mussels back. Basically, we want to reduce that risk to some of the animals and remove some more of the oil. This won't be practical in many cases, but for those sites that are still heavily oiled and are in the upper intertidal zone, we're going to try.

We need to continue to monitor and track this risk because it's still significant. We have evidence that it's linked with injuries to some of the species, even if it isn't conclusive. We need to conduct some research, particularly in the eco-toxicity realm of studies. For example, the pink salmon, herring, possibly the sea ducks and possibly with other species that haven't been studied. Basically, we need to understand better whether these chronic exposures of oil are still having an effect.

In conclusion then, looking at those two pie wedges that are of concern, the intertidal zone has the highest concentration, the subtidal has a relatively low concentration. Is it a problem? I think it is. It is definitely a problem in the intertidal zone even if the geography is not tremendous in terms of massive coverage of the Sound. I'm not willing to say it's not a problem in the subtidal, to give it a flat no. It really approaches being a non-problem. The oil in the subtidal zone probably is a problem to some animals although we've never studied them, maybe we can't even identify the species. Regardless, there's not that much oil there, so it's not going to be a big issue even if it is a problem.

We've conducted very little restoration activity in the intertidal zone since Year Two. We are going to renew that effort. It's not practical, at least right now, to consider the concept of restoring subtidal areas, but those heavily impacted intertidal zones that still have oil, we can have an effect there. We need to continue to monitor both, although I should say that we can reduce the effort in the subtidal regions significantly. But we need to monitor the restoration actions and the effects they have on the oil levels we are able to find in the future. We need to track that risk. And lastly, we need to do some eco-toxicity research on the intertidal areas.

Subsistence

Dr. James A. Fall
Program Manager, Subsistence Division
Alaska Department of Fish & Game

The *Exxon Valdez* oil spill of March 1989 fouled waters, beaches and resources used by Alaskans for subsistence for thousands of years. Concerns about oil spill contamination to subsistence resources had been expressed by the late summer of 1989.

Subsistence harvests play a vital role in the economy and way of life of 15 predominantly Alaska Native communities of the spill area. Before the spill, a wide variety of resources were used for subsistence, such as salmon, halibut and other fish. Marine invertebrates, such as chitons, clams, octopus, snails, mussels and crab were taken in large quantities, as were land mammals, birds and eggs, and wild plants. Before the spill, marine mammals, especially harbor seals and sea lions played an important role in the diets of many residents of these communities.

Subsistence harvests in these villages in the 1980's were very large, averaging 200–400 pounds or more of edible weight per person annually. These harvests were shared widely with relatives, elders and others in need. Harvesting and processing tied families together through cooperative activities and provided a context for young people to learn the skills and values needed to live in their communities.

In the year after the spill, subsistence harvests declined substantially in the ten villages of Prince William Sound, Lower Cook Inlet, and the Kodiak Island Borough. Subsistence harvests were down 55-60 percent in Prince William Sound, 45-50 percent in Lower Cook Inlet, and from 10-70 percent or more in the Kodiak Island Borough. In contrast, although the spill did disrupt subsistence harvesting in the Alaska Peninsula communities, over the long haul for the first year we could not detect any meaningful changes in subsistence uses there.

The range of resources used for subsistence also declined markedly in 1989 in the communities of Prince William Sound, Lower Cook Inlet, and Kodiak Island, down about 50 percent or more compared to pre-spill usage. When asked about these declines, most households cited concerns about possible contamination of subsistence foods as the reason they had reduced or eliminated their uses of subsistence foods in 1989. This included 92 percent of all the households we interviewed in Prince William Sound, 78 percent in Lower Cook Inlet and lower percentages in the other two regions.

It was clear that the spill had created conditions very unfamiliar to subsistence users and raised issues which could not be addressed by their own knowledge and skills. Further, there was little specific information available to help the resource agencies address these concerns. In response, the Indian Health Service organized the Oil Spill Health Task Force. In addition to the IHS, regular participants included the Alaska

Department of Fish and Game Division of Subsistence, the Alaska Department of Health and Social Services, the Alaska Department of Environmental Conservation, the National Oceanic and Atmospheric Administration, Exxon, and two regional Native service organizations: the North Pacific Rim for the Chugach Villages, and the Kodiak Area Native Association.

Subsistence harvests have rebounded throughout the spill area since the first year. Increases were slowest to occur in the Prince William Sound communities of Chenega Bay and Tatitlek, with no recovery seen until the third year after the spill. Recovery was evidenced in Nanwalek, English Bay, and Port Graham in the second year and continued to rebound in subsequent years, and in the Kodiak area communities we also saw an increase in subsistence harvest in the second and third year, and in some cases matching pre-spill averages in the second and third years after the spill.

Looking at the range of resources used for subsistence, we see the same story. We see recovery over time, but slowest in Prince William Sound. In Chenega Bay there was an increase in the average number of resources used per household in each post-spill year. Tatitlek, the other Prince William Sound community, reflected pretty much the same pattern. There was a more rapid increase in the average number of resources used in Nanwalek and Port Graham, matching pre-spill averages by the third year. Same thing in Kodiak.

Despite these indications of rebounding subsistence uses, other information continues to show that the subsistence way of life in a number of communities has not yet fully recovered from the effects of the spill. For example, community members have lingering concerns about the long-term health effects on human health of using subsistence foods. Subsistence users report that, for cultural or economic reasons, in some cases they have resumed uses of resources despite their concerns. Signs of disease and depressed wildlife populations contribute to their concerns. Examples which lead to concern include depressed populations of birds, marine mammals and marine invertebrates, and an outbreak of a virus in Prince William Sound herring stocks in 1993.

Clearly, people have not yet regained confidence in their own abilities to judge if resources are safe to use. Further evidence of this change is a shift in the composition of resource harvests. A major change in the composition of the marine mammal harvest in Chenega Bay occurred from 1985 before the spill to 1991 several years after the spill. The pounds per capita harvest was about the same in these two years. However, the marine mammal portion declined from better than a third of the total production to only 6 percent after the spill.

In contrast, people are now relying a lot more on salmon and other fish, such as halibut, in the post-spill years. These are the resources they have more confidence in and that are in larger supply. Another shift we've seen is a change in people's assessments of subsistence harvests and causes of reduced uses.

Using Chenega Bay as an example, when we interviewed members of the community in 1989 and again in 1991, most households, by their own assessment, said that resource harvests had still not rebounded to pre-spill levels. In 1989, the vast majority of the households said that this was because they were concerned about resource contamination. That reason as a citation for overall declines went down to only 14 percent in 1991 in Chenega Bay. However, most households still said the resource harvests were down, not because they were letting concerns about contamination stop them but because resources were in short supply. Almost the exact same pattern was documented in Tatitlek, with a very striking reduction in contamination concerns causing lowered harvests and a very stark increase in people's perceptions of resource scarcities leading to lower harvests. We see the same thing in Nanwalek and Port Graham, although not as many households point to resource scarcity as a cause of decline. And I must add, that simply because households did not say that resource contamination led to a reduction, that does not mean that they still weren't concerned about contamination, just that it wasn't cited as a reason for lowered harvest.

Here is an example of a couple of observations that we are getting from people in the subsistence communities. The first comes from a letter sent to the Division of Subsistence from John M. Totemoff of Chenega Bay, a subsistence seal hunter. He helped a Subsistence Division researcher named Vicki Vanek collect samples of seals around Chenega Bay in September of 1993. His letter to us is dated January 1994, about three months after he helped Vicki.

> *I went deer hunting along the shore with my bow picker, saw two deer on the beach between four trips. Two days ago I went seal hunting to Prince of Wales Pass and then another trip to Latouche Island. On these trips I did not see a seal, so we haven't eaten any fresh seal meat since we went out hunting with Vicki.*

The second example is from another letter, this one addressed to the Subsistence Division's staff from Jerry O'Brien of Cordova, who we hired to conduct marine mammal interviews in Tatitlek late last year. Mr. O'Brien wrote to us, again in January of 1994:

> *I am no biologist, but Tatitlek is very depressed for no seals or sea lions, no wild ducks or signs of animal life around the Narrows. Very quiet. I brought two seal over for the people. I only wish I could have had more to bring them. They really appreciated that. I only wish that this was all a bad dream and we could all go back to our regular Aleut life and be what we used to be, a proud and good hunter.*

In order to aid in the restoration of subsistence uses, the Oil Spill Trustee Council funded a subsistence foods collection and testing program in 1993, which also included a large, public communications component. The overall goal of the project is to provide updated information to help increase people's knowledge about the spill's effects on resources and to increase their confidence in using subsistence foods. This project was coordinated by the Department of Fish and Game, Subsistence Division, with the testing of samples occurring at the National Marine Fisheries Service's Northwest Fisheries Center in Seattle. The collection of samples was contracted to the Pacific Rim Villages Coalition. About 20 assistants from eight villages helped collect samples in 1993. This included over 100 samples of shellfish and fin fish from 15 sites. As part of this project, samples from five harbor seals taken for subsistence by hunters from Chenega Bay were also tested at the NMFS lab.

The results of the tests for hydrocarbon contamination have been consistent with those from the earlier rounds of collection and testing. Concentrations of PAHs in shellfish samples were very low and did not differ from those from reference areas at Angoon and Yakutat outside the spill area. Findings from the tests on the blubber of harbor seals were also very encouraging. Blubber from samples of seals from oiled areas of Prince William Sound were taken in 1989. In 1990, blubber samples from seals taken in some of these same areas showed reduced but still elevated levels of PAHs. The five blubber samples from western Prince William Sound in 1993 had extremely low levels of PAHs, essentially background levels.

Restoration study findings have been reported to subsistence users and others in several ways. Newsletters have been mailed to literally thousands of people and organizations in the spill area. We have held several series of public meetings. A first round of meetings and consultations in 1993 helped select resources and sites for hydrocarbon testing. A second round of meetings took place in February and March 1994 to present study findings and elicit ideas for this year's projects. In order to increase community knowledge about the hydrocarbon testing process, a group of community representatives traveled to Seattle in August 1993 to tour the NMFS facility. They also attended a meeting of the Oil Spill Health Task Force to review a number of oil spill resource issues.

For 1994 the Trustee Council has so far funded two subsistence restoration projects. The first continues the foods collection and testing program, as well as the public communications efforts. This will likely be the last year for collection and testing. The emphasis this year is on sites that have not previously been part of the program. Again, involvement of local assistants in the project will be emphasized. The second project is a cooperative effort to interpret data about the status of harbor seal and sea otter populations in Prince William Sound and Lower Cook Inlet. A goal of this project is to build a consensus among biologists and subsistence hunters about steps to be taken to speed the recovery of these resource populations, and we hope to continue this project beyond 1994. Finally, another opportunity to restore subsistence uses is a five million dollar appropriation by the Alaska Legislature from the criminal settlement funds to support subsistence restoration projects by the communities of the spill area. The Department of Community and Regional Affairs and the Department of Fish and Game are presently working with the Trustee Council's staff to develop procedures to implement this grants program.

I'd now like to conclude with the following points. First, the *Exxon Valdez* oil spill severely disrupted subsistence uses which are vital to the health and survival of the communities of the spill area. Second, in response to concerns about contamination of subsistence foods, an Oil Spill Health Task Force formed to coordinate studies to provide specific information to subsistence users. More recently, the Trustee Council has supported these studies. Third, subsistence uses have rebounded since 1989.

Few households continue to cite contamination concerns as a cause of lowered uses, although questions about the long-term effects of the spill on human health remain. Some households have returned to using subsistence foods despite their questions, simply because to do otherwise would cost them their way of life. Fourth, a common theme that we have heard from subsistence users is the suspicion that, overall, resource populations have continued to suffer since 1989 and that this is evidence that something is fundamentally wrong with the natural environment of the spill area.

Given these points, it is clear that five years after the spill, the restoration of subsistence uses is not complete. Important resources are scarce, confidence is lacking, information is in demand. Future restoration efforts must build upon the start that has been made to involve all the communities of the spill area in collaborative efforts to heal the resource base. These efforts also need to address the full scope of the subsistence way of life, including restoration and enhancement of the knowledge and skills upon which subsistence depends. Strengthening the subsistence way of life in the wake of the spill is one way we can prepare to face threats of future environmental disasters to the natural resources and the people of our state.

Archeology

Dr. Ted Birkedal
Chief, Cultural Resources
National Park Service

On the eve of European contact, Southcentral Alaska was one of the great population centers of the Pacific Rim. The people of this area were armed with sophisticated maritime hunting and fishing technologies and aided by the redistributive powers of complex yet highly functional social and political structures.

Native people of the coastal provinces of this region were able to take full advantage of the numerous fish and marine mammals that are found in its waters. Village after village dotted the coastlines, some boasting hundreds of inhabitants, although most were considerably smaller.

What few people realize is that the population densities of the Gulf of Alaska may have rivaled those found among the agricultural tribes of the American Southeast and the American Southwest. For Kodiak and the opposite shore of the Shelikof Strait alone, the Russian censuses of the late 18th century record nearly 7,000 people, yet recent scholarship suggests that even this already ample figure represents a reduction from earlier numbers that may easily have been as high as 14,000 and possibly as many as 20,000 at the time of initial contact and before the first Native Alaskan encounters with European disease, warfare, and socio-economic disruption. The abandoned villages and encampments from Alaska's contact and historic era produced an impressive archeological record in the Gulf of Alaska.

The archeological record, however, is not limited to the more recent past. The archeological record of the Gulf of Alaska has been enriched and multiplied by at least 6,000 and possibly 8,000 years of prior occupation by the forerunners and ancestors of the present-day Koniag, Chugach, and other Alutiiq groups in the area, including their Athabaskan neighbors and cultural relatives, the Dena'ina Indians. Countless earlier generations made their own contribution to the region's archeological legacy.

Unfortunately, on the eve of the *Exxon Valdez* oil spill, this archeological legacy remained largely undocumented and uninventoried. Most site locations were unknown and few sites had been evaluated to ascertain their relative significance, either from the point of view their heritage or scientific value. Thus, federal and state agencies were caught quite unprepared as far as archeological resources were concerned.

Luckily, in 1988 a mock oil spill exercise with Russia had identified coastal archeological sites as a potentially vulnerable resource type in the event of an oil spill in the Bering Strait. The lessons learned in this exercise were quickly translated to the *Exxon Valdez* oil spill event, and protective measures were rapidly built into the interagency planning process for oil spill response. Exxon Company, for its part, did not hesitate to assume a share of the responsibility for the protection of cultural resources in the oil spill area and Exxon quickly established the *Exxon Valdez* Cultural Resource Program, a program well staffed by some of the most expert archeologists in the northern Pacific.

Three major types of impact to archeological resources were anticipated. One was direct oiling, which could result in the contamination of archeological soils and specimens. Oiling could possibly invalidate any C^{14} dating samples and also mask archeological artifacts, making them invisible and more vulnerable to disturbance because you could not see them during clean-up actions. Another form of injury anticipated was from clean-up activities, especially, high-impact methods that involved extensive beach disturbance and large crew numbers. A final form of injury that we identified at that time was vandalism and looting—purposeful theft or disturbance of archeological remains by oil spill workers or fellow travelers.

Of the above, direct oiling was the least controllable, except in the limited zones where booming was possible. The real threat was from the clean-up activities and attendant vandalism, so the focus was placed on these two potential impacts. The best tool for the prevention of injury from clean-up activities and clean-up related vandalism was a fast-track review process that was developed by the Alaska State Office of History and Archeology and the participating federal agencies to ensure compliance with the Section 106 of the National Historic Preservation Act.

In its more refined and streamlined form, which had already been developed by 1990, the two essential components of the review process consisted of the formation of a Cultural Technical Advisory Group, or CTAG, and the involvement of the State Historic Preservation Officer. The CTAG's membership consisted of representatives of all the participating state and federal agencies, including the Coast Guard, Exxon Company, and relevant Native Corporations. This group reviewed the oil spill clean-up plans and recommended appropriate constraints or protective measures to prevent injury to archeological resources. The State Historic Preservation Officer then reviewed the recommendations of CTAG and, if approved, these were sent on to the Coast Guard for final approval and implementation. This process rarely took more than a few days, and sometimes it took only a few hours.

Protective measures or constraints were generally simple and included such actions as restrictions on clean-up techniques and methods. Another measure was avoidance of archaeologically sensitive beach segments—they would simply be excluded from clean-up—and restricting clean-up crew traffic to certain sections of beach was an additional technique that was employed. Posting professional archeologists as cleanup monitors also served as a constraint action, as well as educating and briefing clean-up crews off-site and on-site about the need to avoid disturbing archeological sites. And, on rare occasions, actions might even include the collection and mapping of artifacts in advance of clean-up crews if there was no other way to protect a site. The burden of surveying beach segments in advance of clean-up and educating the crews involved in clean-up and monitoring activities usually fell to the *Exxon Valdez* Cultural Resource Program archeologists. They conducted most of the field work during the response effort.

But after all of this effort, what happened to the archeological resources? Injury assessment to determine what actually occurred to archeological resources was difficult compared to actually implementing the compliance process because the various pieces of oil spill legislation were very vague on whether archeological resources could be considered as "natural resources," the category of protected resources specified in the legislative language. And although an archeological interagency Cultural Resources Working Group made up of state and federal archeologists was formed in 1989 to begin planning injury assessment and restoration; cultural resources remained the stepchild of the oil spill injury assessment process for over two years.

The question of whether the oil spill laws covers archeological resource injury and restoration remains controversial to this day. The Oil Spill Trustees finally authorized injury studies to begin in 1991 under the guidance of the Cultural Resources Working Group. Dr. Al Deacon of the State University of New York headed up one of the largest of these studies. This study looked at 60 shoreline segments, tested 10 specially-selected archeological sites, and examined 26 other archeological properties. The archeological team looked at physical, chemical, and soil properties of the soil column of archeological sites, and also used computerized geographical information systems to analyze the spatial data from the archeological work.

The Oil Spill Trustees also authorized the Cultural Resources Working Group to perform a supplemental study, primarily a library study, that sorted through all the records that were available from the response effort to see if there were any clues as to injury contained in these records. This study conducted was by Michele Jesperson of the Alaska State Office of History and Archeology and Kristen Griffin of the National Park Service. One of the major difficulties that hampered the study was the lack of any pre-spill comparative data, the same problem you hear about again and again from the various scientists involved in injury assessments. The problem was we could not compare our findings to any pre-spill data. There was virtually no prior data to look at, maybe a few dozen sites we knew something about.

What are the results of the injury studies? First, let's look at the total universe of sites in the area of the spill. This number has been estimated to be about 3,149 archeological sites, based on projections from known data on 1,287 sites in the oil spill area, and we believe this is probably a conservative figure. It may be a little bit higher than that.

Of these 3,000-some sites, approximately 113, give or take a few sites, sustained more than a negligible amount of injury from oil clean-up activities or vandalism. That is about 3.6 percent of the projected archeological sites in the oil spill sector. Approximately 276 sites were subjected to light to heavy oiling. However, it appears that only 59 of these were subjected to moderate or heavy oiling—this represents less than 2 percent of the total site universe, so that is good news.

The number of sites impacted by archeological vandalism appear to number about 100. There was a close correlation between archeological vandalism and sites with clean-up injuries. Most of the injuries observed came from 1989, near the beginning of the oil spill response effort, before things were really in place in terms of systems of prevention and protection.

While the results are still not certain, it appears that hydrocarbon contamination of upland archeological materials was slight. Hydrocarbon contamination of archeological dating specimens from sites in subsidence zones, however, are more of a problem. In future excavations, if we go into the intertidal zone, we may inadvertently expose lower sediments to oil from above and we will need to also give special cleaning treatment to these formerly uncontaminated radiocarbon samples. A projected 155 sites in subsidence zones may have been subjected to some degree of oil contamination.

Restorative efforts have gone forward on 24 known sites. What we found in 1993, our first year of study, was that a lot of vandalism and other types of injury apparently stopped after 1989. We now have two cases out of 14 we looked at this year that show continuing signs of vandalism. However, overall, the situation looks pretty good. Most oil spill related vandalism to archeological sites ended after 1989, once the constraint system had been firmly put in place.

What did we learn that can benefit future response actions? One, it was obvious we needed good pre-spill baseline data for archeological resources. This is probably the primary lesson for other scientific disciplines as well as for archeology. Prior data on resources is crucial to both effective response and meaningful injury assessment. Secondly, I think the most important point, the reason there was no major injury beyond what I have documented here is because the constraint system I was talking about earlier worked so well. This bureaucratic process, a fast-track version of the Section 106 process outlined in the National Historic Preservation Act, more than anything else, served to protect the archeological sites from injury. We estimate that the injury levels to archeological resources would have been a hundred times more than we see today if this system had not been implemented.

In my mind, one object in particular exemplifies that success. At a particular site in MacArthur Pass that was the scene of concentrated clean-up activity, archeologists last year noted that a stone ax, first recorded three years ago, remains at its original location, still undisturbed.

Fish

Dr. Phillip R. Mundy
Fisheries and Aquatic Sciences

In looking back over the last five years and asking the question — what have we learned? — I believe we've learned a great deal, and I don't think that what we've learned is necessarily consistent with what we knew about the impacts of oil spills on fisheries resources in the past. We've certainly learned that the fisheries resources of Alaska were exposed to oil. We've seen this everywhere we've been able to look, where we had the money and the time to look, and where we had the experimental design that allowed us to look.

Salmon, herring, ground fish, shellfish, and every conceivable intertidal resource was exposed to oil. The damages of the oil spill are currently being tallied and quantified. However, we saw that the fisheries resources of Alaska were damaged both by exposure to oil and by the disruption of harvest management activities that precluded harvest managers from taking appropriate steps to limit escapements in some of our sockeye salmon systems.

We've got exposure and damages— we've learned that. But the other lesson that we learned that's come through loud and clear has been the one of persistence. Oftentimes you hear in oil spills — particularly the one that I recall is the *Amoco Cadiz* because that was a large nearshore oil spill that was much talked about in the biological community — that the effects are over quickly, with the water soluble fractions gone and everything is fine. However, we may indeed have a problem in most fisheries situations because the fish that may have been impacted by the oil died, they sank, they went away. Larval fish are just like pieces of thread in the water — if you want to measure that or look at the impact, it's very, very difficult. In Prince William Sound we were most fortunate to be in a situation to have resources where we had fisheries baseline data, where we had quite a bit of experience with managing these resources, and we have come to understand that, yes, damages were done and the damages are persisting in the environment to this day, and we expect them to persist for some time.

In the amount of time that's available today, I would barely have time to read you the titles of all of the work that's been done under the natural resources damage assessment and under the restoration program, so I'm going to be able just to move through some results fairly quickly and share a few snapshots of work that's been done on the more prominent of the fisheries resources, and offer apologies in advance to all the researchers whose work I must only skim over here.

We know that the damages included loss of salmon reproductive capacity and loss of reproductive potential in the natural environment. We've also been able to measure reproductive impairment in the laboratory in herring. There's been a loss of immunocompetence, that is, a lower disease resistance, also in laboratory experiments in herring. In sum it seems that the damages that we're measuring throughout the environment seem to have a common theme: mortality coming from various sources and also a reduction in growth which leads to mortality.

There is data available which shows both exposure and persistence. For example, Tracy Collier of the National Marine Fisheries Service has found benthic fish at some oiled sites showing persistent exposure to aromatic compounds through the time period 1989 to 1993 by looking at the enzyme induction activity, which occurs in response to petroleum hydrocarbons. Collier looked at data from rock sole, a bottom fish. This will have to do for the bottom fish and the crabs — these are very large and important resources — but we just didn't have a lot of opportunity to study these in relation to the oil spill.

In the case of herring, there was exposure directly on the herring, and oiling of the spawning grounds. We have done laboratory studies which show reproductive impairment and reduced immunocompetency, that is, reduced ability to resist disease. One way to look at these things is to simply simulate the effect. In some areas, we can take a look at mortality, oil-induced mortality, and survival rate in relation to a simulated effect based on the reduction in growth and reduction in survival that may have occurred from the 1989 year class.

In a study on pink salmon growth in the nearshore environment conducted jointly by the National Marine Fisheries Service and Alaska Department of Fish & Game, we saw a reduction in the daily growth rate, although in 1990 they apparently rebounded. A study by Alex Wertheimer and Mark Willette demonstrated something that's extremely important in terms of fisheries effects, and that is reduction in growth and changes in the migration pattern. The migrations of juvenile pink salmon released from the AFK hatchery in Prince William Sound in 1989 appear to have been affected by oil contamination, the growth of juvenile pink salmon appears to have been reduced 17 to 30 percent by oil contamination in nearshore nursery habitats, and lower juvenile growth in oiled areas appear to cause 31 to 53 percent reduction in survival to the adult salmon stage.

Reductions in growth in the fisheries are usually coupled with increased mortality and consequently a loss in adult production. Results from the Prince William Sound embryo mortality study showed increased embryo mortality in the case of the oiled streams as compared to the control streams, which were not oiled. The conclusions showed elevated embryo mortalities in oil-contaminated streams and now there seems to be a possible genetic transmission of these damage effects.

Now let us move out of the realm of damages that might have been due to direct exposure to the oil and into the area of disruption of harvest management activities. In 1989 in Cook Inlet, Kodiak, and also on the Alaska Peninsula at Chignik, harvest management operations for salmon were disrupted substantially. These are examples of what happens when you disrupt the harvest management operation — escapement goals are set based on what we believe a nursery lake for sockeye can bear, and when you put too many fish into the area, you get a reduction in the amount of food due to heavy grazing by prior year classes. The result is lower growth which translates to elevated mortality. The lower growth is certainly going to be translated into fisheries losses, and as Chuck Meacham mentioned earlier, we're going to have to wait until this year, and perhaps 1995 and the year after, to really understand the extent of the damages that were done to the sockeye salmon systems.

What can I offer you, other than a recitation of what we've learned in the course of five years of oil spill studies? I think I can offer you a perspective that comes from a couple of different areas. First of all, having worked as a salmon manager for many years, I've been focused on one species. However, on leaving Alaska, I started to work in other badly damaged ecosystems, and I realized that perhaps there's more to salmon management than putting the right number of salmon in the river, although that's certainly important. I've been working with a group of scientists for the last three years trying to understand what ecosystem management means in terms of protecting salmon resources in a badly damaged ecosystem, in this case it's the Columbia River basin. I think we definitely need to try to understand the fisheries damages in an ecosystem context, and in an ecosystem context we focus on how the parts work together.

For interpretation of damages and what they mean, you've got to avoid, within an ecosystem context, being reductionist. That is, you shouldn't be pulling all the parts apart and trying to understand how they work. In an ecosystem context, you're supposed to take one step back and look at the effect on the whole ecosystem and examine what's happened. I think you can look at the oil spill as a "treatment." I think the ecosystem got a good treatment of oil in 1989, and I think that we've documented the responses of fisheries resources to the oiling. As far as actually getting down to the mechanisms — we're working on that. That's going to take a lot of hard study, a lot of laboratory work. But actually having measured in the field, in situ, such as embryo mortalities resulting from the oiling, I think was a major scientific achievement. The demonstration of reduction in growth in the field as a result of oiling was a very high scientific achievement. But now, trying to understand what's happened, we need to sit back and try to see how the parts fit together.

The second perspective that I would offer you is what I would call the bioassay approach. In years past, about 60 years ago, one of the ancestors of Dr. Stanley Rice was probably out there trying to figure out what happened to people who ate shellfish with paralytic shellfish poison. About 60 years ago the shellfish industry that marketed clams and mussels was almost destroyed because we really didn't understand what paralytic shellfish poison was. So we went to the biochemist and said, "Please, tell us what's in these clams that's killing people!" They looked at them, but 60 years ago analytic techniques were not very good, and they told us they didn't see anything — there was nothing there — there was nothing they could measure.

What biologists do while they're waiting for chemists and physicists to catch up with them is they go out and conduct a bioassay. We knew that these shellfish weren't bad, we knew that they hadn't been improperly handled, we knew they were good, wholesome shellfish, but they were making people sick and sometimes killing them. So, we took these shellfish, ground them up, dried them, and fed them to rats, and we counted how many rats died. Now, this is a fairly crude test, and it's certainly not something that's going to impress a biochemist, but I can tell you it was a very effective way to figure out whether a shellfish was safe to eat or not. That is a bioassay.

It was some 45 years later that the biochemists finally caught up. They said, oh, yeah, we know what this is, at least we know what some of it is, it's saxitoxin, and now we can measure that analytically. However, in the intervening 45 years, we were able to function quite well without knowing exactly what it was in the shellfish that was making people sick and killing them.

So, on the one hand, you need to work very hard to understand the mechanisms, certainly. But on the other hand, you have to take a view of the ecosystem as a whole functioning entity. You can't demand reduction in all aspects in order to be able to measure an effect, and certainly the effects observed in the field are now being confirmed in the laboratory. I believe that the explanations will come if the research is supported.

One other perspective beyond the bioassay perspective that I would like to share is the perspective I bring from working in a damaged ecosystem. In fact, I like to think of the Columbia River basin as sort of the Sarajevo of fisheries management. We have a small problem down there. We have one salmon stock that's an endangered species, we have another salmon stock that's a threatened species, we have a lot of salmon populations — I think well over a quarter of the chinook populations in the basin last time I looked were heading for the X axis, to extinction. We're going to lose a lot of populations in the next ten years.

In 1920, the runs in the Columbia River basin, as near as I can tell, were probably in pretty good shape. Indeed, even when the first dam was built on the Columbia River in 1932, they still weren't in bad shape at that time. But, over the period about 1932 to 1970 we lost those fish, they went down the drain. They went down the drain 2,000 fish at a time; they went down the drain 100,000 fish at a time — when we closed off spawning habitat and when we just simply abused the environment. We are probably spending now, if you count lost hydroelectric revenue, roughly $200 million a year to work on salmon and to try to restore it. So if you think a billion dollars in settlement is a lot of money, try the estimate of $325 million that the administrator of the Bonneville Power Administration estimated was spent last year on research, restoration, and lost electric generating revenues as a result of managing the hydroelectric system to protect salmon. You're talking about a very, very big problem. My estimate of what we're spending per sockeye in the Idaho Snake River basin is about $1 million a fish.

So, I think that you need to take a message from the Ghost of Christmas Future here, a message from Sarajevo. Work hard to understand the effects of the *Exxon Valdez* oil spill on the fisheries resources and on the ecosystem as a whole, because it is very important.

Marine Mammals

Kathy Frost
Marine Mammal Biologist
Alaska Department of Fish & Game

Prince William Sound provides excellent and diverse marine mammal habitat. The most common marine mammals in the region are sea otters, harbor seals, killer whales or Orcas, humpback whales, Stellar sea lions and harbor and Dall's porpoises.

When the *Exxon Valdez* spilled 11 million gallons of crude oil in the Sound on March 24, 1989, many of these marine mammals swam or crawled through oil and inhaled aromatic hydrocarbons as they breathed at the air/water interface. Harbor seals and sea otters rested on oiled rocks and algae. Seal and sea otter pups were born on oiled substrate and nursed on oiled mothers. The prey of some species were contaminated by oil, and this food chain contamination may have lasted for some time.

Shortly after the spill, studies were initiated to assess its impact on marine mammals that were likely to be affected. For some species, baseline data on abundance, seasonal distribution, natural mortality, and reproduction were so incomplete or lacking that it was difficult to conduct meaningful studies (for example, harbor and Dall's porpoises).

Others, such as sea lions, were present for only a short period after the spill and then moved away as part of their annual cycle, and it was not possible to track which animals had been in contact with the spill. Because of the inadequacies of comparative data and study methodology, many of the effects of the *Exxon Valdez* oil spill on mammals as well as other species may never be known.

As a result of damage assessment studies three of these species were found to be injured by the spill and have continued to be studied over the last three or four years as part of restoration and monitoring projects to determine whether recovery is occurring. Those three species are killer whales or Orcas, sea otters, and harbor seals.

Historical studies of killer whales before the spill indicated that about 300 whales sometimes used Prince William Sound. Only some of those are regular residents. Following the *Exxon Valdez* oil spill, killer whales were studied by counting and identifying individuals in the Sound and comparing those individual identifications and counts to pre-spill data.

Every killer whale has a unique color pattern on its dorsal fin and the white saddle below which allows individual identification. This means that when scientists count whales in the Sound, they know not only that they saw 22 killer whales on a particular day, but which particular individuals they were and whether they were the same animals that they saw last year or the year before or the year before.

In one group of Orcas in the Sound, the AB pod, a significant number of animals were found to be missing after the spill and these whales have not been seen since. However, as has been so often common in our oil spill studies, there was no positively demonstrated cause-and-effect relationship between the absence of those whales and the *Exxon Valdez* spill, and we will never be able to say definitively why, in fact, those killer whales disappeared. This is complicated by the fact, as I said, we had an ongoing interaction between commercial fisheries and killer whales. Killer whales like to eat black cod and halibut, and fishermen don't like it when the whales take their catch. However, I think when all was said and done, the fishery interaction had been going on for numerous years, the oil spill was very time specific, it occurred in 1989, and the losses we saw to AB pod also occurred in that year.

In 1989, seven animals were found to be missing from AB pod; in 1990 an additional six animals were missing. To put this in perspective, the total pod consisted of 36 animals, so the mortality in each of those years was approximately 20 percent. Normal mortality in a killer whale pod is about 3 percent to possibly 8 or 9 percent per year, so this is an extremely high and abnormal mortality. No calves were born into AB pod in either 1989 or 1990; however, in 1991, 1992, and 1993 we had one or two calves born each year. From 1984 to 1988 numbers of killer whales in AB pod remained approximately stable, ranging from 31 to about 36 sighted in a particular year. Following the spill, we saw the loss of 6 animals and the additional loss in 1990. Since then the numbers have been relatively stable with a slight increase. As of the end of the 1993 field season, there were 26 animals documented in AB pod.

What should we do about killer whales in the future? I recommend that we continue to monitor AB pod, at least to see if the recovery and the birth of calves continues. In addition, studies of killer whales should be expanded to address their interaction with other components of the Prince William Sound ecosystem, particularly harbor seals and fisheries, and not treat them simply in a world of their own.

Sea otters are an extremely high profile species in Prince William Sound, as they are wherever they occur. They are abundant year–round in the Sound. Even before the *Exxon Valdez*, scientists knew that sea otters would be a problem if a spill were ever to occur. The major reason is that, unlike harbor seals which rely on a thick layer of blubber for insulation, sea otters rely on their fur, much like you and I in a down jacket — if it gets dirty, it doesn't work. So any kind of contamination with oil meant that sea otters were quickly subject to hypothermia.

Not surprisingly, sea otters were one of the first species to be obviously impacted by the spill, and a great variety of studies grew up as a result of this immediate impact. Some studies estimated total otter mortalities. There were also studies of distribution and abundance made during boat and aerial surveys. People looked at survival, reproduction, and mortality patterns after the spill in oiled and unoiled areas. There was a whole suite of studies. To give you some perspective on this effort, between 1989 and 1993, 20 scientists and over $3 million were dedicated to sea otter studies.

Carcasses of approximately 900 sea otters were recovered following the spill, and at a later date after the data were interpreted and the subject of carcass recovery addressed, it was estimated that approximately 2800 otters died as a result of the spill. Sea otter investigators were luckier than some. There actually had been surveys in the Sound in 1984 and 1985. Surveys were again conducted in 1989, '90, '91, and '93. Based on those surveys the conclusion was drawn that there were no significant decreases documented on the Kenai Peninsula, Kodiak, and the Alaska Peninsula.

"No significant declines" does not mean that no animals died, it means that the results did not show numerically, statistically robust evidence of declines in the population. However, the Fish & Wildlife Service analysis did indicate a 35 percent decline in oiled areas of Prince William Sound in 1989. That compared to an increase of 13 percent in the unoiled areas. Since 1989, surveys have been conducted every year except 1992. In 1989 through 1991 the numbers were approximately similar. In 1993 the surveys indicate a slight increase. That increase is not statistically significant, and so we'll have to monitor those numbers in the future and see if that trend holds up.

The studies by Fish & Wildlife Service and Rotterman and Monet between 1989 and 1993 indicated that more prime-age adult animals (between ages two and eight) died during 1989 and the two post-spill years than before the spill and more recently in 1992 and 1993. In a normal sea otter's life, most mortality occurs while it's a very young animal, just weaned as a pup, or as a very much older animal. It's not very usual for a prime–age animal to die. Normal mortality of that prime–age component is around 20 percent. During the years 1989 through 1991 that increased considerably. Of the carcasses found on the beaches, 40 to 43 percent were in that prime–age category. In the last couple of years that mortality appears to have returned to a more normal trend. About 19 percent of the carcasses found along the beach now fall in that prime–age category.

Concurrent with this, studies indicated lower survival of pups in western Prince William Sound. Now, this is one of the things that I'm sure confounds non-scientists more than almost anything you hear. Every time you think you have a result from a biologist, there is always a caveat, but that's just the way life is. There aren't very many easy answers in science. Increased pup mortality certainly has been documented in western Prince William Sound. We don't know what the cause is. It may be oil spill related; it may not be oil spill related. Studies have documented only 13 percent survival in western Prince William Sound, which encompasses the oiled area, versus 36 percent in the eastern Sound. The following year, we saw 46 percent survival in the western or oiled area, but 73 percent in the eastern Sound. Still a differential between the east and the west — is that oil related, or is that habitat related? Only additional studies will ever give us the answer.

In the future, sea otter investigators hope to continue to monitor recovery and continue studies of juvenile survival and reproduction. In addition, any studies of this whole nearshore ecosystem must include sea otters and their role as a keystone species.

We will have to look at how sea otters are affected by some of the things that Pete Peterson told you about in terms of survival of intertidal and subtidal species.

The final species in this three species sweep are harbor seals. Harbor seals are year-round residents of Prince William Sound. Current estimates of population size are around 3,000 to 5,000. No one predicted before the spill that harbor seals would be a problem, and I think this is a warning to all of us not to define our expectations so narrowly that we exclude species from our investigations too early in the game.

Almost everybody stated fairly emphatically that seals would avoid oil, they wouldn't swim into these oiled areas, and that it just wouldn't cause problems. That didn't turn out to be the case. Harbor seals did not avoid oil, they hauled out on oiled rocks, on oiled algae, they swam through oil, they breathed at the oiled water-air interface.

During 1989, 50 to 100 percent of the harbor seals in oiled areas were externally oiled, their behavior was abnormal, and animals were observed to be lethargic and unresponsive. A fairly broad suite of studies looking at harbor seals developed early on. Scientists conducted necropsies which included pathological investigations, looking at tissues microscopically to determine if there was damage to the liver or other organs, and chemical examination to determine if there were elevated levels of hydrocarbons in the tissues. In addition, there were surveys to look at distribution of these animals and see if any detectable pattern was available in their numerical abundance.

To summarize the findings briefly, lesions were found in the brains of some of these heavily oiled seals. The pathologist indicated that these lesions were serious enough to have caused animals to drown. We don't know the actual causative mechanism for those lesions. It is speculated that inhalation of the aromatic fraction of the oil may have caused the problem. Hydrocarbons were found to be elevated in bile of externally oiled seals. Hydrocarbons were slightly elevated in the blubber of some of these seals, but as Jim Fall noted earlier, those levels have returned to normal in the last couple of years.

ADF&G had conducted surveys of harbor seals in Prince William Sound at 25 sites in 1984 and again in 1988. Based on those data, we knew we had an ongoing, pre-spill decline of harbor seals which complicated our interpretation. Our survey sites existed in both the oiled and in the unoiled area. In 1984 and 1988 the rate of decline in both the oiled and unoiled areas was quite similar — 11 percent for one area and 14 in the other.

However, following the spill, we saw a 45 percent decline between '88 and '89 in the oiled area, compared to an 8 percent decline in the adjacent unoiled sites. Studies have been ongoing since then, and it's pretty hard to interpret the data. It looks like, based on surveys conducted in August and September, that numbers may have stabilized after the initial problem in 1989.

In total, our best estimate was that approximately 300 seals died following the spill. The status now in terms of our harbor seal studies, including recent chemical analysis of subsistence-taken seals, suggests that hydrocarbon levels are no longer elevated in their tissues. Pupping, which appeared to be significantly lower in the oiled area in 1989, has apparently returned to normal.

The surveys are a little more complicated to interpret. Our fall surveys suggest that numbers have stabilized on the oiled haulout sites. However, surveys conducted during the pupping period when the reproductive animals are present indicate an ongoing decline. This apparent difference in trend is something that future studies will have to address. We need to continue to monitor the population status of these seals and track whether recovery does, in fact, occur. We need to pursue whichever is the most accurate indicator of the status of the population, whether it's pupping surveys in June or whether it's in fact molting surveys in the fall.

In addition, we need to better understand how harbor seals use their habitat, what habitat is critical to them, and to appreciate how harbor seals interact with the rest of the ecosystem. As I said earlier, we have documented an ongoing decline of harbor seals in Prince William Sound, as well as in the northern Gulf of Alaska. That has been exacerbated by damage caused by the spill, and right now a lot of people's lives stand to be affected in a very real way in the future if we don't figure out what's happening with these species and hopefully figure out a way to turn it around.

Where does all of this information leave us and where do we go from here? We need to continue to monitor the status of these affected species, and more than just counting and documenting injury, we need to understand why they are or are not recovering and what makes a healthy Prince William Sound. We need to take these studies of individual marine mammal species and link them with other studies of Prince William Sound to better understand how the Sound ecosystem works and how the many components inter-connect.

This is neither a simple nor an easy task. No one in this room today can change the fact that the spill occurred, but every one of us can work hard to ensure that we learn as much as we possibly can from it. What we learn should be the basis for better policy decisions and better response in the future. We must ensure that our policy makers have the information they need to safeguard special places like Prince William Sound in the future. The American taxpayer pays millions of dollars each year for scientists like me to predict the potential effects of oil spills or other environmental perturbations. People like me hypothesize about what might or might not happen based on very little real life information. The *Exxon Valdez* oil spill is providing that real experience.

Everyone in this room is remiss if we don't insist that we learn everything possible from that spill. Scientists, fishermen, subsistence hunters, and other members of the public have to work together to collectively design and implement programs that will not only restore the injured resources in Prince William Sound, but will help us be better prepared to deal with and minimize the impacts of any such event in the future.

Birds

Dr. David Irons
Wildlife Biologist
U.S. Fish and Wildlife Service

First I will present background information on the bird studies that were done and why those studies were selected, an overview of the known injuries and the status of recovery, and then I will identify some gaps in our knowledge and make recommendations for future work. Much of the work I will present here today was done by a suite of biologists that are too numerous to name in the time available, but I thank all of them.

During the summer there is over half a million marine birds in the spill area in Prince William Sound and at least a million outside Prince William Sound. Some of those numerous species represented in the region are murres, kittiwakes, fork-tailed storm petrels, marbled murrelets, and puffins. In winter about 300,000 birds reside in Prince William Sound; there are at least that many in the rest of the spill area. In winter the species present are primarily sea ducks and grebes. In all there's over a hundred different species of marine birds that reside or pass through the spill area.

In addition to marine birds — for these purposes I'm including sea ducks and seabirds in that category — there are also shorebirds, bald eagles, and northwest crows, which are important in the spill zone and are also susceptible to oiling. The question asked most often about birds affected by the *Exxon Valdez* oil spill is "how many animals were killed?" However, since the spill we have learned that birds were injured in *two* general ways: through direct mortality and also through long-term sub–lethal effects, such as effects on reproduction.

In order to determine how many birds died after an oil spill, one can go out and count the dead oiled birds. The problem with this method is you don't know what percent were recovered. In some cases, it may be that only 10 percent of the bird carcasses are found. Unfortunately, after most oil spills the only major verifiable measure of bird mortality available has been counting the number found dead.

We also wanted to know whether the oil spill affected bird populations in the oiled area. To determine in a statistical, rigorous way if populations have been affected, there must be data on population levels before the spill, and you also need to examine control populations that were not affected by the spill. Another question people ask after an oil spill is what are the long-term, sub–lethal effects. Again, to answer this question, there should be pre-spill data and a control population. I'm telling you these things so you have an appreciation for the importance of knowing ahead of time the population levels and productivity of birds that may someday be oiled. Without good comparison data from before the spill, you're limited to counting bodies and you will not be able to accurately determine population effects. You may also not be able to detect long-term, sub–lethal effects.

Basically, then, the species that were chosen to be studied after the spill were those for which we had pre-spill data. In the years since the spill, for one or more seasons, there have been studies conducted on murres, marbled murrelets, pigeon guillemots, black-legged kittiwakes, fork-tailed storm petrels, bald eagles, and shorebirds, which include black oyster-catchers, surf birds, and black turnstones. Several of these species were only studied one or two years. In 1994 we plan to study marbled murrelets and pigeon guillemots. In addition to the single species studies, we also studied all species by conducting marine bird surveys in Prince William Sound in summer and winter.

Based on the carcasses found and on damage assessment studies, about 30,000 bird deaths were attributed to the *Exxon Valdez* oil spill. According to one study, the carcasses found extrapolates out to 375,000 total bird mortalities. More carcasses were found after the *Exxon Valdez* oil spill than after any other oil spill in the world. Some of the other major spills compared included the *Torrie Canyon*, the *Hamilton Trader*, and the *Amoco Cadiz*.

Murres are diving seabirds which are abundant in the spill region. Generally, diving birds are affected by oil more than non-diving birds. Murres accounted for over half of all the carcasses found.

Besides the number of birds killed, another important question after an oil spill is "did it affect bird populations?" We were able to investigate this question in Prince William Sound and some colonies outside the Sound because we had some pre-spill data to make comparisons. Surveys were conducted in Prince William Sound in summer and winter to determine population estimates. By comparing the pre-spill and post-spill numbers for Prince William Sound in the oil spill area and in the non-spill area, we found that after the spill, the population level of several species of marine birds were lower than expected. Because the two surveys conducted before the oil spill were somewhat different, these results were calculated separately. When you compare data from the survey conducted in 1972 –73 with post-spill surveys, in the wintertime both the black oystercatchers and pigeon guillemots showed declines. In the summertime, cormorants, harlequin ducks, black oystercatchers, and northwest crows showed declines.

There was also a more recent survey in the Sound, in the summer of 1984. Using those data to compare with post-spill surveys, loons, scoters, harlequin ducks, oystercatchers, mew gulls, and arctic terns all showed population level declines in the oiled area.

Outside Prince William Sound, the only population data available was that of colonial nesting seabirds. Data from the Barren Islands showed that post-spill counts of murres were lower than the pre-spill counts.

Effects on reproduction varied with species. Reproductive pairs of bald eagles were lower in the oiled area than in the unoiled area in 1989. Black oystercatchers showed lower reproduction in the oiled area in 1989 and in areas of oil spill clean-up in 1990. Harlequin ducks have had lower reproductive success in the oiled areas than in the un-oiled areas since the oil spill. Kittiwakes had less reproductive success in the oiled area than in the un-oiled area compared to pre-spill data, and murres also had lower reproductive success after the oil spill.

Before I get into the status of recovery, I want to present some data that may or may not be related to the spill but certainly could affect recovery of several species. Because of the pre-spill survey data from 1972, we have population estimates for birds in Prince William Sound in that year. Those population estimates were about 600,000. The population estimates for the Sound now are about 300,000. That's a 50 percent decline. However, not all the species affected seem to have declined. Most species that did decline were those that feed on forage fish, including marbled murrelets, puffins, pigeon guillemots, kittiwakes, glaucous-winged gulls and arctic terns. Also, as you've heard, harbor seals, which also feed on forage fish, have declined in the Sound both before and after the spill.

Conversely, birds and mammals species that rely on intertidal or subtidal benthic invertebrates for food did not decline from 1972 to after the spill. These species include harlequin ducks, goldeneyes, black oystercatchers, old squaws, scoters, bufflehead ducks, northwest crows and sea otters.

So, of course, the question is, why have these species declined and was it because of the oil spill? Probably not, because we have data from 1984 that indicated that several of these declines had already begun. The most obvious connection between all of these declining species is that they are fish-eaters. It makes one question, of course, if lack of food was a cause for the decline. We'll probably never know exactly what caused these declines, but if the recovery of injured species are limited by problems with their food sources, then they may have little or no chance of recovery.

Data on kittiwakes productivity collected by the U.S. Fish & Wildlife Service and the damage assessment study also suggest that food resources may be declining in Prince William Sound. Prior to the oil spill, total productivity for all kittiwakes in the Sound was consistent at a level of .3 chicks fledged per nest, but in 1989 the oiled colonies had their worst year and the unoiled their best year, so the total remained high. After 1989, the productivity declined. There was very low productivity in 1993, similar to 1992.

For kittiwakes, brood size at fledging may be used as an index of food availability. Brood size at fledging, again from 1984 to '89 in the spill region, was consistently high. In 1990, '91, and '92, it dropped, and again in '93 it was low. So, we have ten years of data from kittiwakes that suggests that food has declined in Prince William Sound. The data available on species decline from '72 are also suggestive that food may have had a role in those declines.

None of the species that showed oil spill-related population declines have recovered. Of the species that showed declines in productivity, bald eagles and black oystercatchers appear to be back to normal. Kittiwakes and harlequins have not recovered. While looking for the recovery of an injured species during the marine bird surveys, we found that goldeneyes and a sea duck species that was not previously listed as injured as showing signs of oil spill effects four years later.

Some of our gaps in knoyledge include that we do not know why kittiwakes reproduction success declined after the spill, or the reasons that other species are not recovering. The problems may or may not be spill-related. There is some information on the large-scale food limitation. Other gaps in our knowledge are in the area of potential oil spill effects that were not identified, either because we did not have enough pre-spill data to show the effects, or because we chose not to study them.

An example of the first case is the marine bird surveys. We have only one survey in 1972 and one in 1984. Had there been more surveys done, say, every other year since 1972, we would have had a much better data set to demonstrate changes or effects by the oil spill. An example of not studying a species could be arctic terns or puffins, because we had no pre-spill data on their productivity in the Sound, we chose not to study them.

Recommendations for the direction of future work: I think the injured species should be re-evaluated at this time to be sure that important injured and potentially injured species are studied to determine when and if recovery occurs. In light of the information that suggests food may be limiting the recovery of several injured species, the food limitation hypothesis should be investigated. To the extent that oil seems to still be in the intertidal and subtidal sediments, invertebrates that are prey for birds should continue to be monitored for hydrocarbons.

In summary, lack of pre-spill data limits our ability to show oil spill effects. Several bird species were impacted, most have not recovered, and recovery of some may be limited by lack of food.

Where Do We Go From Here?

Steven Pennoyer
Federal Trustee Council Member
Alaska Regional Director
National Marine Fisheries Service
National Oceanic & Atmospheric Administration

I was very impressed with the quality of the presentations from our scientists, and I feel somewhat embarrassed to be talking about generalities and concepts after all that rather specific data that you've received. One of the advantages to going last is you get the final word. One of the disadvantages is you can't select ahead of time entirely what's going to be presented before you get there. So, I'm going to have to ask for your forbearance in shuffling through some of the papers here and thereby avoiding any egregious redundancies that I can.

I'd begin to set the stage for the topic of where we go from here with a fairly detailed review of where we have been, but I think you've had that already here today. I don't intend to go back in history, except maybe to make a couple of points for emphasis. I think also the presenters have talked to you about where we go from here in each one of their specialties, and I will try to build in some of the things they've said.

The observations from Kathy Frost in a general way, for example, told some of the things we haven't done and need to do, and some of the obligations I think we have to the future. I would like to re-emphasize a couple of points on history that Kathy and others brought out. That is our preparedness in 1989 to deal with an ecological disaster of this magnitude in terms of damage assessment and restoration. Frankly, we weren't.

We knew that the physical and biological resources likely to be exposed to the spill fell into the jurisdiction of several different state and federal agencies. We knew that some of them would have differing responsibilities in regard to that spill, but we had no game plan. There was no pre-agreement on how damage assessment should be accomplished, or which agencies would be responsible for what.

At the time of the spill there was not an adequate, shared inventory of existing pre-spill background information. In fact, there wasn't pre-spill background information on any of the resources, as you've heard today. We had no idea at that time how far the oil would ultimately spread and which portions of the ecosystem would be affected. We didn't have initially the adequate, predictive models to assess what should have been studied. I think many agencies diverted resources from ongoing programs and projects and immediately sent personnel to start evaluating what needed to be done.

There was no Trustee Council, there wasn't a plan for one at that time or a formula, there were no interagency coordinating groups for damage assessment, and there was no shared database. I think it's a credit to the scientists involved in the program that it came together in the way it did. I think it is clear from the presentations you've seen today that despite all the obstacles, a credible effort was mounted. NOAA and other state and federal agencies did respond, we were told to proceed to get the job done, were given the authority to go out and do battle with the spill.

The first step, of course, was damage assessment. Over the next three years, 50 to 65 projects a year, involving a very large number of scientists that you've heard something about here today went out and did the work on the spill, often without special dispensation in terms of budgets, often dropping their existing work and having to work around what they would normally do. The damage assessment would lead to litigation and get at potentially responsible parties to reimburse, first, the citizens of our country for the damages. I won't go into any detail on the settlement and the financial arrangements, I think they are outlined in some of the brochures that have been handed out today. I think the excellent status report and the newsletter covered a great deal of that, so I will skip over that part of it.

As you've heard from the studies, some of them were strictly damage assessment in regards to looking at numbers of animals and rates of declines, some provided more insightful information that I think has led us to the point that we're at now. I know that in this process many members of the public and even the scientific community were not always pleased with the speed at which the Trustee Council seemed to be proceeding since the settlement. I'd like to just say briefly that we all as Trustees take this obligation seriously, and I think we have to keep our decisions in the context of what we can do in the longer term.

Many restoration options were available for future funding. They range from direct commitment of the funds for short term or immediate restoration activities or research activities, to longer term plans whereby endowments would be set aside to study these resources into the next century. There were many, many options in between those extremes. We've had choices presented to us, including monitoring the natural recovery of injured resources, many direct restoration options including management support, various enhancement projects, habitat protection and acquisition, and other choices.

We did not want to make these decisions in a vacuum and we were unwilling to begin significant restoration projects until a plan for expenditure of the settlement funds was complete. I think you have already been presented with the draft restoration plan that was prepared last fall and sent out for public review. That plan currently is under environmental impact statement review which will be finalized by this fall.

The plan, even in draft form, was used to select the 1994 work plan, and hopefully the final plan will be used for the 1995 work plan and beyond. After that we will be in the planning mode rather than trying to react to emergencies and specific opportunities we were afraid would be lost.

The settlement was finalized in October 1991, late in the third year of the damage assessment effort. We had to end the damage assessment projects and make the transition to restoration, and we had only three months to plan for this eventuality. It was logical for the 1992 effort to give priority to the close-out of damage assessment projects, but the Trustees also used that opportunity to initiate restoration in a number of areas, some of those you've heard about already today.

The Trustees' activities have entered a new phase. With litigation behind us, the major focus is now on restoration. I think also as presented in the documents and other people's comments, restoration is a menu of activities and strategies. The Trustees have settled on a comprehensive approach, which includes direct restoration, research and monitoring, and habitat acquisition and protection. All three are essential elements of the program that is embodied in that draft Restoration Plan that I commented on earlier.

The plan purposely does not prescribe a fixed allocation for each element. We, as Trustees, must exercise our best judgment, taking into account the advice of our scientists, the public, and others to develop proper proportions to ensure recovery. We are married to the concept of better science, and we will continue to use that science. Direct restoration projects are probably the most difficult to design. However the Trustees will certainly continue to support direct restoration when projects are found to be cost effective and aiding the recovery of injured resources. One area of direct restoration that is especially appealing to me is to provide the research funding necessary to support improved systems of management of natural resources by state and federal agencies. I think perhaps in the long term, this may have some of the longest lasting benefits for the citizens of the spill area and the United States.

As you heard, particularly in Phil Mundy's presentation, such studies provide background for better management of sockeye in Cook Inlet. Enhanced natural pink salmon runs in Prince William Sound will continue. Much of the early research and monitoring focused on individual species, and I think you've heard several of those discussions today.

We are now in the next stage of the restoration program: to review and synthesize previous data and obtain new information with the goal of understanding the underlying environmental factors which influence survival and reproduction of these injured resources. The 1994 work plan will be an ecosystem-based investigation for the first time in Prince William Sound. I probably shouldn't put it that way because I think some of our studies in the past have been ecosystem-based if we were to step back and define that term. I perhaps would like to have spent more time talking to George Rose and Phil and others about what we mean by the word "ecosystem." We have indeed studied species as they relate to each other. We haven't, perhaps, taken all of the environmental, potential impacts into account, and we haven't looked at a broad complex of resources as much as we might.

The development of ecosystem studies in a broader base than we have done to date is an exciting development from my perspective because rather than simply measuring rate of decline, I think we're going to try and get more at why resources may continue to decline or remain depressed.

I want to pay a special tribute to the folks in Cordova. Both agency staff and members of the public in Cordova put in a lot of extra time on the current ecosystem-related project the Trustee Council will sign into a court order today. I think this type of ecosystem approach holds dramatic promise for influencing agencies' regulation of controllable factors, such as harvest of fish stocks relative to recovery or enhancement of these injured species. This will be accomplished by putting into perspective the causes for fluctuations in those species.

It is the Trustee Council's intent to move more toward an ecosystem approach with all the resources of Trustee agency concerns both inside and outside the Sound. Again, in general, I mean a broadening of the approach taken in the research, looking more at interactions. I don't prescribe at this time to say how deeply an ecosystem study would go or, in total, what would be involved in different areas.

The Trustee Council is also moving ahead with habitat protection. Last year the Trustee Council purchased inholdings in Kachemak Bay State Park and also purchased lands in Seal Bay near Kodiak in order to protect critical habitat. In these cases, the lands were judged to be imminently threatened habitat through various activities as well as habitat that was important to the protection and the restoration of injured resources.

We are, however, continuing to pursue a habitat protection and acquisition strategy. We are looking at other high-value land parcels in Prince William Sound, the Kenai Peninsula, and the Kodiak-Afognak Archipelago. The Executive Director has been instructed to go forward with a general appraisal of these lands and the priorities for their acquisition so that we can look at it as a package for the Trustee Council.

Another area of concern has been the development and coordination of a repository for Trustee Council data sets which will be used by other scientists and the public. The key areas of the discussion relative to the improved University of Alaska Institute of Marine Science's facility in Seward has to do with this level of coordination for all *Exxon Valdez* oil spill resource and monitoring results.

We are also interested in obtaining meaningful increases in public involvement. I think as George Rose said today, that is a key element in planning any long-range strategy to deal with the restoration of resources in the spill area. As I understand it, the Executive Director has under consideration the formation of a newsletter and has prepared an annual report of which this forum is really a key element.

Additionally, further on, outside agency participation in research and monitoring is being emphasized by the Executive Director and has been increased in the 1994 work plan. In addition, as I think you've heard elsewhere, the Trustees have set aside $12 million to form a reserve account for future research and monitoring activities. I think there's a growing understanding that there will be a need to deal with injured resources and restoration continuing into the next century. The Council will consider as part of their final Restoration Plan at what level such an account should be supported.

The Trustee Council has appointed an executive director, Jim Ayers, who you've met today, with a permanent staff, and I think this is a major step in moving this process forward. The Executive Director is establishing an organizational structure to guide development of the annual work plans consistent with the Trustee Council directive that we expand on an ecosystem approach.

The organizational plan will also include a proposal to establish an independent and highly credible science review board. This will make science-based recommendations to the Executive Director and the Trustee Council. This is not taking away in any way what Bob Spies has done with peer reviewers, but I think we're going to formalize the process perhaps even more than it has been. The Executive Director is also moving forward with fleshing out the draft Restoration Plan. The draft does not contain details relative to specific resources or specific strategies, and the Executive Director, working with our scientific staff and the public, will be fleshing that out. That will provide better decision-making guidance for the Trustee Council on the 1995 and future work plans.

I hope by the time we do the 1995 work plan, we're dealing with a fleshed-out Restoration Plan and aren't trying to play catch-up at all. The development of a long-term science plan is also required, to include monitoring and direct restoration research, as well as ecosystem research. I think that can be accomplished in coordination with the Chief Scientist, peer reviewers, agency scientists, and the public.

My comments have provided you with somewhat of a simplified overview of what has been a complex, arduous, and often argumentative process. We have taken up a very short time here today to cover all the aspects of it, and I've been charged trying to summarize it.

As we've worked within this complex environment, there have been a number of issues that have surfaced and raised questions that I hope we have or are in the process of answering. I don't believe the state and federal natural resource management agencies were prepared to undertake damage assessment and restoration activities of an environmental disaster of this magnitude in Alaska. I think we have to put that at the forefront of our studies and use of the information we're collecting.

As I said before, I think the damage assessment response was confused at the start, but ended up remarkably well coordinated, largely due to the quality and caliber of a number of our scientists that were involved in this process and the assistance we received from the public. I believe the critical jobs of damage assessment were completed, and I hope we are well on the way to our finalizing the restoration program.

But I believe a significant legacy of this effort should be a manual — for want of a better word — on how to respond from a damage assessment and restoration perspective to events of this nature in Alaska, so that none of us will ever be caught unprepared again. Clearly, the formation of the organizational structure and process needed to move the work of restoration forward and marry together the input from the Trustee agencies for the various resources, the public, and scientific advice has not been easy. I think all of that needs to go into this "manual" or summary of what we need to do in the future. In essence, I think a book on the spill needs to be created. It would deal not just with specific data reporting, but more with the process and priorities for research and restoration that we will face again if we have another spill.

There are a number of parts of this already being worked on. Kathy mentioned some of them, others have, and I think it needs to be finalized. I don't think it's complete yet.

When I reflect on all that has happened since the spill, I hope long-term benefits will be gained from the massive effort. We want the northern Gulf of Alaska ecosystem to be healthy and productive so the region's people and wildlife can thrive in a pristine environment. To help realize this goal, the Trustee Council will continue to take positive actions to restore, protect, and monitor the natural resources injured by the spill.

There is little doubt that the oil spill in Prince William Sound created a major ecological disaster. Many species of fish, seabirds, marine mammals, and invertebrates, as you heard, were affected by the spill. I learned some things today about what those injuries may have been and may continue to be, and I think I do every time I come to one of these forums. The spill injured not only fish and wildlife populations and their habitats, but also human use of the affected areas. There was a special social and economic disaster for people in fishing communities and Native villages throughout the spill area because those communities depend on a healthy ecosystem to derive their livelihoods from. The people in the spill area feel the effects of the spill to this day.

Five years later many of the resources in Prince William Sound and other areas of the Gulf of Alaska are recovering. However, some others are not, and the effects of the spill persist. An additional effect, of course, is the feeling that a special, unspoiled place was damaged and it could potentially be damaged again. Hopefully, the program we are putting together will help to strengthen our ability to respond to those concerns.

Perhaps I'll leave you with a quote from the Status Report, and that particularly is the mission statement:

> *The mission of the Trustee Council and all participation in Council efforts is to efficiently restore the environment injured by the Exxon Valdez oil spill to a healthy, productive, world-renowned ecosystem, by taking into account the importance of quality of life and the need for viable opportunities to establish and sustain a reasonable standard of living.*

I hope this forum will help you to evaluate our progress toward accomplishing this goal, but I suspect it will be at a similar forum sometime in the future before the judgment can realistically be made. I think I'll leave you with another quote, again from the Status Report: Perhaps on some future anniversary of this spill, people can walk the beaches and find no fresh oil, and the health of the ecosystem has been fully restored, then all Americans can truly celebrate the close of this unfortunate chapter of Alaskan history. Thank you.