UNITED STATES SENATE

HEARING ON
GLOBAL CHANGE RESEARCH:
OZONE DEPLETION AND ITS IMPACTS

Friday, November 15, 1991

Washington, D.C.

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C O N T E N T S

C O N T E N T S (Contined)

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Friday, November 15, 1991

U.S. Senate

Committee on Commerce, Science,

and Transportation

Washington, D.C.

The committee met, pursuant to notice, at 9:33 a.m. in Room SR-253, Russell Senate Office Building, Hon. Al Gore, Jr., presiding.

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OPENING STATEMENT OF HON. AL GORE, U.S. SENATOR FROM TENNESSEE

Senator Gore: Well, let us get this under way. Let me welcome all of our witnesses and tell you how grateful I am to all of you for arranging your schedules to be here today.

This is another in a series of earth science roundtables, and the difference between a roundtable and a hearing is that this proceeding is a little more informal in the flow of discussion. I will have a few brief opening comments and will call upon my colleague Senator Gorton for any that he might have, and then what we will do is we will take very brief opening statements, and I would like to limit everybody to only three minutes in the opening comments.

I assure you that you will have plenty of time during the proceeding this morning to come back and make whatever points you wish to emphasize during the discussion. But during the discussion that will follow these opening statements, I want to encourage give and take and disagreement if it is necessary, the elucidation of subtleties that you think are important.

I would like, however, to suggest that you follow this rule, the same one that we follow over on the Senate floor, where over the past 200 years they have discovered that it is best to direct all statements through the chair. That has minimized fist fights during the past two centuries on the

Senate floor. Not that we expect any here this morning, but if you could direct your comments through the chair that would be helpful.

I might also, before I give my opening comments, note that we are honored to have in attendance in the audience the Ozone Secretariat for the United Nations Environment Program, Dr. K.M. Sarma from Nairobi. Dr. Sarma --

Voice: I think he may be late.

Senator Gore: He may be a little late, okay. Well, we will be honored when he arrives.

And Dr. Steve Lee-Babty, we will be honored later by his presence, and the Co-Chair of the UN Ozone Technology -- oh, he was the Co-Chair, all right.

We are honored to have with us as part of the panel the Co-Chairs of all three of the UN ozone panels: Doctors Watson and Albritton on the science of ozone depletion and the synthesis of the UN ozone report, Dr. van der Leun from The Netherlands, who was the Co-Chair of the impacts panel along with Dr. Manfred Tevini of Germany; and Dr. Steven Andersen, Co-Chairman of the strategies for reducing emissions panel.

One other thing. Senator Gorton has reminded me that we are going to have some votes on the Senate floor this morning in connection with unemployment. So at various times, unfortunately, I will have to recess the proceeding for 7, 8 minutes at a time, race over and vote, and then come back. So

I will just warn you about that ahead of time.

Now, just by way of my opening comments, we are here today to examine the latest information on the damage that we are doing to the stratospheric ozone layer and what it means to us, our health, our food supply, and the global ecological system.

On October 22nd the United Nations Environmental Program released the executive summary of a report entitled "A Scientific Assessment of Stratospheric Ozone, 1991." That was the first of three parts of a UNEP assessment of ozone depletion due to be released in its entirety early next year. Many of the scientists involved in the study felt that the gravity of the findings was such that advanced word of the nature of the findings ought to be available to peoples and governments throughout the world in advance of the normally slower process by which such information gets published.

That has been done with the first of the three panels. The other two will be presented in essence here this morning. The information contained in the other two will be heard publicly for the first time in this session this morning. We are very interested in hearing that.

Overall, this was the second such assessment done since the Montreal Protocol was signed in 1987, and the protocol itself called for these international assessments so that policymakers would have the information needed to revise and

update the protocol as new scientific data becomes available.

Like that first assessment in 1989, this new one includes very disturbing new data, indicating that ozone radiation is even more serious than we thought. Many of our witnesses today were involved in writing the 1989 assessment concluding that ozone depletion was occurring very much faster than most models predicted.

As a result of that report, of course, the Montreal Protocol was amended to require more rapid phaseout of CFC's, halons, and other ozone deleting chemicals.

According to the report released on October 22nd, ozone depletion is occurring even faster than thought in that 1989 update and it is occurring over more of the globe, everywhere except a narrow band along the Equator, apparently, and throughout most of the year. And one of the most troubling findings, of course, was that it is occurring in spring and summer, when the sun angle is such that the rays are not scattered over a larger swath of the earth's surface and are able to do more damage.

Depletion is occurring, according to the report, not only in the Antarctica ozone hole, but also in the Arctic and mid-latitudes, over our heads here in the United States for example. And worst of all, it appears from the new findings that the depletion is accelerating. According to the data, the ozone layer above the United States is thinning between 3

and 5 percent per decade.

According to Sherwood Rowland, who testified before our committee in April, that means the ozone layer has thinned about 10 percent since the 1960's. We often hear a shorthand description that there has been a 4 to 5 percent depletion, but that is just since the monitoring began in 1978, and when you extrapolate that rate back to the time when the actual depletion started it is about a 10 percent cumulative loss above the mid-latitudes here since the 1960's, according to Dr. Rowland.

That is significant, it is widespread, and it will have major impacts on the environment and on people worldwide. We are only now determining what those impacts will be.

We will hear some testimony today that will be very surprising to many people, I imagine, because the evidence now coming in is in some cases really startling. Unfortunately, however, there has been too little research on the impacts of ozone depletion and the impact specifically of increased ultraviolet radiation which results from the depletion. Until recently, much of the data was preliminary and incomplete.

But fortunately there have been a number of good solid studies completed in the last year or two that give us a much clearer picture. The new UN report effectively summarizes that new research and it provides the most thorough assessment to date of the impacts of ozone depletion.

The news is not good. Researchers here today have discovered that increased UV radiation will reduce the quantity and quality of crops, increase skin cancer and cataracts, suppress the human immune system, and disrupt marine ecosystems, with effects on the entire oceanic food chain.

According to the report, a 10 percent decrease in ozone will lead to between 1.6 and 1.75 million additional cases of cataracts per year worldwide and at least 250,000 additional cases of skin cancer per year. There are indications that increased UV radiation suppresses the human immune system that protects us from disease, and it is now clear that ozone depletion will directly affect the health of many, many millions of people worldwide.

The impact on ecosystems, trees, plants, phytoplankton, all seem vulnerable to these increased levels of ultraviolet radiation. No doubt there will be other serious consequences, many of which cannot yet be anticipated, due in part to a lack of research.

Last year the Federal Government spent almost one billion dollars on global change research, most of it at agencies under the jurisdiction of this committee. I personally feel that we have to do more in researching the impacts of this extra dosing of ultraviolet radiation. I think it is very shortsighted that we have neglected this as much as we have.

Well, with that let me turn to Senator Gorton for any opening remarks he might make, and then we will have our opening statements from the witnesses.

[The prepared statement of Senator Gore follows:]

STATEMENT OF HON. SLADE GORTON, U.S. SENATOR FROM WASHINGTON

Senator Gorton: Mr. Chairman, at 10:00 o'clock or immediately after our vote I have a markup of the supplemental appropriations bill, so I will only be here until that first break. Therefore, I would much rather try to hear the presentations of each of these people, except to welcome a constituent, Dr. Weiler.

Senator Gore: Very good.

Let us start off with Robert Watson, Branch Chief of the Upper Atmosphere Research Tropospheric Chemistry Program at NASA. Dr. Watson, if you could lead off we would appreciate it.

STATEMENT OF DR. ROBERT T. WATSON, BRANCH CHIEF, UPPER ATMOSPHERE RESEARCH TROPOSPHERIC CHEMISTRY, EARTH SCIENCE AND SPACE APPLICATIONS DIVISION, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION HEADQUARTERS, WASHINGTON, D.C.

Dr. Watson: Thank you, Senator Gore and Senator Gorton.

The key findings of the scientific assessment included the following. Based on ground-based and satellite data, ozone losses are now occurring in both hemispheres, not only in the winter but spring and summer. The only area of the globe we have not observed ozone loss is in the tropics.

During the period of the 1980's, we saw a 3 percent ozone loss in the summer over populated areas in the USA and Europe, and effectively the trends, as Senator Gore stated, during the 1980's are faster than the trends observed in the 1970's by about 2 percent. In other words, ozone depletion is accelerating.

In Antarctica ozone losses continue in the springtime, they continue on into the early summer. That is December down in Antarctica. And for the last 5 years we have had very deep and extensive ozone holes, so that the biennial modulation that we used to see in the early 1980's has disappeared at least during the last 3 years.

The ozone loss is primarily occurring in the lower stratosphere, below 20 kilometers. This has significant ramifications for the radiative forcing of the earth's

climate. Dr. Albritton will touch upon that particular subject.

Clearly, the Antarctica ozone hole is due primarily to manmade chlorine and bromine. We now believe the weight of evidence strongly suggests that the observed mid-latitude ozone losses are largely due to chlorine and bromine.

Even if we have the amended Montreal Protocol ratified and complied with by all nations of the world, the amount of chlorine in the earth's atmosphere today, which is about 3.5 parts per billion, will increase to about 4 parts per billion or so by the year 2000. We therefore believe there will be additional ozone losses during the 1990's, at least comparable to those of the 1980's.

There are, however, approaches to limit future ozone depletion. It means we will need additional controls on CFC's, halons, methyl chloroform, carbon tetrachloride, and controls on the HCFC's that are proposed as potential substitutes in some uses.

In addition, our report points out that if methyl bromide is partly anthrogenic in nature then we can have a significant savings on the amount of bromine in the atmosphere, hence saving future ozone depletion by controls on methyl bromide.

The last point I would like to make is we now have for the first time direct evidence that we have significant ozone depletion. There is the increase of ultraviolet radiation at

the ground. Each time in spring time in Antarctica when there have been massive ozone depletions we have seen increases in ultraviolet radiation at the ground to the level we would have predicted from theoretical calculations.

Thank you.

Senator Gore: Thank you very much.

I might note parenthetically, we will get back to this later but methyl bromide is used for preventing misshapen fruit and for preserving grain, is that correct?

Dr. Watson: Correct.

Senator Gore: We are going to be hearing a lot more about that, so I wanted to just throw that in.

Dr. Dan Albritton is Director of the Aeronomy Lab at NOAA in Boulder, Colorado. Dr. Albritton.

STATEMENT OF DR. DANIEL L. ALBRITTON, DIRECTOR, AERONOMY LAB, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, BOULDER, COLORADO

Dr. Albritton: Thank you, Mr. Chairman, Senator Gorton.

In addition to the request that our scientific group summarize the new findings on stratospheric ozone depletion, the United Nations has also asked us to summarize the present state of understanding of how ozone depleters and ozone changes may relate to the heat budget of the planet, in particular how this heat budget change may relate in fact to the CFC's and other compounds.

There have been two major findings of the UN panel that relate to trace gases and the heat budget. As Dr. Watson indicated, the ozone loss appears to be concentrated in the lower stratosphere, and this for the first time raises the possibility that ozone losses are indeed related to changes in the heat budget in the lower atmosphere, and I will provide some details for that finding.

The second emphasis of our report was to examine very carefully the indices that the scientific community placed on the trace gases, in an attempt to show the relative measure that each of the trace gases contributes to the heat budget of the planet. And there have been some very significant findings in terms of how well those indices can be calculated, and I will try to summarize those points.

First of all, the relation between ozone loss and the heat budget of the atmosphere. As Dr. Watson indicated, the loss being in the lower stratosphere raises the possibility that it cools that lower part of the atmosphere, and a cooler lower stratosphere means that less heat is radiated from that slab of the atmosphere down to the lower part of the atmosphere where the climate system actually functions.

So ozone loss in this region caused in fact by the chlorine- and bromine-containing compounds may in fact mean that less heat is radiated to the lower part of the atmosphere.

Now, the direct effect of the CFC's and the other greenhouse gases has been a tendency toward warming. So now for the first time there appears to be an indirect effect on the heat budget due to these same compounds. In fact, the preliminary calculations of this group indicate that this tendency toward a reduction in radiation may in fact roughly offset in many latitudes the direct effect that these compounds are having.

So here for the first time we have to more closely examine the connections between ozone loss and the climate system. There is still considerable research to do in this regard.

What our group did was examine the change in the heat budget, and now climate scientists must apply that change in

the heat budget to asking the questions of how it actually changes patterns on the surface, like temperature or rainfall.

The second point that I mentioned our group examined is how well scientists can compare greenhouse gas A to greenhouse gas B. Many of these gases also have direct and indirect components. What our group found was that perhaps our understanding in calculating the indirect effects are not as solid as in fact had originally been thought a few years ago.

Let me give you an example. A gas like methane can directly trap earth's radiation and directly contribute to the heat budget, but it also creates water vapor, which is itself a greenhouse gas. It also influences other lower atmospheric greenhouse gases and those can contribute. Our ability to calculate in the full impact of those molecules, both the direct effects and the indirect effects, will require considerable more research.

Senator Gore: Thank you.

We will come back to a lot of that, because of course if the cooling partly offsets the warming from CFC's, that places even more emphasis on CO2 as a greenhouse gas, and that has provoked a reaction in many quarters. So I am sure we will have some discussion of that here today.

Dr. van der Leun, as I mentioned, is from The Netherlands. He is with the Institute of Dermatology at the University Hospital of Utrecht in Heidelberglaan in The

Netherlands. Did I get that close?

Dr. van der Leun: Close.

Senator Gore: Close.

I hope our other witnesses will not think it inappropriate for me to suggest that Dr. van der Leun and after him Dr. Andersen, since they are providing the first information on these other two UN assessment panels, take a couple of extra minutes in addition to the 3 that we are allocating to others.

So Dr. van der Leun, please proceed with your findings on the impact of this extra ultraviolet radiation.

STATEMENT OF DR. JAN C. VAN DER LEUN, INSTITUTE OF DERMATOLOGY, UNIVERSITY HOSPITAL UTRECHT, UTRECHT, THE NETHERLANDS

Dr. van der Leun: Thank you, Mr. Chairman, for the opportunity to contribute to this hearing.

My testimony is based on the work of the panel on environmental effects, and today we released the summary of the update 1991. I will take the opportunity to highlight a few key elements of our report.

Our work starts with the relationship between stratospheric ozone and ultraviolet radiation. Stratospheric ozone is the main limiting factor for the penetration of solar ultraviolet radiation to the earth, and it is for that reason that we are worried about release of ozone that would be expected to lead to increased ultraviolet radiation, and that is indeed confirmed now by measurements in our Antarctic region, as Dr. Watson already told.

It is also confirmed by surrounding areas. During the breakup of the ozone hole, branches of it go over inhabited areas of southern Australia and scientists in Melbourne have measured that there are actual increases of ultraviolet-B radiation, in full agreement with the decrease of ozone overhead.

Now, there are also measurements suggesting negative trends in ultraviolet-B radiation, especially in this country,

measurements over a long period of time, and that would indicate a decrease of ultraviolet radiation while ozone was also decreasing, and that has been puzzling for some time.

Senator Gore: That is because of air pollution.

Dr. van der Leun: I think that that is the main cause of this other shield, consisting of tropospheric ozone, aerosols, clouds, and most measurements are done in industrialized areas.

Our report emphasizes that there is no guarantee whatever that these factors will continue to work in the same direction. Indeed, we are spending a lot of effort to reduce these factors, and in some cases with success, with initial success.

So if these factors reverse, the increase of ultraviolet-B radiation by ozone radiation will be amplified, rather than reduced. So we have many reasons to consider the effects.

Our report first starts with human health. Increase of non-melanoma skin cancer is confirmed by new observations and the present estimate is that a 10 percent loss of ozone, if sustained over a long period of time, will lead to an increase of the incidence of this type of skin cancer by 26 percent. That is a smaller number than in the previous report. That is due to new information.

This type of cancer is not only caused by UVB radiation, but also to some extent can be caused by UVA radiation, which

is not affected by ozone. So that decreases the sensitivity of the incidence for ozone change.

Eye problems. We have new experimental data implicating ultraviolet-B even more than before in eye problems. We have no new quantitative estimates, but the new data amplify the estimates given earlier. If we would have 10 percent less ozone over the past decades, there would now be more than a million additional cases of blind people in the world due to cataracts.

Ultraviolet radiation has influences on the immune system. Dr. Kripke will certainly tell more about this. The concern for our committee and for all of us is that this might lead to increase of infectious diseases.

Plants and animals are also sensitive to ultraviolet radiation. Many of them grow less under increased ultraviolet radiation. One of the concerns is that this will lead to smaller production in agriculture and fisheries, but there is a lot between the individual organisms and the production of agriculture and fisheries and we need a lot more knowledge to come to real predictions there.

In the wild ecosystems one species will be more sensitive than another, and this may lead to shifts in the competition ratios and even to loss of species. Again, that is a real loss for the earth.

We need a lot more data. In many places our report says

there is good reason for concern, but we have no solutions, no final answers. So that is the reason we need much more data, and I am glad you emphasized that point.

Thank you, Mr. Chairman.

[The prepared statement of Dr. van der Leun follows:]

Senator Gore: Thank you.

I am going to suggest that we change the order slightly, with your indulgence, Dr. Andersen. Since Senator Gorton has another committee that he is going to have to attend, I would like to take his constituent, Dr. Susan Weiler, out of order and introduce her by saying she is the Executive Director of the American Society of Limnology and Oceanography, with the Department of Biology at Whitman College in Walla Walla, Washington, and is also empowered to represent here today some of the work that has been done and is in progress by Dr. Ray Smith's team.

Dr. Smith is in the Antarctic right now. He and his colleagues have also worked on this problem of ultraviolet radiation's impact on the oceanic food chain.

We are very honored that you could be here, Dr. Weiler. If you can proceed.

STATEMENT OF DR. SUSAN WEILER, EXECUTIVE DIRECTOR, AMERICAN SOCIETY OF LIMNOLOGY AND OCEANOGRAPHY, DEPARTMENT OF BIOLOGY, WHITMAN COLLEGE, WALLA WALLA, WASHINGTON

Dr. Weiler: Thank you very much, and I would also like to applaud you for calling for more research. We know so little about biological systems in comparison with the ozone and other things, which we have already heard we do not know much about, either. So it really is something where we do not really know enough to say too much at this stage.

What we can say is that it is already very well known that current levels of UVB radiation affect phytoplankton cellular processes, including primary production, DNA integrity, which is likely to affect future generations, and also cell viability.

Because species vary greatly in their sensitivity to UVB radiation, it is possible that increased UVB would change phytoplankton species competition and abundance, as well as total primary productions. And again, as we heard before, this is likely to have impacts beyond the primary producers. These effects will ripple through the food chain and have impacts that we really cannot predict right now.

Okay, so we know a fair amount about what happens at current levels of UVB. It has been extremely difficult to measure or predict what is going to happen with increased levels of UVB, because the current generation of lamps,

artificial lamps, bear no relation to the solar spectrum that is observed in the UVB regime and we know that biological consequences are extremely dependent on individual wavelengths of radiation.

So you cannot just say: Okay, we are going to increase UVB by this much and it is going to have that effect. You have to say: We are going to have so much of this wavelength, a little more of this, a little less of whatever. And you have to integrate over that. And you simply cannot do that by artificially augmenting radiation with lights.

The one advantage of the ozone hole, if you could call anything an advantage, is that we are now seeing severely increased levels of UVB radiation in that region resulting from the ozone hole. So for the first time we can actually look over the short scale at the effect of natural levels of UVB radiation.

Because of this, there has been a lot of research since around 1987, when the first programs went down there. There has been a lot of research concentrating on impacts in the Antarctic, and I think one thing to point out to people is I think we have a tendency to say: Well, if something happens in the Antarctic, what does that mean to us here in temperate latitudes?

This is a natural laboratory and we can learn things about even temperate species that we cannot learn by studying

them at this latitude because of the limitation on light.

Anyway, the major Antarctic biological research findings today are: Number one, that, like present levels, increased levels of UVB also adversely affect marine phytoplankton through decreases in primary production, DNA damage, and presumably other factors that have not been studied yet.

Measurements by state of the art instruments confirm that UVB penetrates to significantly, ecological significant depths in the water column. I think most people tend to think as you get down 5 inches or so you do not have to worry about it because it is absorbed out of the water column, and it is simply not true.

Measurements of UVB radiation have now been observed as deep as 70 to 80 meters and ecologically significant levels have been found at depths greater than 30 meters in the water column. So this is something that we really do have to worry about in aquatic systems as well as in terrestrial systems.

Antarctic phytoplankton species do have adaptive mechanisms, such as the production of UVB blocking compounds, that are similar to those found in tropical latitudes. There are adaptive mechanisms in these organisms. There was some question as to whether this was the case earlier.

And it has also been found that, like at temperate latitudes, species vary significantly in their sensitivity to UVB radiation. Again, this is going to have a dramatic effect

potentially on the type as well as the availability, the total availability, of food to higher levels of the ecosystem, such as fish and commercially important species.

Because species vary in their response to UV, ozone depletion might cause changes in species composition or nutritional state and changes in the abundance, size, distribution, or nutritional value of primary producers could affect higher trophic levels by reducing feeding efficiency, potentially causing nutritional deficiencies and other things that could reduce food availability to higher trophic levels, even if total primary production did not decrease. And again, everything suggests that it will decrease. It already has based on the short-term experience.

Thank you.

[The prepared statement of Dr. Weiler follows:]

Senator Gore: Just to draw this out for a minute before Senator Gorton has to leave, the findings indicate, do they not, that the photosynthesis and the growth in production of phytoplankton has decreased by 14 percent in the areas with the higher dosage of UVB in the Antarctic?

Dr. Weiler: Around 6 to 12 percent when integrated over the entire water column. The effects at surface are much higher, and of course that is where the primary productivity is, generally higher near the surface. It has been reduced by as much as, I think, around 20 percent.

Senator Gore: At the surface?

Dr. Weiler: At the surface.

Senator Gore: Now, the phytoplankton production zone is about 30 meters deep, 50 meters deep?

Dr. Weiler: Again, it varies with season, with water type, a variety of other factors. Depending on the clarity of the water, it could occur down to no more than a couple of meters or it could occur, in the clearest water, down to about 150 meters.

But in the Antarctic it is probably around 40 meters.

Senator Gore: Is it accurate to say that most of the zone where phytoplankton productivity occurs is penetrated by ecologically significant levels of ultraviolet radiation?

Dr. Weiler: This is particularly true in the Antarctic. Yes, that would be true generally speaking, because in the

Antarctic the phytoplankton concentrate in the upper water due to the melting of ice in the springtime, because this water is less dense, so it forms a lens on top, so it confines mixing to shorter, smaller depths than would be found otherwise.

So these organisms are confined to the upper levels, even though at other times of the year they might be going down further.

Senator Gore: Now, the blooming, the blooming of phytoplankton, is in the same time of the year when the ozone hole is over it, right?

Dr. Weiler: That is increasingly true. The major bloom occurs around October through November, and the ozone hole has been most pronounced around the first week or so in October. But now as the ozone hole is getting larger and also lasting longer, it's penetrating more and more into that time of maximum growth.

Senator Gore: Now, my final question before turning to Senator Gorton is -- well, one note. You mentioned DNA. I have heard it said that over the billions of years of evolution DNA has evolved in a way that the radiation which penetrates it harmfully is the radiation blocked by the ozone layer, and I believe Sherwood Rowland said this, and that for this reason the UV that is coming in extra amounts as the ozone layer is depleted does have an effect on DNA.

You said that a suppression of phytoplankton productivity

would ripple through the food chain. Is that a linear or arithmetic rippling effect, or is there some non-linear effect that we do not know about?

Well, that is a hard question to ask. Is there likely to be a non-linear effect, in your best judgment?

Dr. Weiler: I would like to clarify. We do not know for certain, but our best guess is that there will be changes because of the differential sensitivity. It is likely that these effects may be non-linear simply because there are so many confounding species.

You have got the producers and some consumers are differentially sensitive to those, and then you have got secondary producers that are selective on some of the primary consumers. So we will see impacts, but we cannot predict how much that will happen.

Senator Gore: We will turn to Senator Gorton.

Senator Gorton: I am not going to ask any questions, so let us go on to the next one.

Senator Lott: Mr. Chairman, I do have a statement I would like to submit for the record.

Senator Gore: Sure.

[The prepared statement of Senator Lott follows:]

[COMMITTEE INSERT]

Senator Lott: And depending on what happens with this vote and the subsequent votes, I do have some questions specifically for Dr. Watson to put in the record, if you could respond in writing.

Senator Gore: Sure, absolutely. We want to encourage that. I appreciate that.

I took Dr. Weiler out of order and I apologize for doing this out of order.

Senator Gorton: Thank you. I thank you for that.

Senator Gore: Let us move on. Dr. Stephen Andersen is Director for the Technology Transfer and Industry Program at the EPA and is a Co-Chair, as I said earlier, of that third part of the UN assessment panel.

STATEMENT OF DR. STEPHEN ANDERSEN, DIRECTOR, TECHNOLOGY TRANSFER AND INDUSTRY PROGRAM, U.S. ENVIRONMENTAL PROTECTION AGENCY, WASHINGTON, D.C.

Dr. Andersen: Thank you, Senator Gore, Senator Gorton, and Senator Lott.

The 1991 UNEP technical and economic assessment was undertaken by over 240 experts from 48 countries, and they produced six separate reports that are not only quite large, but also quite detailed, and I think their findings are impressive.

The assessment will not be final until December of this year, but I am able to report consensus findings and conclusions. I will report to you on the progress at eliminating these chemicals, about the technical feasibility of a faster phaseout, and some of the special circumstances of developing countries and their phaseout.

Since 1986 there has been a 40 percent worldwide decrease in the consumption and production of CFC's. This is faster than predicted by the 1989 assessment and it is faster than the controls of the Montreal Protocol as amended in London. At that rate of progress, we will meet the 1995 Montreal Protocol goal next year.

It is also impressive to look at the work that has been part of this progress. Already by the end of this year, several multinational companies will eliminate their use of

ozone-depleting solvents in all of their worldwide operations. By next year, the first automobiles will have ozone-safe air conditioners and the first domestic refrigerators will be commercially available. Many other ozone-safe technologies are fully commercial.

We also had progress in the area of fire protection. The international fire protection community has virtually halted the emissions caused by discharge testing, training, and accidental discharges.

The second point I would like to make is that, based on this elaborate evaluation, we have concluded that it is technically feasible in developed countries to phase out the production of CFC's and halons by 1997 or earlier, methyl chloroform as early as 1995, and carbon tetrachloride in the vast majority of its applications by 1995.

These rapid schedules require the use of transitional HCFC's and HFC's for the important applications of refrigeration, air conditioning, insulating foam, and for some aerosol, sterilization and minor solvent uses. Toxicity studies and risk assessments are not yet complete for some of these important transitional substances.

The halon phaseout is contingent on the use of recycled halons as the primary supply, and I think it is a real credit to the fire protection industry that what was first considered in 1987 as essential for all applications we now are finding

that an adequate supply will carry essentially fire protection uses well into the next century.

The final important technical conclusions of the technical and economic assessment is that there are efforts that can be made in the developing countries to accelerate their phaseout. It is important to developing countries that the technologies are available, that technical assistance, including information and training, be provided, and that there be an accelerated effort at financing.

There has also been some impressive progress in the developing countries and I will just cite one, which is the case of Mexico, that has announced to the world that they will make it a goal to phase out the ozone-depleting substances on the same schedule as the developed countries if adequate financing is available.

The final point I would make is that part of this great progress with developing countries is due to some innovative partnerships with multinational corporations and associations, and I think we can look forward to more progress if that cooperation continues.

Thank you.

[The prepared statement of Dr. Andersen follows:]

Senator Gore: I think it ought to be noted for the record that Mexico was also the first nation to sign the Montreal Protocol.

I wanted to make one point before we go to vote. Wearing your EPA hat, section 606 of the Clean Air Act, the anniversary of the signing of which is today, legally requires the President through his agent, the head of the EPA, to accelerate the phaseout schedule to bring the deadline from the year 2000 much nearer to the present time.

You have said in your statement that it is technologically feasible to do that. The requirement I refer to is contingent upon the availability of new scientific information which says the health and environmental impacts are more serious than thought when the act was passed.

Since the act was signed, we had the April report and we had the report of October 22nd. Is EPA recommending that this provision of the law be triggered and that faster phaseout be implemented?

Dr. Andersen: Senator Gore, I am here to only represent the technical and economic assessment, and I cannot represent the position of EPA.

Senator Gore: All right. I will come back to that and try to get it out of you another way.

[Laughter.]

Senator Gore: That is why I wanted to mention it before

my colleagues left, to give fair warning on that one.

We are going to have a short recess for this vote. I anticipate it will take about 8 minutes to run over and back, so we will crank it back up then.

[Recess.]

Senator Gore: The session will come back to order.

Let me follow up briefly on a question, while Dr. Kripke is returning, with you, Dr. Weiler. I wanted to clarify this business about productivity in the oceans. Just to make sure that I have a clear understanding of this business of the food chain, phytoplankton are these very small critters, plants.

Dr. Weiler: Right, single-cell organisms.

Senator Gore: Single-cell organisms in the top layer of the ocean, that bigger critters feed on, and then critters that are bigger still feed on them, and so on up the food chain. That is a simplistic way of putting it, but is that pretty accurate?

Dr. Weiler: That is correct, they are the base of the food chain, just like grasses are for cows.

Senator Gore: Therefore, if you have a 14 percent or at the surface 20 percent, overall a 6 to 14 percent, decrease in the amount of basic food available at the bottom of the food chain, that would mean probably a decrease in the amount of food available all the way up the food chain, including the bigger fish that provide part of the human diet, correct?

Dr. Weiler: That is correct. If the effect is linear, you would expect about that same amount at each of the trophic levels reduction.

Senator Gore: But it may be worse than that?

Dr. Weiler: That is correct.

Senator Gore: Because at higher levels in the food chain any interruption in the mix of species might have effects that are difficult to predict, that would have as a consequence more loss of food at that level of the chain, correct?

Dr. Weiler: That is correct, and there are a couple of reasons for this. One is that there is such a tremendous range in the size of the phytoplankton cells. Even though they are all single-celled organisms or virtually all, the size variation can be a couple of orders of magnitude.

So you have organisms that are better adapted to feeding on a particular size class. And then in addition to that, there are changes in the nutritional value of cells. So they are not all -- a single cell of a diatom is not the same in terms of food as a single cell of a dynoflagellate or a blue-green algae or whatever it might be.

It is really hard, again. We know that the species vary in their sensitivity, but we cannot yet predict and say, okay, if you increased UVB radiation by such and such, the long-term effects would be that you would get more of this species and less of that.

Then even if you did not change the species composition, UV does not just alter primary production. It also influences things like protein content, dry weight of cells, et cetera, et cetera, and cells tend to develop more protein or less. Those effects on nutritional status, even if everything else stayed the same, would have some sort of an effect.

So it presumably is non-linear, but we do not know in what way it will change.

Senator Gore: I hope we will have a chance to discuss that further also, and we will hear from another witness about the impact, not on the oceanic food chain, but on the terrestrial food chain.

Now, however, I would like to turn to Dr. Margaret Kripke, Chairperson of the Department of Immunology at the M.D. Anderson Cancer Center at the University of Texas in Houston. I have heard of Dr. Kripke's work for many years now, and with the report of this impact assessment panel the world is beginning to pay more attention to the effects of extra UV radiation on the human immune system.

I think it is fair to say that Dr. Kripke is one of, if not the world's leading expert, on this subject, and we are very anxious to hear what you have to say, Dr. Kripke.

STATEMENT OF DR. MARGARET L. KRIPKE, CHAIRPERSON, DEPARTMENT OF IMMUNOLOGY, M.D. ANDERSON CANCER CENTER, UNIVERSITY OF TEXAS, HOUSTON, TEXAS

Dr. Kripke: Thank you very much, Senator Gore. I very much appreciate the opportunity to be here to make some comments on this topic.

My interest in this topic comes from research that we have carried out in the laboratory over about the last 20 years. We started out to investigate the immunology of skin cancers and have ended up investigating the immunological effects of ultraviolet radiation.

So at this point what can we actually say about the immunological effects of ultraviolet radiation? Well, from animal models we can say unequivocally at this point, based on evidence from many laboratories, that ultraviolet radiation interferes with certain immunological functions. These include a decreased resistance against skin cancers, including melanoma, decreased activity of the skin's immune system, decrease of some systemic immune responses, and a decrease in the ability of some of the white blood cells to take up foreign particles, including bacteria.

The second thing that we can conclude from the animal studies is that recent studies have demonstrated that these immunological effects of ultraviolet light can have an influence on the course of some infectious diseases.

Specifically, there is decreased immunity to herpes simplex virus, to Leishmania parasites, to microbacteria, to candida albicans, and increases in the severity of infections with these particular agents.

For humans we also know that immune cells in the skin are damaged by exposure to ultraviolet light. We know that the proportions of white blood cells in the circulation are changed after exposures to sunlight or to tanning salon lights.

We know that a cell-mediated immune reaction initiated in the skin called contact allergy is decreased after ultraviolet radiation of the skin. There are recent studies by Dr. Wayne Streilein and his colleagues at the University of Miami in humans that I think have provided the most important recent findings in this area.

This group has found that the sensitivity of humans to immune suppression by ultraviolet light is genetically controlled, and this means that some people are more sensitive to immune suppression by ultraviolet light than others. They have also shown that people who are very sensitive to the immunological effects of ultraviolet light are more likely to develop skin cancer.

So it appears that immune suppression is an additional risk factor in light-skinned populations for the development of cancers of the skin.

The third point, and an extremely important one, is that the amount of pigmentation present in the skin is not protective against immunological damage. This is rather surprising because we know that pigmentation protects against sunburn and it protects against skin cancer. But apparently it does not provide any protection against immunological damage from ultraviolet light.

So we know that ultraviolet light affects the immune responses in humans. We know that the population at risk of such alterations is very large and is not limited to Caucasians who are at risk for skin cancer.

What we do not know is the significance of these findings for infectious diseases in humans. With the possible exception of herpes simplex virus, we have no information on the effects of ultraviolet radiation on infectious disease processes.

Another important point is that we do not know if sunscreens which protect against sunburn also protect against immunological damage, and we need to know the answer to that question as well.

I would like to conclude by leaving you with three questions to think about. First of all, the immune system is the body's main defense mechanism against infectious diseases. It is what keeps us healthy. And if you want an illustration of what it does for you, all you have to do is look at people

who do not have an immune system, people with AIDS, people with combined immunodeficiency diseases. These people are at lethal risk of death from infectious diseases. So anything that perturbs this immune system, our body's defense mechanism, constitutes a serious threat to the maintenance of health.

The second point is that there are two major public health problems in the world. These are inadequate nutrition and infectious diseases. These are the real health problems worldwide, and anything that exacerbates these two problems are likely to have a devastating effect on human health. Ultraviolet radiation has the potential to adversely affect both of these things by affecting plants and by affecting the immune system.

Finally, a point that you raised earlier, Senator Gore, is that we are not in a position at the present time to evaluate the health effects of ozone depletion. We do not have enough information. In my opinion we do not have enough information because there has been a lack of sustained commitment to funding of research on effects in this area, and I was very happy to hear you make that point earlier.

We will never be able to make predictions in this area unless we spend the money to get the answers, and these are long and hard and difficult questions.

Thank you very much.

[The prepared statement of Dr. Kripke follows:]

Senator Gore: Correct. Just to interject a question here. There is another class of diseases that are affected by a suppression, or potentially affected by a suppression of the immune system. There are all of those diseases which could be more of a threat because the body's ability to fight them off is suppressed.

There is also a whole category of diseases which are characterized by the immune system attacking healthy cells, or malfunctioning in some other way.

Lupus would be an example of that. Epstein-Barr would be an example of that, and chronic fatigue syndrome. Graves' Disease would be an example of that latter category.

I asked the staff to check, and it looks as if all of the diseases in that latter category have been increasing in their occurrence fairly significantly in the last two decades. Is that correct?

Dr. Kripke: That is correct.

Senator Gore: What category would a disease like arthritis be in. Is that related to the immune system more directly?

Dr. Kripke: Rheumatoid arthritis is thought to be an immunological disease. The pathogenesis of the disease is related to the body's immune reaction.

Senator Gore: So that would be in that category also?

Dr. Kripke: Yes, that is possible.

Senator Gore: According to the National Center for Health Statistics, in 1969, 92.9 out of 1,000 Americans suffered from arthritis. 20 years later, the number had jumped to 126.5, a 36 percent increase in only 20 years. And, to show that it is not a reflection of the aging of the American population, for people between the ages of 18 and 34, there was a 78 percent increase in the number of cases.

Just to take arthritis as an example, is it reasonable to express the concern that increased dosage of UV-B radiation could be implicated in the increasing frequency of a disease involving the malfunction of the autoimmune system?

Dr. Kripke: It is possible, but that would be widely speculative at the present time. I know of no information that links ultraviolet light effects on the immune system with the occurrence of arthritis or other autoimmune diseases. The only known link is the ability of ultraviolet light to trigger lupus erythematosus, and the mechanism of that is not known.

Senator Gore: Now, let us take that one then. I asked the earlier question because it is troubling that there would be an across-the-board increase, and a fairly dramatic increase, in the incidence of all of these diseases that come as a result of a malfunctioning immune system.

You say that, in the case of lupus, there is a known link between exposure to ultraviolet radiation and the onset of lupus, correct?

Dr. Kripke: That is correct.

Senator Gore: Do you think that it is reasonable to say -- I do not know quite how to express the question; you know what I am getting at --

Dr. Kripke: I know what you are getting at, and let me put it in terms that I am comfortable with.

Senator Gore: Yes.

Dr. Kripke: Is this something that should be looked at? There is no information. We cannot speculate on whether ultraviolet light is important here or not, because no one has really asked that question in a scientific way.

So the information does not exist. I would also point out that one of the great increases in cancer at the present time is also in some of the lymphomas, particularly non-Hodgkins lymphoma; which, again, is immunologic; the cancer of the immune system, which is increasing in the population for no apparent reason.

Senator Gore: Now, you mentioned herpes. There, too, you feel there is a definite link to exposure to ultraviolet radiation and the onset of herpes in some patients?

Dr. Kripke: It is very well established, from the medical literature, that ultraviolet radiation -- sunburns -- will trigger herpes simplex virus infections of the oral cavity.

These kinds of experiments have also been done on

experimental animals as well; and in the animal models, it has been fairly well documented that at least some of the effects of ultraviolet radiation on the viral disease are mediated by the effect of ultraviolet light on the immune system.

So here, we have a link between ultraviolet light, immuno-suppression, and an infectious disease process.

Senator Gore: Now, drawing back your focus a little bit to look at the epidemiology of this category of diseases, in assessing the impacts of extra ultraviolet radiation -- ultraviolet B radiation -- should we include, in our assessment of the likely impacts, a probable increase in the rate of spread of diseases in this category?

Dr. Kripke: In which category?

Senator Gore: Those diseases that are intimately related to the efficient functioning of the immune system.

Dr. Kripke: I know you would like me to say yes to that question --

[Laughter.]

Senator Gore: No, seriously. Let me clarify the question. I really do not want you to say yes, if you do not feel the answer is yes, seriously.

Dr. Kripke: Senator Gore, if there is no information, you cannot get an answer. It is as simple as that.

Senator Gore: Okay. All right. Well, I appreciate your response. We will come back to this as well.

I want to now turn it to Dr. Alan Teramura, professor, and chair, of the Department of Botany at the University of Maryland in nearby College Park. Dr. Teramura was also a member of the Impacts assessment panel. We are interested in hearing from you.

STATEMENT OF ALAN H. TERAMURA, PROFESSOR AND CHAIRMAN, DEPARTMENT OF BOTANY, UNIVERSITY OF MARYLAND, COLLEGE PARK, MARYLAND

Dr. Teramura: Thank you very much, Senator Gore, for the opportunity to participate in this rectangle table. My training has been in stress physiology. And over the past 15 years, I have been examining the effects of increased levels of solar, ultraviolet radiation on crop plants, on forest tree species, as well as on native plants.

And so what I want to do in the next 2 or 3 minutes here is try and encapsulate some of the conclusions from these studies, as well as studies from others.

We know that a large number of agricultural crop plants and forest tree species and native plants, may be negatively impacted by increases in ultraviolet radiation. Some of these plants are directly affected by increases in ultraviolet radiation. Others will be indirectly affected, because exposure to ultraviolet radiation can alter these plants interactions with other plants, as well as alter their capacity to be able to defend themselves from disease or from insect attack. So both a direct, as well as an indirect affect on plants seems to be the case.

Because of extremely small number of studies which have specifically examined UV effects on crop yields, it is presently not possible for us to make any sort of

comprehensive, quantitative assessments of crop losses due to increases in solar, ultraviolet radiation.

Furthermore, due to the limited number of on-going studies -- I know of only two or three studies world-wide, using realistic, UV supplements, I do not believe that we will be any closer to a quantitative assessment in the near future.

However, we do have experimental data to show that yield in some specific crops, such as Essex soybean, which happens to be the most important -- economically-speaking -- the most important soybean for the mid-Atlantic States, will be decreased with increases in solar, ultraviolet radiation. We also have specific examples for decreases in production for Loblolly pine, which is probably the most important commercial tree species for your State, Tennessee, as well as Mississippi.

Due to the presence of genetic adaptations in our modern crop plants, an optimist would say that plant breeders may be able to help us by utilizing these beneficial, genetic adaptations and breed for more UV-resistant crops in the future. So that would be an optimist.

Those that are a pessimist, however, would point out that we currently do not know enough about these UV-resistent crops to know whether they might not carry some genetic baggage in the sense of being less disease-resistant, and perhaps require a higher water or fertilization applications. So there are

some down sides to breeding, as well.

Whereas breeding may help minimize the impacts -- the negative impacts on crop plants, breeding is not an option for natural plant communities, and is probably not a very good option for forest tree species.

Long-lived tree species tend to accumulate the damaging effects of ultraviolet radiation over many years. And it is because of this long, life-span, and the length of time required for breeding, that we think that forest tree species and forests, in general, may be particularly vulnerable to increases in ultraviolet radiation.

Due to differences in species sensitivity that was mentioned earlier, both in native plants as well as in forest tree species, that means that more resistant species are going to replace more sensitive species to UV radiation, resulting ultimately then in changes in bio-diversity of forests, as well as natural ecosystems.

Since other climatic changes, such as CO2 and global warming will occur simultaneously with increases in ultraviolet radiation, it is logical to be concerned how plants will respond to that combination.

CO2 generally increases plant growth, and UV radiation generally decreases it in the most simple case.

Senator Gore: Just to interject on that point -- when you say CO2 increases plant growth, the limiting factor in

plant growth is the availability of nutrients and sunlight, correct?

Dr. Teramura: In many cases, it is. But we know that if you increase CO2 for most plants, that their growth will increase, as well, if they have enough nutrients and water.

Senator Gore: Okay, but if the nutrient loading, if the availability of nutrients is kept at its present limit, and CO2 is increased, then the studies indicate that what?

Dr. Teramura: It always happens that the most limiting factor, then, will limit the growth of the plant. And if it happens to be water or nutrients, then that will limit growth before CO2.

Senator Gore: This is an aside, or a parenthetical -- but I am informed that laboratory experiments which purport to show that extra CO2 stimulates plant growth are ones that have accommodated the plants by supplying lots of extra nutrients at the same time.

Dr. Teramura: That is right.

Senator Gore: And therefore, if in the wild, or in the forest the availability of nutrients is not increased, and there is a little more CO2 in the are, you are not going to get extra plant growth there.

Dr. Teramura: That is correct.

Senator Gore: Go ahead.

Dr. Teramura: But just assuming that, all else being

equal, that if CO2 does increase growth, in general, UV decreases plant growth. And that leads, then, people to make the assumption that one, CO2 will cancel out the effects of ultraviolet radiation.

Senator Gore: So even if you had more nutrients to go with the extra CO2, the additional growth might well be cancelled out by the impact of the extra UV ratings.

Dr. Teramura: That is what the common assumption is. The point I would like to make is that this is not always borne out by experimental evidence. The evidence seems to suggest that under dual stresses, plants are even more adversely affected than under a single stress. So the case may actually be worse -- rather than just a cancelling out, plants may actually do much worse.

And then the final point I would like to make is related to some recent evidence coming from the Federal Republic of German which seems to suggest that even in the absence of further ozone depletion, some sensitive plants are already sensitive to present-day ambient levels of ultraviolet light, such as the garden bean.

[The prepared statement of Dr. Teramura follows:]

Senator Gore: Now thank you very much.

Just a brief follow up here -- is it true that soybeans and rice are particularly susceptible to having their growth rate and quality suppressed by extra UV radiation?

Dr. Teramura: They probably have the best information for soybean than any other crop plant, or any plant in the world. And in one field study examining soybean for a 6-year period, a 25-percent ozone depletion was simulated during the 6-year period. The yield was reduced in soybean by 20 to 25 percent each year. That is quite a substantial loss.

Senator Gore: It is one for one.

Dr. Teramura: It is one for one.

What we do not know, however, is whether this can be then extrapolated to all the soybeans grown throughout the United States, as well as throughout the world.

Senator Gore: There may be some varieties that are less susceptible.

Dr. Teramura: There are some varieties that are less susceptible. We know that. And so what we need to -- what we do not know, however, is how all soybeans can respond, and whether -- what the implications of breeding for this additional UV resistance may be.

In rice, we have more limited preliminary information. It seems as though maybe on the order of 200 different cultivars of rice have now been screened for UV sensitivity.

And between 1/2 and 1/3 of all of those cultivars are very sensitive to ultraviolet light.

The other side of the equation is a small proportion of those rice cultivars, maybe 10-percent, seem to be very resistant. Again, that suggests to us that possibly, we may be able to breed around the problem. But we still really do not know about some of the problems associated with breeding.

Senator Gore: Well also, if you are forced by extra UV loading to focus on a narrow part of the spectrum of the genetic diversity of rice, you are severely limited in your ability to select traits from across the spectrum in order to confer resistance characteristics against the rapidly evolving pests and blights that they are constantly having to fight off. Is that correct?

Dr. Teramura: That is correct. One way of getting around that, is using some of the techniques of molecular biology and biotechnology. Right now, some individuals have been able, actually, to clone the genes that cause sun-tanning in plants. And if you can take sun-tanning genes, and put them into your modern, crop plants, you may be able to protect them as well. But that is still -- it is not really science fiction, but it is still quite distant.

Senator Gore: Well, it would not be wise or prudent to pin our hopes for the future of the world's food supply on that?

Dr. Teramura: Absolutely not. That is too much of a risk, I think.

Senator Gore: And in any event, genes are found predominantly still, for most food species, in the wild and in the genetic homes, the Vavalovian centers, and the land races. And if those are damaged by the extra UV radiation, then the potential availability of genes of the sort you are looking to clone is going to be sharply diminished.

Dr. Teramura: And furthermore, even if you assume that the breeders, the scientists working with crop genetics can improve crops for the future, against harmful UV effects, you still are not going to be able to do anything for native plants, nor will we have much impact for forest tree species. Despite the fact that agricultural plants are certainly of vast economic importance for humans, probably 80 percent of all plant material really lies in forests. And we know very little about effects of UV on forest tree species.

Senator Gore: Okay, I keep saying we are going to come back to this stuff. This is all so interesting. But we are going to move on here.

Dr. Ari Patrinos is Acting Director of the Environmental Sciences Division with the Department of Energy. We are happy to welcome you, Dr. Patrinos. The Department of Energy asked to participate in this hearing a few days ago. And I think it is not only appropriate, but extremely helpful to have the DOE

perspective here.

Please proceed.

STATEMENT OF DR. ARI PATRINOS, DIRECTOR OF THE ENVIRONMENTAL SCIENCES DIVISION, OFFICE OF HEALTH AND ENVIRONMENTAL RESEARCH, OFFICE OF ENERGY RESEARCH, U.S. DEPARTMENT OF ENERGY

Dr. Patrinos: Thank you, Senator Gore.

I welcome the opportunity to respond to your invitation to present the Department's views on stratospheric, ozone, and its climate change implications.

As you may know, for over 12 years, we have been in the business of global environmental change. And our current focus is primarily on improving the capability to predict global and regional climate change.

Our research, more directly related to stratospheric, ozone depletion, involves primarily modeling stratospheric, atmospheric chemical processes and their impacts on climate change.

We also fund research for many years on the nature of ultraviolet radiation, induced damage to DNA, and the repair to that damage as a surrogate to studying damage from ionizing radiation.

DOE is certainly concerned about the mounting evidence of stratospheric ozone depletion caused by CFC's. The summary of the unit report that we discussed this morning certainly indicates a worsening situation. We believe that despite some remaining scientific uncertainties, it is clear that action to